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Tribhuvan University
Institute of Engineering
Central Campus, Pulchowk

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Event Summary

With a noble objective of making a venue for Institute of Engineering, under Tribhuvan University, Graduate students for their research work presentation to the large audience as well as to get institute-wide recognition, IOE Graduate Conference was planned a few months back and it was widely circulated among graduate students and faculty members. The first IOE Graduate Conference (IOE-GC 2013) was observed whole day from 9:00 am till 5:00 pm on Friday, November 29th, 2013 (Mangsir 14, 2070 BS), with overwhelming participation from every segments of academia at Central Campus, Pulchowk. There were 300 plus participants and guests with almost 150 paid registrations of graduate students, which was around 70% of research-stage student population enrolled in more than a dozen graduate programs within the campus. Altogether forty-two papers were presented in six different sessions simultaneously running in two parallel tracks.

Associate Prof. Kumudini Koirala (Head, Dept. of Electrical Engineering) started the inaugural session with the program highlights in the Library Hall of Central Campus, Pulchowk. Dr. Arun Kumar Timalsina (Head, Dept. of Electronics and Computer Engineering), Convener, IOE-GC 2013, welcomed everyone in the program and also emphasized the requirement of such activities in order to extend the global visibility of IOE research works. Prof. Dr. Bhakta Bahadur Ale (Director, Center for Applied Research and Development) provided the chronological advancements and research milestones of IOE. His research memoir was inspiring to the audience present in that ceremony. Dr. Arbind Kumar Mishra (Campus Chief, Central Campus, Pulchowk) shared overall goal and vision of the research that is to be promoted within the Institute in the days ahead. He also made firm commitment on making such event regular. The Chief Guest of the program, Prof. Dr. Bharat Raj Pahari (Dean, Institute of Engineering) presented the holistic approach of research process with his remarkable and vowing comments and concluded the opening session.

After the coffee break followed by inaugural session, there were two parallel sessions (A and B) running in Library Hall and CES seminar hall. Session A was on *Energy* theme, which was chaired by Dr. Netra Gyawali and there were nine different research papers on varied topics ranging from energy demand forecasting, load balancing, loss minimization and overall optimization of power stations to efficient planning of municipality from energy perspective. Alternative and renewal energy issues were central on the whole session. Similarly, session B was on *IT and Computing* theme, which was chaired by Dr. Sanjeeb Prasad Panday. Eight different research result presentations were made, where latest communication technology related issues with focus on performance optimization remained the prime discussion. The Nepali language feature study for automated classification and wireless power transformer design were also remarked during the session.

During the one hour break, every participant enjoyed the delicious lunch from *The Bakery Café* stall on the venue. After the lunch, another two parallel sessions were held in CES. Session C was on *Technology and Management* and chaired by Dr. Rajendra Shrestha. Out of six interesting research topics, the decision analysis based banking sector performance evaluation and bio-ethanol blending proposition and exact status analysis, presenters received record number of queries in the session. In another parallel track session D on *General Science* theme, participants had chance to know about various interesting research on indigenous fruit, *Lapsi* with its seed-stone features and wide applications. There was couple of papers on solar radiation and terrain effects. The session was chaired by Prof. Dr. Bhadra Pokharel and there were six papers in the session.

After having another coffee break, the last two sessions (E and F) were conducted in parallel. Session E was on *Urban Management* theme, chaired by Prof. Dr. Sudha Shrestha. There were six interesting research results mainly on disaster prone developments, demographics and unplanned growth issues pertaining to urban management. Similarly, there were another six papers presented in session F that was on *Infrastructure and Technology* theme, which was chaired by Dr. Kamal Bahadur Thapa. The research on pedestrian behavior analysis, overall transport energy consumption forecasting even in the absence of accurate traffic age and counts and twin tunnel simulations run for local terrain were quite interesting to audiences as per their responses during the session.

The soft copy of the papers was distributed in CD to all participants and authors on the conference day. Few authors made minor corrections on their papers as they got valuable comments from the participants during the presentation on the conference day. This is the final hard copy of the proceeding after incorporating all of the corrections.

Finally, IOE-GC 2013 organizing committee would like to thank Center for Applied Research and Development (CARD) for providing the generous sponsorship in organizing this Graduate Conference, which will be considered as another stepping stone in IOE research endeavors and remembered in the days to come.

IOE Graduate Conference 2013 Committee

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Current Status of Micro Hydro Technology in Nepal

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Abstract*: Installation of the Micro Hydro Power (MHP) began in Nepal around fifty years ago and around 23 MW of micro hydro schemes have been installed in the country and around 250,000 households in the rural area are electrified by the micro hydropower plants. Since micro hydro has lot of positive socio economic impacts, it has been well accepted by our society in this period. The pace of installation has increased from few kW per years to around 5 MW per year in fifty years. This research aimed at finding the current technological status of the micro hydro in Nepal and find out the areas for future improvement. Power Output Verification (POV) reports of nineteen different micro hydro were collected and data from these reports were analysed. The results obtained suggest that Nepalese micro hydro have on average 59.8% water to wire efficiency which is well below the average efficiency of the micro hydro in developed countries. The lower efficiency was found to be caused by lower turbine efficiency. Nepalese micro hydro with Cross Flow turbines have higher efficiency as compared with the Pelton turbines. Efficiency of Pelton turbine installations was found to increase slightly with size of micro hydro while that of Cross Flow turbine installations remained indifferent. Efficiency of the Cross Flow turbine installations was found to decrease with increase in net head. It was found that Nepalese micro hydro have nearly same penstock efficiency as that in developed countries. Nepalese micro hydro in average supply 90W per household connected. In average turbine and generator each has below four per cent share in total cost but efficiency of these components determine the power output from the micro hydro. Reduction in cost of electrification through micro hydro system is possible only through improvement in performance of turbine and generator and use of local materials for civil works and electrical works.

Keywords: water to wire efficiency, electromechanical efficiency, electrification, cost share

1. INTRODUCTION

In the fiscal year 2008/09 total energy consumption in Nepal was estimated to be 401 million GJ among which 77.7% was contributed by fuel wood followed by petroleum 8.2%, animal dung 5.7%, agro residue 3.7%, electricity 2%, and other renewable sources including micro hydro, biogas and solar total 1% of the total energy consumption. In the same year 89.1% of total energy consumption was on household sector, followed by transport 5.2%, industrial 3.3%, commercial 1.3%, agricultural 0.9%, and other 0.2% respectively (WECS, 2010). This shows the energy consumption in Nepal is based on traditional fuels like fuel wood and agro residue. Nepal has per capita Gross National Income (GNI) of US$ 540 which is less than average of low income countries US$ 571 and far less than world average US$ 9514 for the year 2011 [2].

Population of Nepal was 26.5 million on June 2011 and is increasing with an annual average growth rate of 1.35 per cent (CBS, 2012). The average household size is 4.88 in 2011 at the national level. Only 67.26 per cent of the total households in Nepal use electricity as main source of lighting. Kerosene is still being used by 18.28 per cent of total households for lighting. Solar is being used by 7.44 per cent and bio-gas by 0.28 per cent of the total households for lighting. Similarly, about 64% of the total households use firewood as usual source of fuel for cooking followed by liquefied petroleum gas (LPG) (21.03 per cent), cow dung (10.38 per cent), Bio-gas (2.43%), and kerosene (1.03%). Very few households (0.08 per cent) use electricity as usual fuel for cooking (CBS, 2012). There is strong need for substituting the kerosene from lighting and traditional fuel from cooking by other renewable energy sources.

Nepal had per capita electricity consumption of 93kWH in the year 2010. Total primary energy supply in the same year was 14.28GJ/capita while average of the world was 78.12 GJ/capita [4]. Energy poverty is the situation in which there is lack of modern energy source sufficient for cooking and electricity for lighting which means, there is large dependency on traditional fuels for cooking and lighting as is the case of our country [5]. Energy poverty has serious and growing public health concerns related to indoor air pollution. Energy poverty affects both the gender roles within society and the educational opportunities available to children and adults [6]. The estimated households living in energy poverty in cooking, lighting, and drinking water boiling was 51%, 60%, 88% with overall end uses combining 68% in Nepal in year 2006 [7].

Alternative Energy Promotion Centre (AEPC) is the coordinating and regulating body for renewable energy sector in Nepal. Among the renewable energy technologies being promoted by AEPC for rural electrification to meet the energy need of the rural people, micro hydropower is the most prominent one. Two main programs of AEPC had been actively working for the development of micro hydropower plants. The UNDP and the World Bank funded Renewable Energy for Rural Livelihood Program (RERL) and the Denmark and Norway funded Mini Grid Support Program under Energy Sector Assistance Program (MGSP/ESAP). ESAP completed its second phase by 2012 and new program has been designed named National Rural and Renewable Energy Program. In 2011, the Government of Nepal and development partners jointly agreed to support formulation of National Rural and Renewable Energy Program (NRREP). NRREP expects to install 25 MW of mini and micro hydro benefitting 150,000 households from community electrification component during its five year implementation period starting from 2012 [8].

A. Methodology

Calculation of different parameters of micro hydro components are based on data obtained from the power output verification reports of micro hydro from AEPC. Data of 19 different micro hydro power plants whose installation was completed in year 2012 were collected from their respective Power Output Verification (POV) reports. From the processed data, efficiency of different components of micro hydro including penstock, electromechanical (combined efficiency of turbine and generator and drive system), and water to wire efficiency of the system were calculated. Results from the calculations were analysed to find out trends and to find out the future improvement possibilities in the performance. Data obtained was analysed using simple excel model for different results. To study the cost structure of Nepalese micro hydro detailed feasibility study reports of five different micro hydro of different size were referred.

2. Literature Review

A. Micro Hydropower Plant

Micro hydro power plants are the small scale hydro power plants of the sizes in between 5 kW and 100kW [9]. In general, micro hydro does not need dams and a reservoir as water is diverted and then conducted in a penstock to a lower elevation and the water turbine. In most cases, the end production is the generation of electricity. Micro hydro schemes can be adapted as the most economical option for rural electrification than any other available renewable energy sources such as solar and wind [10, 11]. From life cycle assessment of micro hydro in rural Thailand for twenty years it was concluded that smaller hydro power systems have a greater environmental impact per kWh, perform less well environmentally than larger systems. Placed within a rural electrification context, however, the micro hydropower system yields better environmental and financial outcomes than diesel generator and grid connection alternatives [12]. Cost per kW of the MHP vary with site due to different size of the scheme, specific nature of civil work at required site, varying length of transmission and distribution network, possibility of procuring equipment from local as well as foreign suppliers etc. [13]. Cost per unit power output of the micro hydro schemes decreases when micro hydro are promoted with day time productive end use and social infrastructures along with electrification of the village than electrification of the village alone due to high plant load factor in former case [14]. The cost of mini hydro electrification can be in the range of $2500-3000/kW, but for small schemes may reach up to $10,000/kW depending upon specific site. Cost can be reduced by using indigenous technology below $1000/kW [11].

B. Micro Hydro in Nepal

Nepalese micro hydro powers are sustainable in three dimensions of sustainability framework: ecology, economy and social. Ecologically, MHP are causing no significant negative impacts but improvement in some cases. Economically, the broader benefit of MHP technology in Nepal is the creation of industrial base of hydropower development in the long-term [15]. Micro hydro have positive socio-economic impact in the rural communities like lower consumption of firewood, extended study time for children, reduced drudgery for women, increased economic activity due to productive end use, and social participation [16]. Micro hydropower should be given precedence to solar PV for lighting since solar lighting is costlier than micro hydropower projects in terms of unit costs and carbon abatement [17]. One of the major hindrances to the development of micro hydropower project in Nepal is being costly [18]. In average per kW cost of in Nepalese micro hydro is around Rs. 430,646 among which 26% is contributed by the AEPC as subsidy [19]. Around 23 MW of MHP has been installed in Nepal by mid July 2013. Nepal government has targeted to complete installation of 4.5 MW of micro hydro schemes within current fiscal year 2070/71 (MoF, 2013). This signifies that installation capacity per annum in micro hydro sector is reaching around 5MW. There is declining trend in project completion time in recent years. On average, it takes 8 months to start construction once the project is approved and 19 months to complete the construction once it is started [19].

C. Previous Research in Nepalese MHPs

Parajuli [21] studied on the cost reduction possibilities in the civil components of the Nepalese MHP systems and suggested different methods based on the same. According to his findings among the civil component there is a greater cost reduction possibility in canal. Gyanwali [22] studied on cost reduction possibilities in mechanical components of MHP systems in Nepal and suggested different methods based on the same.

According to his findings most of the turbines in Nepalese MHPs were oversized and that's why turbines were found to be relatively costly. According to his findings most of the turbines are not designed as per the required parameters but are selected from already designed templates, which are near about the requirements. Aryal [23] studied on the cost reduction possibilities in electrical components of the Nepalese MHP systems. Ghimire [24] studied on end use promotions in the MHP sector in Nepal. Mainali and Silveira [25] studied off grid rural electrification of Nepal and showed that cost per kW of installation decreases with size of installation.

D. Efficiency of the Micro Hydro Power Plants

Hydro turbines convert energy available in water into mechanical shaft power, which can be used to drive an electric generator, or other machinery. The power available is proportional to the product of head and flow rate. Electrical power output generated from hydroelectric power plants like micro hydro power (MHP) is given by,

$$P = \eta_o \rho g Q H \tag{1}$$

Where,

P is the electric power output from the scheme,

η_o is the overall efficiency of the scheme,

ρ is the density of water (1000 kg/m^3),

g is the acceleration due to gravity (9.81m/s^2),

Q is the volume flow rate passing through the turbine (m^3/s),

H is the gross head of water available at the site (m)

Thus, power output from micro hydro power plant depends upon available head, flow rate and the efficiency of the different components of the scheme. For given specific site with given flow rate and gross head the power that can be harnessed can vary slightly with efficiency of the components.

The overall system efficiency, η_o, is the ratio of useful power output to hydraulic power input. It is the product of separate efficiencies for several components of the system [26].

$$\eta_o = \eta_p \eta_t \eta_g \eta_{tr} \tag{2}$$

Where,

η_p is the penstock efficiency, typically 0.90 - 0.95,

η_t is the turbine efficiency, typically 0.65 - 0.80,

η_g is the generator efficiency, typically 0.85 - 0.90,

η_{tr} is the transmission efficiency, typically 0.85 - 0.90.

Holland [27] suggested that the efficiency of a small turbine is typically 75% and generator efficiency is 80%. Paish [11] suggested micro hydro systems tend to have efficiency in the range 60 to 80%.

E. Efficiency of Different Components of Micro Hydro

i) Penstock Efficiency

Penstock efficiency is the ratio of the net head of the micro hydro to the gross head of the micro hydro scheme. Higher efficiency signifies lower friction loss in the penstock. Penstocks in micro hydro have typical efficiency of 96% [28]. There is trade off to be made between cost of the penstock and the efficiency. For lower friction loss and hence higher efficiency smooth surface and larger penstock size is required.

ii) Turbine Efficiency

Turbine efficiency is its ability to convert available energy in water at turbine inlet to mechanical energy to drive the generator. Efficiency of the turbines varies with its type and size of the plant. Pelton turbine and Cross flow turbines are most widely used in Nepalese MHPs. Pelton turbines have best efficiency of 89% with single jet and 90% in multi jet configuration [28]. Cross Flow turbines have lower efficiency as compared with Pelton turbines. Cross Flow turbines have good part load efficiency as compared with Pelton turbine. Best efficiency achieved with Cross Flow turbine is 78.6%, this value was obtained when tested in a laboratory in 2008 in Norway [29]. Efficiency of Cross Flow turbine can reach 79% for size 100 kW for model T15. Cross Flow turbine efficiency slightly decreases with head due to increased friction loss in turbine blades [30]. Drive system efficiency for belt drive of the generator is normally 98% [28].

iii) Generator Efficiency

The efficiency of the generator is defined as the ratio of the electric power output from generator to the input mechanical power. Efficiency of the generator is less than one due to five major losses which are friction loss, core loss, field copper loss, armature copper loss, and stray loss or load loss. First two of these are fixed losses which are independent of load whereas remaining three are variable losses which vary with change in load [31]. Typical efficiency of generator ranges from 91% for rated power of 10kW to 95% for 100kW rated power [28]. The efficiency of the generator is almost independent of the load on the generator.

Assuming transmission and distribution efficiency to be 90%, maximum efficiencies possible from Pelton turbine installations are 68.57%, 76.2%, 79.4% in overall, water to wire, and electromechanical. Similarly, for Cross Flow turbine installations maximum efficiencies achievable are 60.10%, 66.77%, 69.5% in overall, water to wire and electromechanical. Where, electromechanical efficiency is the combined efficiency of the drive transmission system with efficiency of turbine and generator.

F. Component Efficiency Limitations in Design Standards of MHP in Nepal

The following are the minimum limitations on component efficiencies stated in the Nepal Micro Hydro Standards prepared by AEPC [32]:

- Total headloss including losses in bends and valves on Penstock at design flow rate should not exceed 10% of the gross head.
- Turbine efficiency limitations

  Pelton turbines 5kW to 30 kW, 70% to 80%

  Pelton turbines above 30 kW, 75% to 85%

  Cross Flow turbines 5kW to 30 kW, 60% to 70%

  Cross Flow turbines above 30kW, 65% to 78%
- No limitation for generator efficiency but should meet manufacturer's efficiency specification.
- Ballast load should be at least 20% higher than the plant capacity in thyristor type controller.
- Maximum voltage drop permissible at the farthest end of the distribution line is 10% of the nominal value.

Assuming generator efficiency to be 85%, minimum efficiency required for the installations with Pelton turbine are 47.2%, 52.5%, 58.3% in overall, water to wire and electromechanical efficiency. Making the same assumption in generator efficiency to be 85%, minimum efficiency required for the installations with Cross Flow turbine are 40.5%, 45%, and 50% in overall, water to wire and electromechanical efficiency. Below these efficiency levels the project does not meet the national standard for efficiency.

G. Measurement of Efficiency of Different Components

Efficiency of the penstock can be determined by measuring gross head and net head of the micro hydro. Gross head is the vertical height level difference between forebay water level and the turbine nozzle centreline for impulse turbine where as it is the vertical height difference between forebay water level and water level at draft tube discharge tail race reservoir water level for reaction turbine. The gross head can be measured by using Abney level and tape method with less than 5% error [33]. Net head available can be directly read from the pressure gauge fitted at the turbine intake. If gauge is properly calibrated this method gives less than 5% error.

Except for the thermodynamic method, determination of the turbine efficiency requires measurement of discharge Q, mechanical power available at the shaft P_m, electrical power as well as net and gross head. Combined efficiency of the turbine generator unit can be determined by measuring the electrical power output from the micro hydro, discharge and net head. If efficiency of the turbine is determined with thermodynamic method then efficiency of the generator can be determined by dividing combined turbine generator efficiency by the turbine efficiency. Thermodynamic method is one of the methods for field performance testing of hydropower system, which can give satisfactory results by measuring the temperature and pressure of water before entry to the turbine and after discharge from the turbine in the tail race canal about four runner diameters downstream of the discharge from the runner. Temperature measurement instrument should be capable of measuring temperature change in milliKelvin [34]. But this method cannot be used for low head site since it gives higher uncertainty level with decrease in head. Below 100m head uncertainty reaches to higher value making this method unsatisfactory for efficiency measurement [35].

Discharge measurement can be carried out with salt dilution method with error less than 7% [33]. Ultrasonic flow meters use Doppler Effect to estimate the velocity of flow. Current meters measure velocity at specific points in a defined cross section and is integrated with area by area velocity method. Ultrasonic method requires penstock to be fabricated with provision for installing instrument probes. These methods can give results with less than 2% error [36].

Since mechanical power available in the turbine shaft can only be measured with dynamometers, it cannot be measured at site conditions. Hence, turbine efficiency and generator efficiency cannot be measured at site conditions and therefore combined turbine and generator efficiency is to be measured. Efficiency of the generator remains almost constant around its full load efficiency. Though efficiency of the generator varies slightly with temperature and altitude, it can be corrected for such variations. Efficiency be assumed to be constant for specific test condition for given altitude, temperature and installation. Efficiency of the turbine can be approximated by using generator efficiency and combined efficiency of turbine and generator.

Provisions Related with Efficiency Measurement in POV Guideline [37]

Gross head measurement with Abney level and tape method. Net head is to be measured with pressure gauge at end of the penstock.

Flow measurement using salt dilution method or area velocity method to be carried out at the headwork site.

Stream flow measurement at intake is to be carried out using salt dilution method or area velocity method.

Voltage, current and power factor in each phase, and frequency is to be measured using RMS meters. Ballast voltage and power to be measured in each phase of the ballast load. Each parameter is to be measured with variation of load at various position of the valve for flow variation.

3. CALCULATIONS AND RESULTS

A. Observations

From collected data it was found that most of the micro hydro is community owned and operated. Similarly, almost all the Nepalese micro hydro schemes used temporary weir for diverting water. There is variation in the canal type, some use stone masonry, some cemented lined and few have used high density polythene pipes. All of the micro hydro use mild steel penstock pipe. Many of the micro hydro use stepped thickness in penstock design. All micro hydro with net head lower than 50m used Cross Flow turbines while above 50m used Pelton turbines. Almost all of the micro hydro used synchronous three phase generators with Electronic Load Controller (ELC) and water heating type ballast load. Most of the micro hydro are using three phase four wire transmission system with single phase supply to individual households. From the collected data it was found that there was significant error on head measurement at the time of designing. Most of the micro hydro reported design gross head to be less than the actual gross head. This may be due to lack of confidence in the designer for design output. Also most of the micro hydro reported power output from the scheme to be higher than the design power output value. While going through the different POV reports some MHPs were reported to have trouble with their ELC and at least one MHP reported that design flow was not possible to pass through the given scheme but power output from the same scheme was higher than the design power output because of the error in the head measurement before design. Only one out of nineteen MHP has reported to have productive end use application at the time before POV test, while none of the others have any end use application except lighting.

B. Calculated Parameters

Overall efficiency is the ratio of power available at the location of the user to the hydraulic energy available in the site. It is the product of water to wire efficiency with transmission and distribution efficiency. In actual practice transmission and distribution efficiency is less than 95%. Overall efficiency is calculated as:

Overall efficiency = Electric power output available at end use/Power available in water (3)

Power available in water at given site = ρgHQ (4)

Where,

ρ is the density of water (1000 kg/m^3),

g is the acceleration due to gravity (9.81m/s^2),

Q is the volume flow rate passing through the turbine (m^3/s),

H is the actual gross head of water at given site (m).

Water to wire efficiency is the ratio of power output measured at the powerhouse to the power available in the water. Water to wire efficiency is obtained by dividing overall efficiency with transmission efficiency.

Water to wire efficiency = Electric power output / Power available in water (5)

Design HH/kW is the ratio of targeted number of households at the design time to the design power output. It shows the targeted power supply to the each household of the scheme.

Actual HH/kW is the ratio of actual number of households connected to the scheme to the actual power output. It shows the actual power supply to the each household of the scheme. *Penstock efficiency* is the ratio of the actual net head of the scheme to the actual gross head of the scheme.

Electromechanical efficiency is the combined efficiency of the electromechanical components of the MHP. It is the product of the turbine efficiency, drive system efficiency and the generator efficiency. Since efficiency of the turbine and generator was not possible to be calculated from the obtained data combined efficiency was calculated as:

Electromechanical efficiency = power output from the scheme/power available at turbine inlet (6)

Power available at turbine inlet = ρgH_nQ (7)

Where, H_n is the net head of the scheme.

Actual/design gross head is the ratio of the actual head of the scheme to the gross head assumed at the time of design of the same scheme.

Actual/design power is the ratio of the actual power output of the scheme to the design power output assumed at the time of design of the same scheme.

Ballast load/design power is the ratio of the ballast load installed at the plant to the design power output.

Ballast load/actual power is the ratio of the ballast load installed at the plant to the actual power output measured at the plant.

Results from Analysis of POV Data

From results obtained after calculation it can be seen that the Nepalese MHP have water to wire efficiency of

59.8% on average with minimum value of 39.7% and maximum value of 73.5%. Schemes with Pelton turbines have average efficiency of 57.4% while that with cross flow turbines have 63.1% average efficiency. Detail results obtained are shown on the Table 1. Nepalese MHPs have penstock efficiency on average of 94.8% with minimum value of 90% and maximum value of 98% which is quite good. Nepalese MHPs are designed with 10.7 HH/kW but are actually 11.2 households are connected per kW of the power output (i.e. each household gets around 90W in average). Schemes with Pelton turbines have electromechanical efficiency of 60.5% on average while schemes with Cross Flow turbine have average electromechanical efficiency of 64.5%. About 73% of Nepalese MHPs have actual gross head higher than design gross head where few schemes have more than 10 m error in head measurement. Actual power output of 68.4% of Nepalese MHPs is higher than design power output. Due to discrepancies in the design power output and actual power output 21% of the Nepalese MHPs have ballast load less than the actual power output at design flow rate of the scheme. On average Nepalese MHPs have ballast load of 127.9% of design power output. Considering power factor to be 0.8 Nepalese MHPs have generator oversized by 171.9% in average.

Table 1: Different Parameters Calculated for Nepalese MHPs

Parameters	Mean	Median	Min	Max	Standard Deviation	Skewness	Kurtosis
Water to wire Efficiency	59.8%	60.3%	39.7%	73.5%	8.7%	-0.41	0.2
Penstock efficiency	94.7%	95%	90%	98%	2%	-0.49	0.32
Electromechanical efficiency	62.2%	64%	43%	77%	10%	-0.43	-0.45
Design HH/kW	10.4	10.0	7.89	13.95	1.66	0.42	-0.37
Actual HH/kW	10.2	10.4	5.8	16.96	2.77	0.53	0.67
Actual/Design Gross Head	105.5%	107%	93%	119%	7%	0.06	0.09
Actual/Design Power	109.0%	109%	78%	138%	17%	0.01	-0.81
Ballast load/Design Power	127.9%	123%	118%	157%	11%	1.59	2.16
Ballast load/Actual Power	120.1%	115%	87%	157%	21%	0.08	-0.97
Actual/Design Discharge	101.9%	100%	75%	137%	16%	0.41	-0.32
Generator oversizing	171.9%	173.9%	133.3%	220.0%	18.7%	0.64	1.81

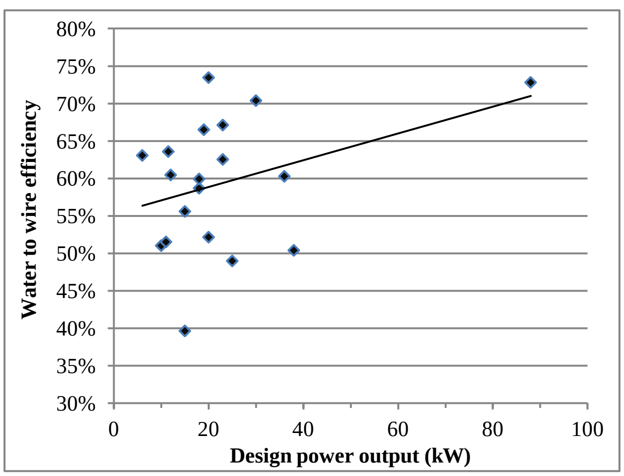

Figure 1: Variation of water to wire efficiency with size of MHPs

Figure 1 shows the variation of water to wire efficiency with size of the MHP. The correlation coefficient between water to wire efficiency and size of the micro hydro was calculated to be 0.358 which shows slight correlation between water to wire efficiency and size of the MHP. Scatter plot shows that water to wire efficiency varies widely with site location even the size of the micro hydro is nearly the same. From results of regression analysis, at 10% level of significance $t_{critical} = 1.771$, $t_{statistic} = 1.65$, null hypothesis is accepted since $t_{statistic}$ is less than $t_{critical}$, and it can be concluded that size of the micro hydro does not influence the water to wire efficiency.

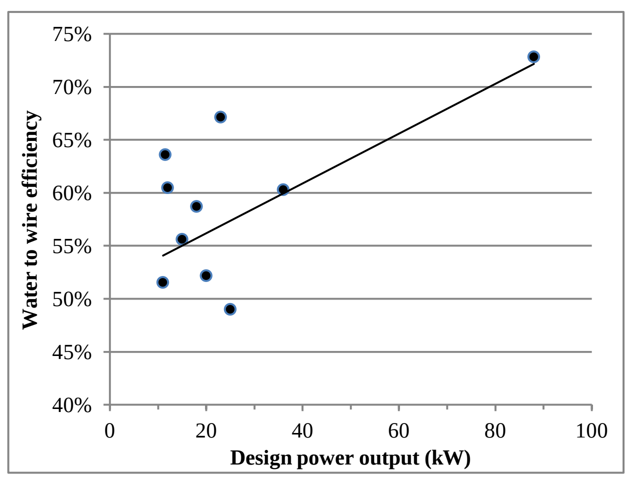

Figure 2: Variation of water to wire efficiency with size of MHPs with Pelton turbine

Figure 2 shows the relationship between water to wire efficiency with size of the micro hydro with Pelton turbine installation. Coefficient of correlation calculated between water to wire efficiency of Pelton turbine installations and size was found to be 0.59. Positive value of correlation coefficient signifies that these two variables vary in the same direction. That means larger size micro hydro will tend to have higher efficiency compared with that of the smaller.

Variation of water to wire efficiency with size of micro hydro is given by the regression equation:

$$\eta_{ww} = 0.515 + 0.0023P \quad (8)$$

From results of regression analysis, at 10% level of significance $t_{critical} = 1.833$, $t_{statistic} = 2.07$, null hypothesis is rejected since $t_{statistic}$ exceeds $t_{critical}$, and it can be concluded that size of the micro hydro influences the water to wire efficiency for Pelton turbine installation. Similarly, test statistic exceeds the critical value of the F distribution at the 10% significance level, so the regression as a whole is significant.

Figure 3 shows the relationship between electro-mechanical efficiency with the size of the Nepalese MHPs having Pelton turbine installation. Coefficient of correlation between electromechanical efficiency and size of the micro hydro with Pelton turbine is 0.56. The positive value of correlation coefficient signifies that with increase in size of micro hydro tends to cause an increase in electromechanical efficiency of the installation.

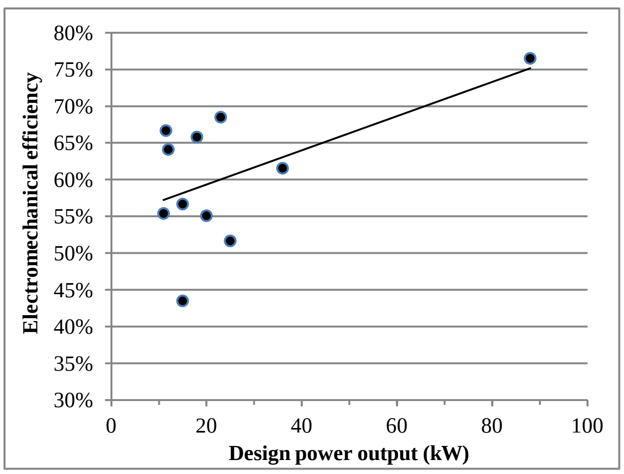

Figure 3: Variation of electromechanical efficiency with size for MHPs with Pelton turbines

Variation of electromechanical efficiency with size of micro hydro with Pelton turbine is given by the regression equation:

$$\eta_{em} = 0.547+0.0023P \quad (9)$$

From results of regression analysis, at 10% level of significance $t_{critical} = 1.833$, $t_{statistic} = 2.04$, null hypothesis is rejected since $t_{statistic}$ exceeds $t_{critical}$, and it can be concluded that size of the micro hydro influences the electromechanical efficiency for Pelton turbine installation. Similarly, test statistic exceeds the critical value of the F distribution at the 10% significance level, so the regression as a whole is significant.

Figure 4 shows the relationship between electro-mechanical efficiency of the micro hydro with net head for Cross Flow type installations. Carl Pearson correlation coefficient between electromechanical efficiency and net head was found to be -0.695. The negative value signifies that the electromechanical efficiency decreases with increase in net head of the micro hydro for Cross Flow turbine type installations. This means micro hydro with Cross Flow turbine installations are more efficient in low head installations compared with high head installations. Variation of electromechanical efficiency with net head of micro hydro with Cross Flow turbine is given by the regression equation:

$$\eta_{em} = 0.848 - 0.0054H_n \quad (10)$$

From results of regression analysis, at 10% level of significance $t_{critical} = 1.943$, $t_{statistic} = 2.37$, null hypothesis is rejected since $t_{statistic}$ exceeds $t_{critical}$, and it can be concluded that the electromechanical efficiency decreases with increase in net head for Cross Flow turbine installations. Similarly, test statistic exceeds the critical value of the F distribution at the 10% significance level, so the regression as a whole is significant.

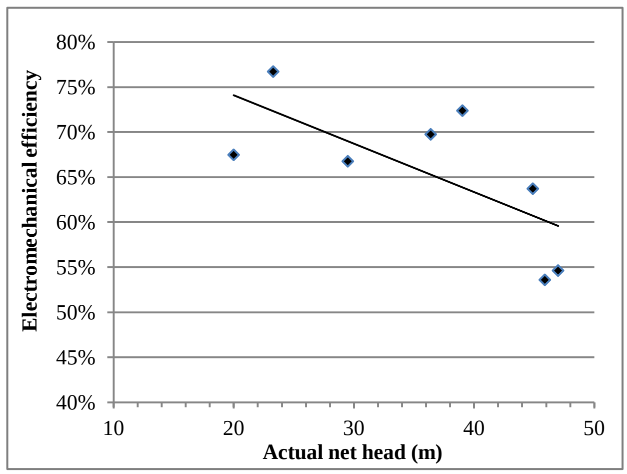

Figure 4: Variation of electromechanical efficiency with net head for MHPs with Cross Flow turbines

C. Cost Structure of Nepalese MHP

Share of different sectors in installation of micro hydro was found to vary according to size of installation, and location as shown in **Error! Reference source not found.** on next page. These costs are as estimated in detailed feasibility reports of Suntale Khola MHP (100kW) Taplejung, Nurkhuwa Khola MHP (31kW) Khotang, Yari Khola MHP (23kW) Udayapur, Chima Khola MHP (13kW) Khotang, and Rumrunga Khola MHP Khotang in [38], [39], [40], [41], and [42] respectively. Percentages share of electrical, mechanical and civil works varies from 30% to 47%, 7% to 13% and 16% to 28% respectively. Share of mechanical and civil works in total installation cost increases with decrease in size of the MHP and cost of the electrical works increases with increase in size of the micro hydro. This increase in electrical cost is mainly due to increase in transmission and distribution cost of the micro hydro. The transmission and distribution cost of micro hydro with larger capacity is high due to involvement of transformer and steel poles for high voltage transmission. Cost of installation, commissioning and testing increase in slight amount with increase in size but percentage share in total cost decreases with increase in size of the micro hydro. Miscellaneous cost component includes tax paid on purchase of nonlocal material and contingency expenses which remains almost constant at around 12 to 13% even with variation in size of the micro hydro.

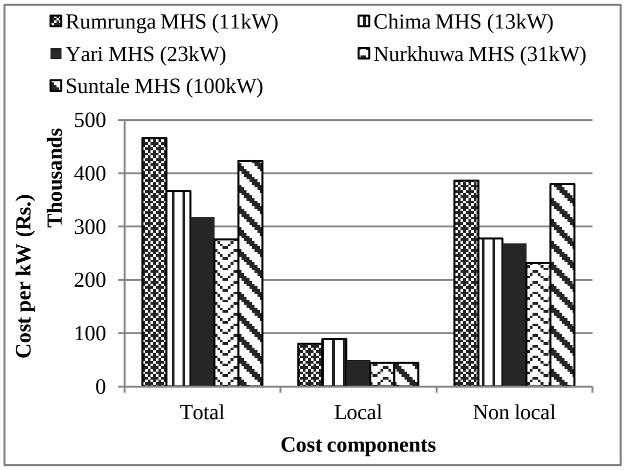

Figure 5: Cost per kW of Nepalese MHPs

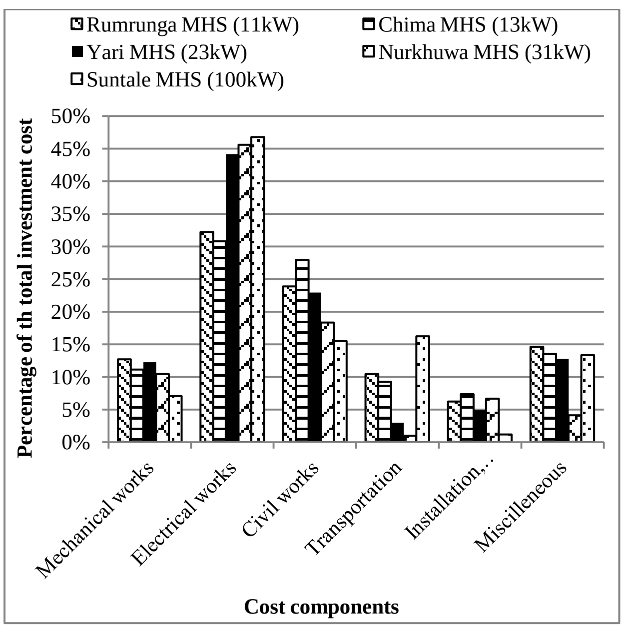

Figure 6: Cost contribtion of different components in MHP

Figure 5 shows variation of cost per kW of installation for micro hydro with its size. Cost per kW of installation decreases with size from per kW cost around Rs. 475,000 for 11kW size to Rs. 275,000 for 31kW. Cost per kW for 100kW size is higher due to involvement of high transmission and distribution cost for high voltage transmission.

Error! Reference source not found. shows the contribution of different components of micro hydro in total installation cost. From this table it can be seen that turbines cost around four percentage of the total cost and generator costs around four percentage of total cost while both of these have smaller share in larger installations.

Table 2: Shares of Different Components of MHP in Total Cost

Name of the scheme	Suntale MHS (100kW)	Nurkhuwa MHS (31kW)	Chima MHS (13kW)	Rumrunga MHS (11kW)	Average cost share
Head works	3.3%	1.3%	1.6%	1.2%	1.9%
Headrace canal	12.1%	10.4%	18.6%	14.8%	14.0%
Generator	1.2%	3.5%	4.7%	3.9%	3.3%
ELC	0.9%	2.9%	2.6%	2.9%	2.4%
Transformers	4.8%	4.5%	0.0%	0.0%	2.3%
Conductors	15.5%	14.8%	12.0%	15.3%	14.4%
Poles	11.1%	0.6%	2.0%	0.5%	3.5%
Turbine	1.4%	4.1%	3.8%	3.9%	3.3%
Penstock	3.3%	3.0%	2.8%	5.9%	3.7%

4. DISCUSSIONS

From observations and results it can be seen that the Nepalese MHPs have average efficiency lower than MHPs in developed countries. From the results of the efficiencies of Pelton and cross flow schemes it can be seen that cross flow turbines have better efficiencies as compared with Pelton schemes in case of Nepalese MHPs. In other countries Cross Flow installations have lower efficiency due to lower efficiency of the Cross Flow turbine as compared with the Pelton turbine installations. Either the Pelton turbines are operating in part load condition due to oversizing or there are some problems in design or fabrication in the Pelton turbines for having lower efficiency. Performance testing of Pelton turbines is needed to determine the exact cause of lower efficiency. Every effort should be made in improvement in turbine efficiency since it increases the efficiency of the whole power plant. Assuming generator efficiency to be 88% since it varies between 85% to 90% in Nepalese context and transmission drive efficiency to be 98%, turbine efficiency in Pelton installation in average becomes 67%. Similarly if same assumptions were made to calculate the turbine efficiency of the Cross Flow installations turbine efficiency becomes 71%. This means Pelton turbines are less efficient than the minimum standard fixed and Cross Flow turbines barely meet the minimum efficiency limitations. It is clearly seen that there is lot of space for improvement in turbine efficiency for both Cross Flow and Pelton turbines. Turbine and generator each cost around 4% at maximum of the total cost of the installation but have great influence in the power output from the scheme. Since all the material cost is already included, slight increase in cost of fabrication will increase the cost of turbine only by small amount. The cost increment incurred to increase the efficiency of turbine can be offset by the saving in extra cost that may be incurred in generating the power equal to the difference in two cases. Consider a micro hydro site with 10kW gross power available in water. If micro hydro is installed with water to wire efficiency of 70% it will generate 7kW of power. If micro hydro has the water to wire efficiency of 50% then 5kW of power will be generated. From analysis carried above cost of generation of one kilowatt of electricity from micro hydro is above Rs. 275,000. Increasing power output by 2kW from the same scheme at least Rs. 550,000 can be saved which can electrify extra 20 rural households. If extra cost incurred in selecting turbine and generator with more efficiency is less than this amount it should be selected and in most of the cases which is true. Efficiency of the micro hydro with Pelton turbines is found to increase with size of micro hydro which has also been reported by other literatures. Similarly, Cross Flow turbines have decreasing trend in efficiency with increase in size of the micro hydro due to increased friction loss in the blades as reported in the literatures. Cost reduction in Nepalese micro hydro is possible only by combined effort in improvement in component efficiencies, and use of local materials in civil works and electrical transmission and distribution system. First of all resource should be assessed well before designing of any MHP which will eliminate the error in head measurement. Well trained surveyor/technician use of well calibrated proper instrument will remove such error which will increase the certainty of the availability of the properly designed power output from the scheme. There should be end use promotion activities at the time of installation of the MHP to make sure the sustainability of the scheme. If we can increase the efficiency of these components specially turbines Nepalese MHPs will be more economic due to lower installation cost per kW power output from the scheme. ELCs should have rating higher than the actual power output of the scheme otherwise it will be damaged while dissipating excess power from the MHP.

5. CONCLUSIONS

From the analysis of the data obtained it is concluded that Nepalese MHPs have average water to wire efficiency of 59.8% which is well below the average efficiency of the MHPs in developed countries. Micro hydro with Pelton turbine installations have in average 57.4% water to wire efficiency, and that with Cross Flow turbine installations have 63.1% water to wire efficiency. Best efficiencies achieved in other country are 76.2% and 66.8% for Pelton and Cross Flow installations. The lower value of efficiency was found to be mainly caused by lower turbine efficiency. It can be seen that there is a wide space for improvement in efficiency. Though turbine and generators in average share around four per cent of the total cost in average they determine the power output from the scheme so every endeavour is to be made to increase the efficiency of these components which is causing the micro hydro to have lower efficiency. It was found that Nepalese MHPs have in average penstock efficiency of 94.7%; this value can be considered to be good. Cost per kW of power was found to decrease with larger installation, so larger size installations are to be promoted.

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Scenario Analysis of Road Transport Energy Consumption and Greenhouse Gas Emission in Nepal

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***Abstract*: This research paper analyzes the passenger transport sector of Nepal for future growth of vehicles, energy consumptions and greenhouse gas emissions. Various scenarios is developed to implicate the policy variables. The road transportation model has been developed in LEAP framework. The analysis is done from the year 2015 to 2040. Five different scenarios: Business as Usual, Improved Fuel Economy, Increased Public Transportation, Electric Microbus, Electric Two Wheelers and Combined option have been developed and the most effective alternative is the combined scenario. The final energy demand in Business as Usual scenario is 1943 ktoe in 2040 whereas it will be just 822.1 ktoe in combined option.**

1. INTRODUCTION

Transportation sector is one of the major energy consuming sector as well as major global greenhouse gas emitting sector. It accounts for about 28% of global primary energy consumption [1], mostly being liquid petroleum product and 13.5% of World greenhouse gas emission, of which road sector accounts for 9.9% [2]. In the transport related greenhouse gas emission, road transport contributes the highest share which is 79.5% [2]. Economic growth, rapid urbanization and increasing population are considered the main drivers for transportation sector energy demand. Energy use for transportation in developing countries are increasing and is expected to grow rapidly in future [3]. By the year 2030, there is projected to be more vehicles in developing world than in developed nations [4].

In Nepal, transport sector accounts for 5.2 % , second highest after residential sector , of primary energy consumption and 63.2% of total imported petroleum fuel [5]. It is in the increasing trend. The contribution of petroleum fuel in this sector is virtually 100 %. On an average, the energy consumption growth rate in this sector is 8.9% annually [5].

As far as CO2 emission is concerned, transport sector, road transport is the major mode of transport and dominates the energy use pattern, accounting for 86.5% of total sectoral consumption in Nepal [5].

The growth of vehicles accelerated after 1991 which are mostly concentrated in Kathmandu and other big cities of Nepal. The total number of vehicles registered as on 2012 [6]. This growth is mainly in personal vehicle sector occupies the top most position, accounting for 31% of total CO2 emission in Nepal [7]. Within the transport 1991 was 157,123 which outnumbered to 1,280,690 in like two wheelers and light duty vehicles like car, jeep and van. This rapid growth of vehicles has caused the tremendous demand of petroleum fuel in Nepal causing the importation of petroleum fuel which was 33.57% of total annual earnings from export in 2000/01 has increased to 126% in 2010/11 [8]. This outstripped growth of vehicle has manifested environmental problem in Kathmandu. Studies have shown that one of the major causes of air pollution in Kathmandu valley is due to transportation sector [9], [10]. According to the Ministry of Environment, Science and Technology (MoEST), the total suspended particles (TSP) due to vehicle emissions had increased by almost four times from 571 ton/year to 1971 ton/year between 1993 and 2001. Similarly PM10 due to vehicle emissions had increased by almost six times from 570 ton/year to 4708 ton/year between 1993 and 2005 accounting for 38% of total PM10 emission in Kathmandu valley [11]. These emission levels are well above the National Ambient Air Quality Standards (NAAQS) [12].

Most of the past studies concerning the implications of different transportation policy options to manage the energy demand and curb the emissions in this regard have been concentrated only in Kathmandu valley and very few studies have been done to cover the country as a whole. Shrestha and Malla, 1996 [9] studied the sectoral energy-use patterns including transport sector and the associated emissions in Kathmandu valley. The focus of the study was to build the inventory of pollutant emissions rather than the analysis of policy implications. Dhakal, 2003 [13] analyzed the implications of different transportation policies like public transportation, promotion of electric vehicles and improvement of traffic management on future energy demand and environmental emissions from passenger vehicles of Kathmandu valley in Long-range Energy Alternative Planning (LEAP) framework to construct future scenarios up to year 2020. Pradhan et al., 2006 [14] studied the potential implication of the extension of trolley bus in Kathmandu valley on fuel consumption and greenhouse gas emission up to the year 2025 in LEAP framework. Shrestha and Rajbhandari, 2010 [15] analyzed the sectoral energy consumption pattern including transport sector and emissions in Kathmandu Valley in MARKet ALlocation (MARKAL) framework for the period 2005 - 2050. Altogether nine fuel options were considered for the road transport. Shrestha, R., 2012 [16] studied the implication of low carbon transport (LCT) plans on low carbon development (LCD) for Kathmandu Metropolitan City using urban accessibility based planning support system.

To the knowledge of authors, the only study dealing with transport sector for the whole country was by Shakya and Shrestha, 2011 [17]. They studied and analyzed in detail the electrification of transport system of Nepal using the hydropower resource of the country under five different scenarios for the period 2015-2050 and the resulting reduction in greenhouse gas emission and improvement in energy security in MARKAL framework. However, the focus of this study was only on the electrification of transport sector. Various transportation policy options have not been dealt with. To deal with the looming danger of the burgeoning demand of petroleum fuel for vehicles and associated environmental emissions need holistic approach that combines various transportation policies to avert such situation. However, no such study has been carried out yet in Nepal. Therefore, the main objective of this study is to analyze the energy consumption by road transport under different scenarios and resulting greenhouse gas emissions and implication of various transportation policy options on the reduction of energy demand and improvement of environmental emissions for the period 2010-2040.

This study is performed on Long -range Energy Alternative Planning System (LEAP) framework. This study uses the concept of Weibull distribution function to estimate the survival profile of vehicles.

2. METHODOLOGY

Modeling energy use and emissions of motor vehicles in a region or country requires three parameters: present and future vehicle stock, vehicle-use intensity usually expressed in total kilometers travelled by a vehicle per year (VKT), vehicle fuel-use intensity (usually in liters per 100 km) and emission factors (in grams per kilometer) [18].

2.1 Vehicle Stock

All motorized road vehicles have to be registered at zonal-level Transportation Management Office, a government agency under the Department of Transport Management, Nepal. However, the statistics of registered vehicles given by Department of Transport Management represents the cumulative number of vehicles since their first registration. There is no de-registered vehicles data available when they go out of service. Therefore, the registered vehicle data do not represent the actual vehicles survived and plying on road. In order to model the energy demand and emissions by vehicles, it is necessary to know the actual vehicle stock plying on road. If the data on annual scrap rate is available, then the total survived vehicle each year can be calculated. However, data does not exist in Nepal and no study has been done so far in this regard.

Zachariadis T. et al., 1995,& 2001 [19], [20] have shown that modified two parameter Weibull function can be used to model the renewal of the vehicle fleet in European context. Baidya S. et al., 2009 [21] have used the same function in Indian context.

$$\emptyset_i(k) = e^{-\left[\left(\frac{k+b_i}{T_i}\right)^{b_i}\right]} \text{ and } \emptyset_i(0) = 1 \qquad (1)$$

where k is the age of vehicles , expressed in years, $\emptyset_i(k)$ is the survival probability of vehicle of type i having age k, b_i is the failure steepness for vehicles of type i ($b_i > 1$, i.e., failure rate increases with age) and T_i is the characteristic service life for vehicles of type i. The value of parameters b and T are very important to model the survived vehicle fleet and their value can be obtained by iterative process to match the actual real-world data. However, such data do not exist in Nepal. Baidya S. et al., 2009 [21] have assumed the values of b and T to Indian context. The vehicles' origin, road and driving conditions in Nepal are pretty much similar to Indian context. Therefore, the values of b can been taken from [21] for low survival rate. The characteristics service life, T_i assumed in [21] is bit higher to Nepalese context. Therefore, the value of T_i is taken from [17]. Table 1 shows the values of b and T . With equation (1) , survival profiles for different vehicles have been drawn as shown in figure 1.

Table 1: Parameters assumed for survival probability of vehicles in Nepal.

Vehicle Category	Bus	Truck	LDV[a]	M2W[b]	3W[c]
B	2.29	2.29	2.03	1.99	1.94
T	14	12	12	8.5[c]	10[d]

[a] Light Duty Vehicles , [b] Motorized Two Wheelers, [c] Three Wheelers
[d] Survey of existing motor M2W, [e] Survey of existing 3Wheelers

With the survival probability from equation (1), the number of vehicles actually circulating on the road for the year y can be calculated from the following equation [21].

$$N_{i,y} = 0.5 \times D_{i,y} + \sum_{x=1990}^{y-1} D_{i,y} \times \emptyset_i\,(y-x) \qquad (2)$$

where $D_{i,y}$ is the number of vehicles of type i sold in year y , $\emptyset_i(y\text{-}x)$ is the survival probability of vehicles of type i for age $(y\text{-}x)$. Sales since 1990/91 to reference year, 2010 have been taken into account to model the vehicle stock. Since vehicle sales data were not available, the registered vehicle numbers each year were assumed as the sales data for that year.

After having calculated the survival probability, the life cycle profile for each vehicle can be easily calculated by dividing each year's survived vehicles by the total vehicles from equation (2). Figure 1 and 2 show the life cycle profile of different vehicles.

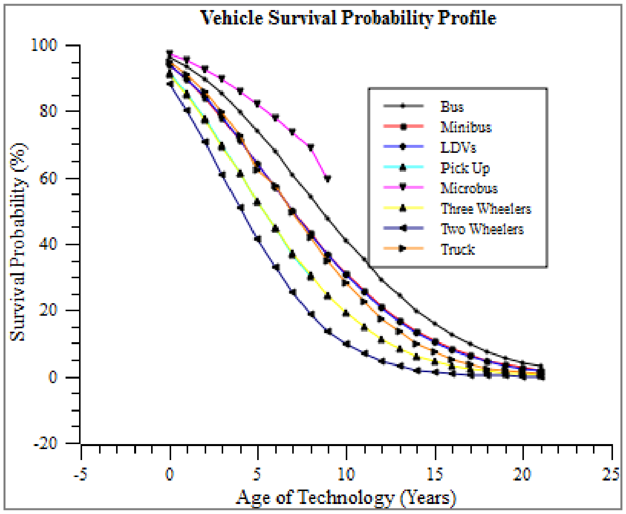

Figure 1: Vehicle Survival Probability Profile

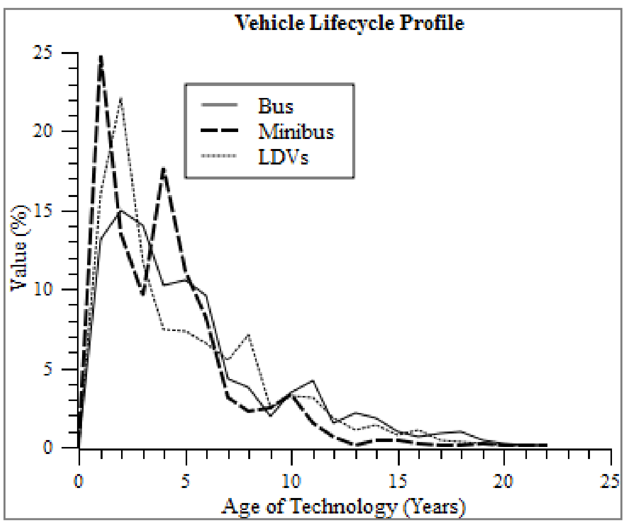

Figure 2: Lifecycle Profile of Bus, Minibus and Light Duty Vehicles

2.2. Vehicle-use Intensity

For the purpose of vehicle registration, Department of Transport Management, Nepal has classified the vehicles as bus, minibus, truck/tripper, car/jeep/van, pick-up, microbus, tempo (three wheelers), motorcycles, tractor/power tiller. For our study, we have classified the motor vehicles as bus, minibus, truck/tripper as heavy duty vehicles (HDVs), car/jeep/van as light duty vehicles (LDVs), microbus, pick-up , three wheelers (3W) and motorized two wheelers (M2W).

Buses, minibuses, microbuses and truck/tripper are further classified into local route and long route because they operate both locally within the city and long distance route. Similarly, light duty vehicles are further classified as private LDVs (gasoline car and diesel SUVs), commercial LDVs (gasoline taxi and diesel SUVs), government LDVs (gasoline car and diesel SUVs) and UN & Diplomatic "CD" license plate (gasoline car and diesel SUVs).

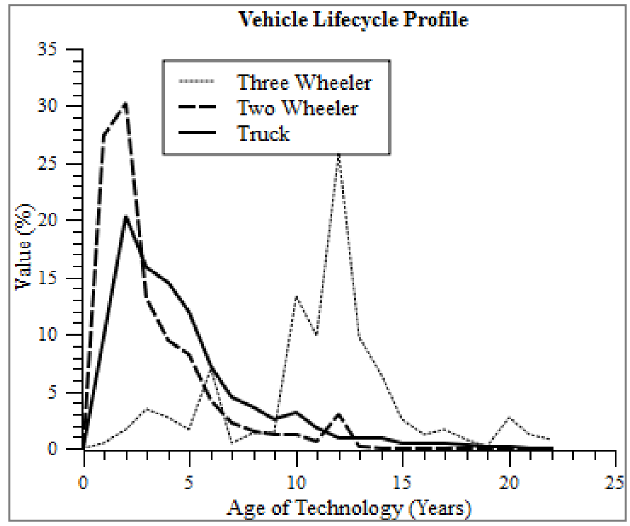

Figure 3: Lifecycle Profile of Three Wheelers, Two Wheelers and Truck

Very little studies have been done in Nepal regarding the vehicle-use intensity in terms of annual vehicle kilometer travelled (VKT). Dhakal, S., 1996 [22] surveyed the different vehicles (car, taxi, jeep, van, microbus, bus, minibus, two wheeler and three wheelers) in Kathmandu valley and estimated the annual VKT for local route. Ale, B.B., 2001 [23] studied the vehicles in Kathmandu valley and calculated the annual VKT. A survey was conducted by Department of Road, Nepal in 2001 [24] on long route bus and trucks and estimated the annual VKT.

In 2013, we conducted the survey of various vehicles in Kathmandu city and estimated the annual VKT for both short route and long route operating vehicles. Table 2 presents the estimated annual VKT by different studies.

In annual VKT of vehicles decline gradually as vehicles become older over a period of time [18]. In U.S. Department of Transportation, Technical Report, 2006 [25], following exponential model has been used to model the annual VKT as a function of vehicle age.

$$VKT_x = e^{-\alpha x} \tag{3}$$

Where, VKT_x is the annual VKT of vehicle of age x and α is the constant parameter for a given vehicle category. The values of α assumed for Nepalese vehicles are presented in Table 3.

Table 2: Annual Vehicle Kilometer Travel (VKT) estimated by different authors

Vehicle Type	Annual Vehicle Kilometer Travel (VKT) estimated by				
	Dhakal, S., 1996 (City route)	Ale, B.B., 2001 (City route)	DOR, 2001 (Long route vehicle)	Authors, 2013	
				City route	Long route
Bus	33,522	39,600	54,407	44,105	56,826
Minibus	31,790	37,125		43,307	47,500
Private car/SUV	16,349			12,310	
Taxi	41,970	32,340		25,356	
Microbus (Diesel/LPG)	41,970	37,125		38,520	
Government vehicle	34,830				
UN & CD Vehicles					
Battery operated 3W	29,848				
LPG 3W	29,848	32,340			
M2W	10,952				
Truck			83,654	37,800	46,860
Mini truck				37,415	

2.3. Vehicle Fuel-use Intensity and Occupancy Rate

Vehicle-fuel use intensity expressed in kilometer per liter or kilometer per kWh or kilometer per kg are taken from [13], [24], [26], [27] and [28]. We conducted vehicle survey as well for occupancy rate and fuel consumption. Table 4 presents the vehicle fuel use intensity and occupancy rate.

Table 3: Parameters assumed for annual VKT estimation as a function of vehicle age.

Vehicle Type	Value of α
Bus, Minibus	0.085
Truck/Tanker	0.1
Light Duty Vehicles	0.072
Microbus/Pickups	0.075
Three Wheelers	0.11
Two Wheelers	0.08

2.4. Econometric Model of Vehicle Stock

An econometric model was developed to project the future vehicle stock. Separate equations were estimated for each vehicle category. The registered vehicle data for the period 1990 - 2010 were used and regressed with population in case of bus and minibus, with urban population in case of LDVs and microbus, with per capita income in case of motorized two wheelers, with industrial and agricultural GDP with truck and pick up. The relationship was evaluated by the statistical significance.

$ln(Bus)_t = -40.26 + 2.76\, ln\,(pop)_t$, $R^2 = 0.70$

(t-stat: -4.45) (t-stat: 5.20)

$ln(Minibus)_t = -155.53 + 9.45\, ln\,(pop)_t$, $R^2 = 0.94$

(t-stat:-18.94) (t-stat:19.71)

$ln(\,LVDs)_t = -8.59 + 1.13\, ln\,(Urban\,pop)_t$, $R^2 = 0.68$

(t-stat:-3.49) (t-stat:6.88)

$ln(\,Truck)_t = -8.86 + 5.97 \ln(\,GDP_{Ag})_t - 3.30 \ln(GDP_{In})_t$

$R^2 = 0.79$ *(t-stat:-2.50) (t-stat:3.81 (t-stat:-2.92)*

$ln(\,M2W)_t = -34.58 + 2.99 \ln(\,Urban\,pop)_t$, $R^2 = 0.94$

(t-stat:-5.44) (t-stat:7.07)

$(Pick\,up)_t = -65439.8 + 3044.28\, ln\,(GDP_{In})_t$, $R^2 = 0.76$

(t-stat:-5.11) (t-stat:5.19)

$(Minibus)_t$: No. minibus in the year t
$(LDVs)_t$: No. of light duty vehicles in year t
$(Truck)_t$: No. of truck in year t
$(M2W)_t$: No. of motorized two wheelers in year t
$(Pick\ up)_t$: No. of pick-ups in year t
$(pop)_t$: Population in year t
$(GDP_{Ag})_t$: Agricultural GDP in year t at 1990 constant price
$(GDP_{In})_t$: Industrial GDP in year t at 1990 constant price
$(Urban\ pop)_t$: Urban population in year t
$(GDP_{In})_t$: Industrial GDP in year t at 1990 constant price

Table 4: Fuel Consumption by vehicle type

Vehicle Type	Fuel Type	Fuel consumption estimated by (km/l)			Occupancy Rate (passenger/vehicle)	
		Dhakal ,S.,1996	Authors,2013[a]		Dhakal,S.,1996	Authors
		City Drive	City Drive	Highway Drive	City Drive	City Drive
Bus	Diesel	3	3.5	4.5	50	43
Minibus	Diesel	4.5	4	4.5	35	31
Microbus	Diesel		6.2			16
Microbus, LPG	Gasoline	8.4 km/kg			12	
Gasoline Car	Diesel	10.6	13.5		2.6	3
Taxi	Gasoline	10.6	12.5		2.6	2.9
Diesel Car/SUVs	Diesel	8	8.5		2.6	3
Pick-up	Diesel		6.5			
Three Wheelers						
LPG	LPG	20.2 km/kg			9	
Battery	Electricity	5 km/kwh DC			9	
Motorcycle	Gasoline	53.8	42.5		1.6	1.8
Truck/Tanker	Diesel		3.5	4.08		
Mini Truck	Diesel		4.0			
Hybrid Car	Gasoline		22.22[b]			
Electric Microbus	Electricity		28.73[c]			
Biogas Bus	Biogas		2.88 [d] km/kg			
Biogas Car	Biogas		16.15[d] km/kg			

Notes:

[a] In total 836 vehicles consisting of bus , minibus, microbus, private vehicles, truck and mini truck plying on both city and highway drive were surveyed in 2013 and drivers were interviewed regarding fuel consumption and occupancy rate. The figures were then averaged.

[b] Hybrid car fuel consumption is taken from [29].

[c] Electric microbus fuel consumption rate is taken from [26].

[d] Biogas bus and car fuel consumption are taken from [27] & [28].

2.5. Emission Factors

Due to lack of published vehicle emission data in Nepal, the emission factors were taken from various existing literatures , mainly from Indian literature because of the similarities in vehicle type, conditions and fuel economy. The literature reviewed are Indian Clean Air Program (ICAP) report, 2007 [29], Dhakal,S.,2003 [13], Baidya & Borken-Kleefeld, 2009 [21], Nepal Vehicle Mass Emission Standard, 1999 [30], Ramachandra & Shwetmala, 2009 [31], Howey, D.A.et al.,2011[32], and UNEP, 2009 [33]. Table 5 presents the emission factors used in this study.

2.6. Scenario Development and Assumptions

As described in section 2.2, bus, minibus and truck/tripper are further classified as local drive (city drive) and long route drive (highway drive) vehicles. During the model development this classification has been used. As there is no formal statistics exists in Nepal regarding the fraction of vehicles operating within urban drive and long route drive, the fraction has been assumed based on the personal talking with various transport entrepreneurs and officers from Department of Transport Management, Nepal.

The fraction assumed for bus is 45% city drive bus and 55% long drive bus. For minibus the fraction assumed is 50% city drive and 50% long drive. Similarly, for heavy duty vehicles the fraction assumed is 35% city drive and 65% long drive.

Fuel economy rate of vehicles degrades along with the age of vehicles. However, it has been assumed constant in the model. Generally annual travel demand of vehicles changes over a period of time. However, it has been assumed constant in the model. Furthermore, tested emission factors for urban and highway driving do not exist in Nepal and therefore the emissions factors mentioned in Table No. 5 has been used for both city and highway drive conditions. Altogether eight different scenarios have been developed to estimate the total transport energy demand and environmental emissions.

BAU Scenarios: Business as usual scenario studies the continuance of existing trend. The year 1996 has been assumed as the base year. In this scenario, the growth of vehicles has been estimated using the econometric models described in section 2.4 with the existing growth trend in population and GDP. The emission factors, fuel economy and modal split have been assumed to remain constant as in base year. However, the base annual vehicle kilometer travelled (VKT) has been changed from 1996 to 2013 and thereafter assumed to remain constant. For the year 1996, the annual vehicle travel estimated by Dhakal, S., 1996 [13] has been used and from the year 2013 onwards, authors own estimation has been used in the model.

Improved Fuel Economy Scenario: In this scenario, it has been assumed that the fuel consumption rate of vehicle can be improved by different methods like timely servicing and maintenance of engine, increasing average vehicle speed by proper traffic management and introducing new fuel efficient vehicles in the market. It has been assumed that the fuel economy will be improved by 5% in 2015 to 25% in 2040 compared to the base year.

Increased Public Transportation: In this scenario, it has been assumed that share of public transportation like buses and minibuses will increase in future provided that government will encourage the public transportation and discourage the private vehicles. It has been assumed that the sales of buses will increase each year by 10% compared to as BAU scenario

and the sales of private vehicles will be decreased by the same percentage.

Introduction of Hybrid Electric Car: In this scenario, it has been assumed that the hybrid electric car will be introduced in Nepal by 2015 and the share of this car will be increased each year by 1% and the share of conventional car will be decreased by similar percentage.

Introduction of Electric Micro Bus: In this scenario, it has been assumed that government will bring the policy to encourage the electric vehicles in city drive and hence the electric microbus will be introduced by 2015. The share of electric microbus will be increased from 5% in 2015 to 55% in 2040 and the share of conventional diesel microbus will be decreased by the same percentage.

Introduction of Electric Two Wheelers: In this scenario, it has been assumed that government will encourage the electric two wheelers and hence the sale of the same will be increased from 5% in 2015 to 35 % in 2040.

Combined Scenario: The effect of only one scenario aforementioned will be negligible. In order to bring the visible effect in the energy demand and environmental emissions, the combined effect will be more effective. Therefore, in this scenario the combined effort of all the aforementioned scenarios will be used.

Table 5: Emission factors by vehicle type

Vehicle Type	CO_2 [a] (kg/GJ)	CO[b] (g/km)	NO_x [c] (g/km)	HC[d] (g/km)	PM_{10}[e] (gm/km)
Bus	79.70	4.9	6.8	0.87	1.075
Minibus	79.70	4.9	6.8	0.87	1.075
Light Duty Vehicles					
Gasoline car	70.54	3.16	0.21	0.19	0.06
Diesel car	54.82	3.16	0.26	0.14	0.18
Other diesel LDVs	75.66	3.16	0.28	0.32	0.48
LPG Vehicle	65.00	3.16	2.11	3.51	0.00271
3 Wheelers, LPG	63.00	3.34	0.88	1.46	0.17
3 Wheelers, Diesel	99.40	2.24	13	1.26	0.90
Motorized Two Wheelers	34.71	2.40	0.19	0.52	0.06
Truck/Tanker	82.61	4.90	9.3	0.87	1.24
Hybrid Car	58.85	0.03	1.3	0.004	0.01

Notes:

[a] CO_2 emissions data for buses, trucks and other LDVs are taken from Indian Clean Air Program (ICAP) report (2007). For gasoline and diesel car, data are taken from Baidya & Borken- Kleefeld (2009). For diesel and LPG three wheelers, data are taken from Dhakal (2003) and IPCC default value respectively. For hybrid car, it is taken from Howey (2011) [32].

[b] CO emission data for bus, minibus, LDVs, two wheelers are assumed Nepal Vehicle Mass Standard (1999) limit. For three wheelers and hybrid car, data are taken from Dhakal (2003) [13] and Hybrid Electric Vehicles, UNEP (2009) [33] respectively.

[c] NO_x emission data for bus, minibus, gasoline & diesel car, other diesel vehicles and truck are taken from Indian Clean Air Program (ICAP) report. The data for two wheeler are taken from Ramachandra & Shwetmala (2009) [31]. For LPG vehicle, and three wheelers, data are taken from Dhakal (2003) [13].

[d] HC emission data for bus , minibus, truck are taken from Ramachandra & Shwetmala (2009) [31]. For gasoline , diesel and other diesel LDVs, the emission data are taken from Indian Clean Air Program (ICAP) report. For three wheelers and LPG vehicles, the emission data are taken from Dhakal (2003). Emission data for hybrid vehicle is taken from Hybrid Electric Vehicles, UNEP (2009).

[e] PM_{10} emission data for bus, minibus, truck, other LDVs, diesel car and three wheelers are taken from Indian Clean Air Program (ICAP) report. Data for two wheelers, gasoline car and LPG vehicle are taken from Ramachandra & Shwetmala (2009) and for LPG vehicle are taken from Emission Estimation Technique Manual, Austria (2000).

[f] Heat value used for diesel, gasoline and LPG are 42.2029,44.7988, 47.3100 GJ/ton respectively. Specific gravity used for diesel, gasoline and LPG are 0.82, 0.75, 0.54 kg/l respectively. Efficiency of vehicles are taken from Table 3.

3. Biogas as a Renewable Transport Fuel

Biogas is considered as the source of renewable energy. It has been used for cooking and lighting in many countries since long time [34]. It has been already used for the production of heat and electricity in many countries. In recent years, there is growing interest in the use of this gas as a fuel for vehicles in many countries [35]. The use of biogas as a transport fuel is established and proven in European countries , mainly in municipalities in Sweden, Switzerland, France, Iceland and Italy and other European countries [28], [36].

The use of biogas as a vehicle fuel has lot of advantages compared with the conventional fossil fuels. Biogas driven vehicles can reduce CO_2 emission by between 75% and 200% compared with fossil fuels. Also biogas driven vehicles are quieter than diesel run vehicles**.** Thus biogas when used as vehicle fuel will help to reduce greenhouse gas emission, improves air quality, reduces dependency on oil and help manage waste [28], [37], [38], [39].

The Mysore City Corporation, India is also planning to establish Biogas Plant in the city to convert waste into fuel to be used in vehicles. Pune and Delhi are also in the race [40].

Nepal has huge potential for biogas production. Water and Energy Commission Secretariat (WECS), Nepal estimated that the biogas production potential in Nepal in 2008/09 was 1865.3 million m^3/year [5]. This estimation was based on the production of cattle and buffalo dung only, excluding municipal waste. Despite this huge potential, biogas has not yet been used for commercial utilization like heat & electricity production and transport fuel apart from being used for cooking and lighting in villages.

Municipal solid waste can be utilized to produce biogas which can be used to drive city buses, minibuses and other city drive vehicles. Solid waste generated in municipalities of Nepal is composed of 60-71% organic matter [41], [42], [43], [44], [45] which is biodegradable and can be used for the production of biogas. Table 6 and 7 show the municipal solid waste generation in Kathmandu Valley and in other major municipalities of Nepal. Table 6 shows that the potential of producing the biogas in Kathmandu valley (five metropolitan cities) is 77031.36 kg/day. The average fuel consumption for a typical large heavy goods vehicle is 34.65kg/100 km [28]. Assuming that the average daily vehicle kilometer travelled is 150 km in Kathmandu valley, this biogas is sufficient to run 1480 number of heavy goods vehicles in Kathmandu. If we could tap even 10% of this potential, we will be able to run 148 number of heady duty vehicles in Kathmandu valley. Similar is the case in other metropolis. Scenario has been developed to see the effect on total demand of diesel and emissions when biogas vehicle is introduced in urban driving.

4. Model Validation

After the model has been constructed, it has been validated using the historical energy consumption data. Figure 4 shows the comparison of model predicted and actual road sector diesel consumption.

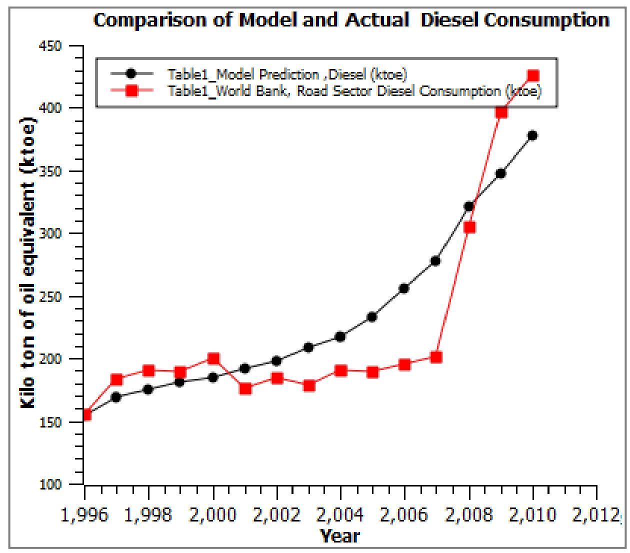

Figure 4: Comparison of model prediction and actual road sector diesel consumption

Figure 4 and Table 8 show that there is close agreement between the model predicted value and actual value of road sector diesel consumption from the year 1996 to 2000. The variation is less than 8% and this is due to the fact that the model has not taken into account the diesel consumed by tractor. From the year 2001 to 2007, actual value of diesel consumption has decreased and again has started increasing from 2008. One of the reason for this may be argued that mobility of people , specially long route drive might have decreased due to the Maoist insurgent in the country. The insurgent ended with peace accord on November 21, 2006 and again the consumption started increasing. Since the model is static in nature, it could not replicate this situation.

Table 6: Solid waste production and potential biogas generation in Kathmandu valley

SN	Name of Municipality	Waste Produc-tion (ton/day)[a]	Organic Waste (ton/day)[b]	Biogas Produc-tion (kg/day)[c]
1	Kathmandu Metropolitan	523.8	366.66	52799.04
2	Lalitpur Sub-Metropolitan	115.8	81.06	11672.64
3	Bhaktapur Sub-Metropolitan	61.4	42.98	6189.12
4	Madhyapur -Thimi Municipality	31.9	22.23	3215.52
5	Kirtipur Municipality	31.3	21.91	3155.04
	Total Biogas in Kathmandu Valley		534.94	77031.36

Table 7: Solid waste production and potential biogas generation in major municipalities

SN	Name of Municipality	Waste Production (ton/day)[a]	Organic Waste (ton/day)[b]	Biogas Production (kg/day)[c]
1	Biratnagar	129.3	90.51	13033.44
2	Pokhara	95.2	66.64	9596.16
3	Birganj	69.0	48.3	6955.20
4	Dharan	66.4	46.51	6698.16
5	Mahandranagar	62.0	43.4	6245.64

Notes:

[a] Municipal waste production data are taken from Dangi, Mohan & et.al.,2011[41] and state of environment ,Nepal 2001 [45].

[b] 70% of the solid waste was assumed as organic waste.

[c] 1 ton of municipal solid waste produces 144 kg of useable biogas from Anaerobic Digestion that can be used to drive vehicles [28].

Table 8: Comparison of predicted and actual road sector diesel consumption

Year	Model Predicted Diesel Consumption (ktoe)	Actual[a] Diesel Fuel Consumption (ktoe)	Difference in percentage
1996	154.2	156	1.15
1997	168.2	183	8.09
1998	174.7	190	8.05
1999	180.4	189	4.55
2000	184.2	200	7.90
2001	191.7	176	-8.92
2002	198.3	184	-7.77
2003	208.3	179	-16.37
2004	217.0	191	-13.61
2005	232.7	189	-23.12
2006	255.8	195	-31.18
2007	277.9	201	-38.18
2008	320.8	305	-5.18
2009	347.0	397	12.59
2010	377.2	426	11.46

[a] Road Sector Diesel Consumption , World Bank Data [46].

However, from the year 2009 onwards again the model has predicted closely to the actual diesel consumption. Similarly, figure 5 and table 9 show the comparison of predicted and actual gasoline consumption. Figure 5 and Table 9 show that there is close agreement between the model predicted value and actual value of road sector gasoline consumption. Therefore, this model is validated and can be used for further scenario analysis.

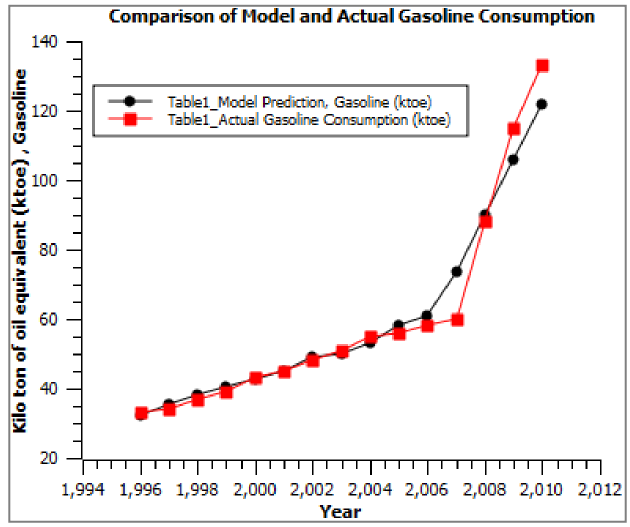

Figure 5: Comparison of model prediction and actual road sector gasoline consumption

5. Result and Analysis

5.1. BAU Scenario

The result of BAU scenario analysis shows that the total demand of diesel for passenger transportation increases from 184.6 ktoe in 2011 to 581.1 ktoe in 2040 whereas the demand of gasoline consumption increases from 136 ktoe in 2011 to 1362 ktoe in 2040. Thus the demand of gasoline will be more than two times the demand of diesel in the year 2040. Figure 6 shows growth of diesel and gasoline consumption in passenger transport sector. Similarly, out of the total passenger transport diesel consumption, the share of urban drive fuel consumption increases from 67.17% in 2011 to 71.94% in 2040.

CO_2 emission from diesel passenger transport in 2011 is 502.8 thousand ton which increases to 1581.4 thousand ton in 2040. Similarly, the emission from gasoline passenger transport in 2011 is 249.4 thousand ton which increases to 2153.9 thousand ton in 2040. Figure 7 shows the growth of CO_2 emission from passenger transport.

Table 9: Comparison of predicted and actual road sector gasoline consumption

Year	Prediction Gasoline Consumption (ktoe)	Actual [a] Gasoline Consumption (ktoe)	Difference in percentage
1996	32.1	33	2.73
1997	35.3	34	-3.82
1998	38.1	37	-2.97
1999	40.5	39	-3.85
2000	42.7	43	0.70
2001	45.0	45	0.00
2002	49.2	48	-2.5
2003	49.9	51	2.16
2004	53.3	55	3.09
2005	58.0	56	-3.57
2006	61.1	58	-5.34
2007	73.5	60	-22.50
2008	90.0	88	-2.27
2009	105.9	115	7.91
2010	121.9	133	8.35

[a] Road Sector Gasoline Consumption, World Bank Data[46].

5.2 Alternative Scenarios

Alternative scenarios include improved fuel economy, increased public transportation, introduction of hybrid car and electric microbus and combined scenario. Table 10 and figure 7 show the comparison of result of simulations for different alternative scenarios. Among the scenarios, the total final energy demand for improved fuel economy (both gasoline & diesel) is 1662.3 ktoe, for increased public transportation is 1317.9 and for combined scenario is 822.1 ktoe compared to1943 ktoe in the BAU scenario. Similarly, the introduction of electric two wheelers will reduce the demand of gasoline from 1362 ktoe in BAU to 974.1 ktoe.

6. Conclusion and Discussion

The alternative scenario analysis has some policy implications. As seen in table 10, the introduction of electric two wheelers alone will reduce the gasoline consumption from 1362 ktoe to 974.1 ktoe in 2040. This will reduce the environmental emissions as well as the importation of gasoline. Similarly the increased public transportation reduces the total energy demand from 1643 ktoe to 1317.9 in 2040 which is about 625.1 ktoe. The most effective option is the combined scenario in which all the scenarios are implemented together. In order to achieve the visible effect, government should consider this combined option.

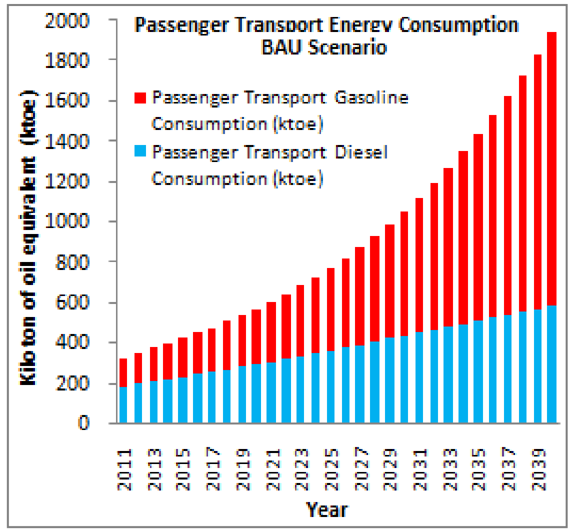

Figure 6: Growth of diesel and gasoline consumption in passenger transport sector

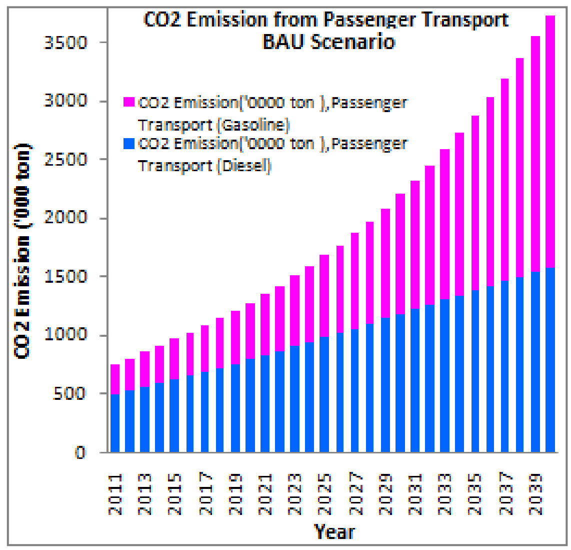

Figure 6: Growth of CO2 emission from gasoline and diesel passenger transport

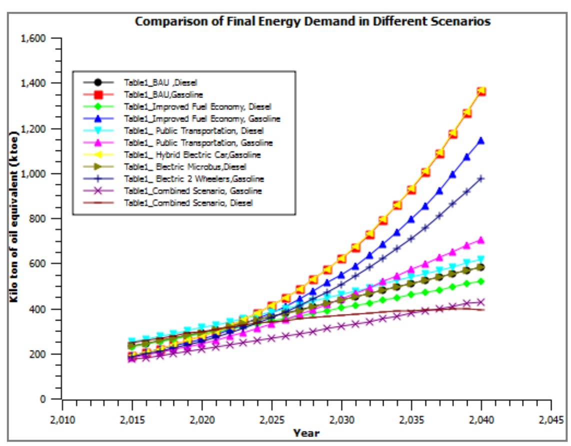

Figure 7: Comparison of final energy demand in different scenarios

Table 10: Final energy demand of passenger transport in different scenarios

Year	BAU Diesel	BAU Gasoline	Fuel Economy Diesel	Fuel Economy Gasoline	Public Transport Diesel	Public Transport Gasoline	Hyb.El. Car Gasoline	Electric Microbus Diesel	Electric 2 Wheeler Gasoline	Comb. Scenario Gasoline	Comb. Scenario Diesel
2015	231.5	190.5	230.2	189.3	252.4	181.3	190.5	231.5	184.5	172.7	248
2020	292.6	274.2	284.4	264.1	313	243.3	274.1	292.5	254.1	217.1	297.9
2025	361.6	409.9	342.1	379.3	384	330.2	410.1	361.5	356.4	266.5	340
2030	434.7	618.6	400.1	548.6	460.3	440.6	619.6	434.5	505.2	319.6	369.6
2035	508.7	925.9	458.4	793.2	538.1	569.7	929.6	508.5	709.2	375.9	389.8
2040	581	1362	517.9	1144.4	614.3	703.6	1368.8	580.7	974.1	428	394.1

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Optimization of Energy Detection Approach of Spectrum Sensing in Cognitive Radio Network

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***Abstract*: In the cognitive radio, spectrum sensing is the first task to check the presence of licensed users. Among the different approaches of spectrum sensing, energy detection (ED) is the easiest approach in terms of computational complexity which requires less prior information. In this paper, energy detection (ED) is considered under a typical fading unknown as channel and white Gaussian noises. Introducing an idea of auxiliary noise variance estimation for the absence of prior knowledge of noise power, Hybrid Energy Detection-1 (HED1) / Hybrid Energy Detection-2 (HED2) approach of signal detection is set forth. For HED1, noise variance is estimated in S auxiliary noise only slots and for HED2 noise variance is estimated in S auxiliary slots which are declared only noise signal slots by ED. The detection performance of the considered methods are derived and expressed by analytical formulas. The impact of noise estimation accuracy on the performance of ED is compared based on Receiver Operating Characteristics (ROC) curves and Performance Curves. This study shows that the performance of ED can be increased in terms of ROC performance even in low SNR by increasing the number of samples considered for noise variance estimation.**

Index Terms – Energy Detection, Receiver Operating Charactersitics

1. INTRODUCTION

Spectrum is a valuable resource. The rapid development in communication and technologies evolving day by day demands more spectrum. Those ranges of spectrum which are highly demanded in terms of propagation properties are already assigned. The spectrum assigned is also underutilized. Cognitive radio is an evolving technology that can provide dynamic spectrum access to the unlicensed users whenever the licensed users are inactive in that range. The main purpose of cognitive radio is to obtain the best available spectrum through cognitive capability and provide dynamic spectrum access. Dynamic spectrum access techniques allow the cognitive radio to operate in the best available channel. The cognitive radio enables the usage of temporally unused spectrum, which is referred to as spectrum hole or white space. If this band is further used by a licensed user, the cognitive radio moves to another spectrum hole or stays in the same band, altering its transmission power level or modulation scheme to avoid interference. “Cognitive radio” is a fully programmable wireless device that can sense their environment and dynamically adapt their transmission waveform, channel access method, spectrum use, and networking protocols as needed for good network and application performance [1]. Cognitive radio network is a combination of Spectrum sensing, Spectrum management, Spectrum mobility and Spectrum sharing. This network will perform efficiently if all the functions of the Cognitive radio network are attained at a desirable rate. Cognitive radio gives the unlicensed users access to the licensed spectrum whenever the primary users are not active within the given spectrum and thus contribute to the effective bandwidth utilization.

Spectrum Sensing is the first task needed to be performed for Dynamic Spectrum access in a Cognitive radio network which enables the cognitive radio to adapt to its environment by detecting spectrum holes. The most efficient way to detect spectrum holes is to detect the primary users that are receiving data within the communication range of a secondary user. In reality, however, it is difficult for a secondary user to have accurate channel information between a primary receiver and a transmitter due to the inherent property of cognitive radio. The most recent work engages in primary transmitter detection based on local observations of secondary users. The current spectrum sensing methods can be classified as three categories: Non-cooperative spectrum sensing, cooperative spectrum sensing and interference temperature spectrum sensing [3]. In the aspect of spectrum sensing, the sensing device located at secondary user section measures certain characteristics of the radio waveform and then decides if a primary user is actively using the spectrum. Among different transmitter detection spectrum sensing techniques such as the matched filter detection (coherent detection through maximization of the signal to noise ratio) and the cyclostationary (exploitation of the inherent periodicity of primary signals) “Energy detection” is the most popular method addressed in literature [3].

Measuring only the received signal energy, the energy detector is a non coherent detection device with low implementation complexity. It doesn’t need any prior information about the signal characteristics as in other types of transmitter detection techniques of spectrum sensing. The energy detector measures the energy of the input wave over a specific period and compares it with the threshold for deciding the presence/absence of spectrum usage by primary user. Absence of primary user provides opportunity for secondary users to access the spectrum until the former use that spectrum. Once the primary user is active in the spectrum, the secondary user should vacate that range of frequency.

Energy detection was first discussed in [3] which evaluates the closed form expressions of the performance parameters P_d(probability of Detection) and P_f(Probability of false alarm rate) based on the scenario of unknown signal of known amplitude transmitted over a flat-band limited Gaussian noise channel. The result of this work was extended in [5] which derived the closed form expression of P_d and P_f of the signal with random amplitude for different types of distributions. [6] studied about the problem of Unknown signals over different fading channels. Starting with no diversity case, it presented the closed form of expression of system performance when different diversity techniques are employed. Based on the assumption that we cannot estimate the actual noise variance of the channel, which has a direct effect in the estimation of Pf, [7] analyze the performance of spectrum sensing based on energy detection using an estimated noise variance to calculate the threshold where noise variance was estimated using a spare channel dedicated for analyzing noise characteristics. Performance of ED in AWGN and different fading channels has been studied in many works including [8, 9, 10]. These works assumed a perfect knowledge of the noise power at the receiver, which allows for the perfect threshold design. In that case ED can work with arbitrarily small value of False Alarm Probability and Miss-detection Probability (PMd), by using sufficiently large observation time, even in low SNR environment [11]. However, in real systems the detector does not have a prior knowledge of the noise level. Variation and unpredictability of the precise noise level at the sensing device came as a critical issue, which is also known as noise uncertainty. With the motive of reducing the impact of noise uncertainty on the signal detection performance of ED, several researches have been proposed. Hybrid Spectrum Sensing Algorithms based on the combination of ED and Feature Detection techniques are put forwarded for the reduction of the effect of noise variance uncertainty [13, 14]. In [11] the fundamental bounds of signal detection in presence of noise uncertainty are analyzed. This study showed that there are some SNR thresholds under noise uncertainty known as SNR Wall that prevents achieving the desired performance even if the detection interval is made infinitely large. It concludes that the robustness of any detector can be quantified in terms of the SNR Wall giving the threshold below which weak signals cannot be detected reliably no matter how many samples are taken. In [12] author performed the asymptotic analysis of the estimated noise power (ENP) to derive the condition of SNR Wall phenomenon which suggested that the SNR Wall can be avoided if the variance of the noise power estimator can be reduced while the observation time increases. [14] proposed an uniform noise power distribution model for the noise uncertainty study of ED in low SNR regime.

This paper formulates the detection performance of Hybrid approach of ED which is named as Hybrid Energy Detection (HED) and Hybrid Energy Detection 2 (HED2) to optimize the performance of Energy detection techniques with high probability of detection.

2. System Modeling

In our system model, we consider a single sensor Energy Detector which senses and decides the presence or absence of the primary signal within a defined spectrum band W. In a given sensing time interval T, the Energy Detector calculates its detection statistic $\boldsymbol{T_{ED}}$ taking N samples of received signal $y(n)$. Let

$$Y = [\, y(1) \dots \dots \dots y(n) \dots \dots \dots y(N)]^T \qquad (1)$$

be the $N \times 1$ received vector at an arbitrary sensing interval T, where the element $y(n)$ is the discrete baseband complex sample at the receiver at time n. Now the spectrum sensing problem using Energy Detection can be viewed as a binary detection problem. The decision of the Energy Detector is the test of the following hypothesis.

$$\boldsymbol{Y} = \begin{cases} \boldsymbol{V}, & H_o(Noise\ alone) \\ \boldsymbol{hS} + \boldsymbol{V}, & H_1(Signal\ and\ Noise) \end{cases} \qquad (2)$$

Where,

- n = 1, 2, 3…N, represents the samples (detection period).
- $\boldsymbol{Y}$ is the received signal vector at the sensor and $\boldsymbol{h}$ is a channel vector which is assumed to be constant and memory less within the sampling interval,
- $\boldsymbol{S}$ is the primary signal vector, $\boldsymbol{S} = [s(1) \dots \dots s(n) \dots \dots s(N)]^T$, which is assumed to be Complex Gaussian Distributed signal with zero mean and variance σ_s^2 having flat band limited power spectrum density PSD: $s(n) \sim N_¢(0, \sigma_s^2)$
- $\boldsymbol{V}$ is noise vector, $\boldsymbol{V} = [v(1) \dots \dots v(n) \dots \dots v(N)]^T$ also assumed to be Complex Gaussian Distributed Noise signal with zero mean and variance σ_v^2: $v(n) \sim N_¢(0, \sigma_v^2)$.

[Note: $N_¢$ is the notation for Complex Normal Distribution Random Variable and N_R is the Real Normal Distribution Random Variable]

Using the information of the received signal vector $\boldsymbol{Y}$ to develop a test statistic $\boldsymbol{T_{ED}}$, which is the measure of the average energy of the received signal over a sensing interval N, the detector compares $\boldsymbol{T_{ED}}$ against a predefined threshold $\boldsymbol{t}$. If $\boldsymbol{T_{ED}} < t$ then it decides in favor of Null Hypothesis $\boldsymbol{H_0}$ otherwise in favor of Alternate Hypothesis $\boldsymbol{H_1}$. The average energy of the received signal vector $\boldsymbol{Y}$ normalized by the noise variance can be represented as,

$$\boldsymbol{T_{ED}} = \left(\frac{1}{N\sigma_v^2}\right)\sum_{n=1}^{N}|y(n)|^2 \qquad (3)$$

A. Energy Detection

In energy detection we compare the calculated decision statistic of the sample with the predefined threshold. The detection statistic is obtained by integrating the energy of the signal over certain time interval T.

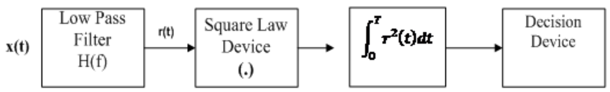

Figure 1: Energy based detector

For Null Hypothesis rearranging the above equation (3) using $y(n) = v(n)$, we get,

$$\boldsymbol{T_{ED}}|_{H_0} = \left(\frac{1}{N\sigma_v^2}\right)\sum_{n=1}^{N}|v(n)|^2 \qquad (4)$$

The decision statistic$\boldsymbol{T_{ED}}|_{H_0}$ for null hypothesis can be summarized as Chi Square Distribution with 2N degrees of freedom scaled by the factor$\left(\frac{1}{2N}\right)$.

$$\boldsymbol{T_{ED}}|_{H_0} = \left(\frac{1}{2N}\right)\chi_{2N}^2 \qquad (5)$$

Similarly for Alternate Hypothesis, considering the channel coefficient as a constant value rather than a vector and rearranging the equation (3) using $y(n) = hs(n) + v(n)$, we summarize the decision statistics as,

$$\boldsymbol{T_{ED}}|_{H_1} = \left(\frac{h^2\rho+1}{2N}\right)\chi_{2N}^2 \qquad (6)$$

A numerical study shows that Energy Detection ROC curve based on chi-squared distributions may be accurately represented by binomial receiver operating characteristics (ROC) curves. This allows the detector accuracy and the ROC shape assymetry to be expressed simply in terms of distribution parameters[5]. The probabilities of false alarm P_f and probability of detection P_d for a given threshold energy $\boldsymbol{T_{ED}}$is given by,

$$P_f = Prob\left\{\boldsymbol{T_{ED}} > \frac{\boldsymbol{t}}{H_0}\right\} \qquad (7)$$

$$P_d = Prob\left\{\boldsymbol{T_{ED}} > \frac{\boldsymbol{t}}{H_1}\right\} \qquad (8)$$

Based on the statistics, P_d and P_f for Gaussian distributed T_{ED} can be evaluated finally as a Q function given as,

$$P_f = Q\left(\frac{(t-\mu)}{\sqrt{\sigma^2}}\right) \qquad (9)$$

$$P_d = Q\left[\frac{(t-w)\sqrt{N}}{w}\right] \qquad (10)$$

B. Hybrid Energy Detection

In HED, Noise Variance is estimated on L auxiliary noise only slots and supposing the noise variance is constant over the adjacent slots, we perform independent noise estimation in auxiliary “noise only” slots where we are sure that the primary signal is absent. Since we are sure that there is only noise in each slots, noise variance can be estimated by using all the samples. Consider a sampling window of length M before and adjacent to the detection window which is containing only the noise samples for sure. Then the estimated noise variance from the noise only samples using a Maximum Likelihood noise power estimate can be written as,

$$\hat{\sigma}_v^2 = \frac{1}{M}\sum_{k=1}^{M}|v(k)|^2 \qquad (11)$$

k denotes that the noise only samples are adjacent to the detection window. If the estimated variance is constant, the estimation can be averaged over S successive noise-only slots. Thus, above equation (11) can be modified by averaging over S successive noise-only slots as,

$$\hat{\sigma}_v^2(S) = \frac{1}{MS}\sum_{j=1}^{S}\sum_{k=1}^{M}|v(k)|^2 \qquad (12)$$

Now the Energy Detection Test statistics using equation (12) becomes,

$$\boldsymbol{T_{ED}^H} = \left(\frac{1}{N\hat{\sigma}_v^2}\right)\sum_{n=1}^{N}|y(n)|^2 \qquad (13)$$

Here $\boldsymbol{T_{ED}^H}$ denotes the detection statistics for the Hybrid Energy Detection scheme and the statistical distribution of $\boldsymbol{T_{ED}^H}$ depends upon the particular estimation technique considered. Moreover equation (13) can be considered as the parametric likelihood ratio test when the signal to be detected is assumed to be Gaussian with zero mean and variance σ_s^2. Now for Null Hypothesis rearranging the above equation (13) using $y(n) = v(n)$ and equation (11), we get,

$$\boldsymbol{T_{ED}^H}\Big|_{H_0} = \left(\frac{1}{N\hat{\sigma}_v^2}\right)\sum_{n=1}^{N}|v(n)|^2 \qquad (14)$$

Summarizing the result of decision statistics$\boldsymbol{T_{ED}^H}$, it follows the F-Distribution for both the hypothesis with different scaling factor.

$$\begin{cases} \boldsymbol{T_{ED}^H}\Big|_{H_0} = F(2N, 2MS) \\ \dfrac{\boldsymbol{T_{ED}^H}|_{H_1}}{w} = F(2N, 2MS) \end{cases} \qquad (15)$$

According to the Central Limit Theorem, when N and M are made sufficiently large, the F-Distributed Random Variable in equation (15) converges to a Gaussian distribution [23]. It gave two approximation models where both transform the C-CDF of F-Distributed Random Variable to a Q-function with different parameter. In figure 2, we have plotted the Mean Square Error (MSE) of the approximation considering pdf of distributions as a comparison criteria for varying N and found that the approximation shows perfect result for N greater than 40. It also shows that the MSE is nearly zero, i.e. the Gaussian approximation is perfectly true for N > 40, which indicated that the degree of freedom greater than 40 is sufficient for approximating Chi Squared Distribution of the detection statistic to a Gaussian distribution.

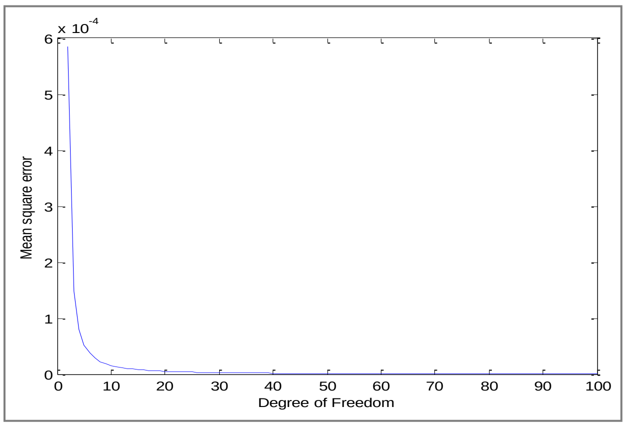

Figure 2: Mean Square Error of the approximation considering pdf as a comparison criteria

For the result in equation (15), using **Approximation 2** for approximating F-Distribution Function to a Normal Distribution Function, we get,

$$\begin{cases} \boldsymbol{T^H_{ED}}\big|_{H_0} = N_{\cent}\left(\alpha, \frac{\alpha^2(2N+2MS-1)}{4N(MS-1)}\right) \\ \frac{\boldsymbol{T^H_{ED}}|_{H_1}}{w} = N_{\cent}\left(\alpha, \frac{\alpha^2(2N+2MS-1)}{4N(MS-1)}\right) \end{cases} \tag{16}$$

$$where, \alpha = \frac{2MS}{(2MS-1)}$$

For Gaussian distributed T^H_{ED}, following above approximation based on the statistics of $\boldsymbol{T^H_{ED}}$, P^H_f can be evaluated as,

$$P^H_f = Q\left[\frac{(\boldsymbol{t}-\alpha)}{\alpha\sqrt{\frac{(N+MS-1)}{N(MS-2)}}}\right] \tag{17}$$

Where $Q(x)$ is the Q-function which is also known as the tail probability of the Standard Normal Distribution. Similarly, for the same threshold level $\boldsymbol{T_{ED}}$ the probability of detection is given by,

$$P^H_d = Prob\{\boldsymbol{T_{ED}} > \boldsymbol{t}/H_1\} \tag{18}$$

Following the same line of reasoning, we get the expression of P_d as shown below.

$$P^H_d = Q\left[\frac{(\boldsymbol{t}-\alpha w)}{\alpha w\sqrt{\frac{(N+MS-1)}{N(MS-2)}}}\right] \tag{19}$$

C. Hybrid Energy Detection-2

In HED2, Noise Variance is estimated on S auxiliary noise only slots which are declared noise only by ED. Supposing the noise variance is constant over the adjacent slots, we perform independent noise estimation in auxiliary "noise only" slots which are declared H_0 by ED by considering a sampling window of length M before and adjacent to the detection window containing only the noise samples. Optimum performance of Energy detection technique can be achieved if there is prior knowledge of nose samples. But in absence of that also, ED can be optimized. HED2 optimize the performance of ED by estimating the noise power knowledge from a large number of noise samples. Also, it is difficult to guarantee the availability of signal free samples to estimate the noise variance in real time. The average noise variance or estimated noise variance from the noise only samples declared by ED can now be modified as,

$$\hat{\sigma}_v^2(S) = \frac{1}{MS}\left[\begin{array}{c}\sum_{j=1}^{S_S}\sum_{k=1}^{M}|h(k)s(k)+v(k)|^2 \\ +\sum_{j=1}^{S_N}\sum_{k=1}^{M}|v(k)|^2\end{array}\right] \tag{20}$$

Where $S_s = P_s \times (1-P_d^{ED})S$ and $S_N = S - S_S$

Now the Energy Detection Test Statistic in equation (3) becomes,

$$\boldsymbol{T^{H2}_{ED}} = \left(\frac{1}{N\hat{\sigma}_v^2}\right)\sum_{n=1}^{N}|y(n)|^2 \tag{21}$$

Here $\boldsymbol{T^{H2}_{ED}}$ denotes the detection statistics for the Hybrid Energy Detection-2 scheme and the statistical distribution of $\boldsymbol{T^{H2}_{ED}}$ depends upon the particular estimation technique considered. After applying the equation in case of Null and Alternate hypothesis, we obtain the sum of square of Standard normal random variable following a Chi Square Distribution with degree of freedom equal to the summation order.

Noting the result we get,

$$\begin{cases} \boldsymbol{T^{H2}_{ED}}\big|_{H_0} = \left(\frac{MS}{N}\right)\left[w\frac{\chi^2_{2MS_S}}{\chi^2_{2N}} + \frac{\chi^2_{2MS_N}}{\chi^2_{2N}}\right]^{-1} \\ \boldsymbol{T^{H2}_{ED}}\big|_{H_1} = \left(\frac{MS}{N}\right)\left[\frac{\chi^2_{2MS_S}}{\chi^2_{2N}} + \frac{1}{w}\frac{\chi^2_{2MS_N}}{\chi^2_{2N}}\right]^{-1} \end{cases} \tag{22}$$

For large N and M, equation (22) with Chi Square Distributions in numerator and denominators can be approximated with their Normal approximates given by the approximation formula $\chi^2_N \cong N_{\cent}(N/2, N)$). Thus, simplifying the expression of $\boldsymbol{T^{H2}_{ED}}$ for Null hypothesis in equation (22) using the normal approximates, we get,

$$\boldsymbol{T_{ED}^{H2}}\Big|_{H_0} = N_R\left(\frac{S}{(S_s w + S_N)}, \ \frac{\boldsymbol{t}^2 N(S_s w^2 + S_N) + MS^2}{MN(S_s w + S_N)^2}\right) \tag{23}$$

$$\boldsymbol{T_{ED}^{H2}}\Big|_{\boldsymbol{H_1}} = N_R\left(\frac{S}{\left(S_s + \frac{S_N}{w}\right)}, \quad \frac{\boldsymbol{t}^2 N\left(S_s + \frac{S_N}{w^2}\right) + MS^2}{MN\left(S_s + \frac{S_N}{w}\right)^2}\right) \tag{24}$$

Based on the statistics of $\boldsymbol{T_{ED}^{H2}}$ shown in equation(23,24) , P_f^{H2} can be evaluated as,

$$P_f^{H2} = \int_{\boldsymbol{t}}^{\infty} \boldsymbol{T_{ED}^{H2}}/H_o dt$$

After certain mathematical procesiing using equation (24), we get

$$P_f^{H2} = Q\left[\frac{(\boldsymbol{t}-\mu_1)}{\sqrt{\sigma_1^2}}\right] \tag{25}$$

Similarly, for the same threshold level $\boldsymbol{T_{ED}^{H2}}$ the probability of detection is given by,

$$P_d^{H2} = Prob\left\{\boldsymbol{T_{ED}^{H2}} > \frac{\boldsymbol{t}}{H_1}\right\}$$

Following the same line of reasoning and using equation(24), we get the expression of P_d as shown below.

$$P_d^{H2} = Q\left[\frac{(\boldsymbol{t}-\mu_2)}{\sqrt{\sigma_2^2}}\right] \tag{26}$$

3. Results and Discussion

This section implements the simulation of Energy Detection in single sensor environment. Signal, channel and the noise environment is set in such a way it matches the scenario explained in previous sections.

Figure.3 illustrates the ROC plot of single sensor Energy Detector with its detection statistic following Normal distribution. Analytical result of ROC for Energy Detection computed for SNR = -10dB, number of sensors K = 1 and N=20, 50, 100 and 200 respectively where N represents the number of samples taken to calculate the decision statistics. This figure shows high detection probability with higher number of samples (i.e. N=200) taken to calculate decision statistics and the proper detection rate decreases simultaneously with lower number of samples considered.

The accuracy of the closed-form expression of the theoretical formula is compared against simulated detection performance over S auxiliary noise only slots (S ranges from 1 to 10). It can be realized from Figure 6.4 that the analytical and the numerical curves are perfectly matching which validates the analytical expressions. Also, it can be noted that, the increase in number of slots for noise variance estimation correspondingly increases the performance of HED and approaches closer to the optimal one (ED with known noise variance). Under the considered scenario with M = N = 400 which is the number of noise samples in each slot, just S = 10(i.e., 4000 samples) provides very near convergence to ideal performance. For each numerical curve, its analytical counterpart is superimposed to evaluate the accuracy of the model for different values of S.

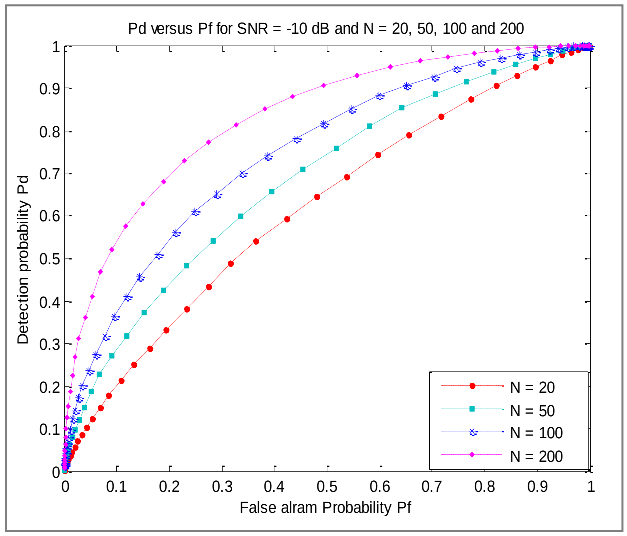

Figure 3: ROC plot of Energy Detection with SNR = -10dB for varying number of samples

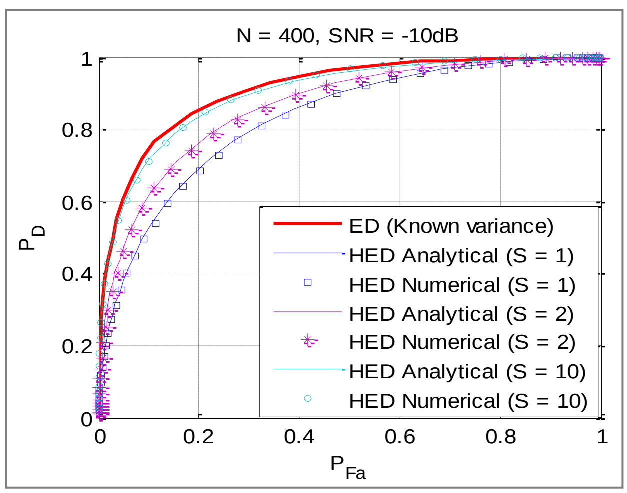

Figure 4: ROC curve of Single Sensor Hybrid Energy Detection for N = 100, M = 100, S = {1, 3, 5 and 10}, σ_v^2 = 400, σ_s^2 = 40, SNR = -10dB

For given probability of false alarm P_{Fa} = 0.05 and considered parameter (K = 1;N = 50;M = 50), the performance of Hybrid Energy Detection is also evaluated in terms of probability of detection against different values of SNR as shown in figure 5. This validates our result showing that the increase in number of slots for noise variance estimation correspondingly increases the performance of HED. The probability of detection is increased with increase in number of slots and plot for S=10 almost coincide with the optimal one (known noise variance)

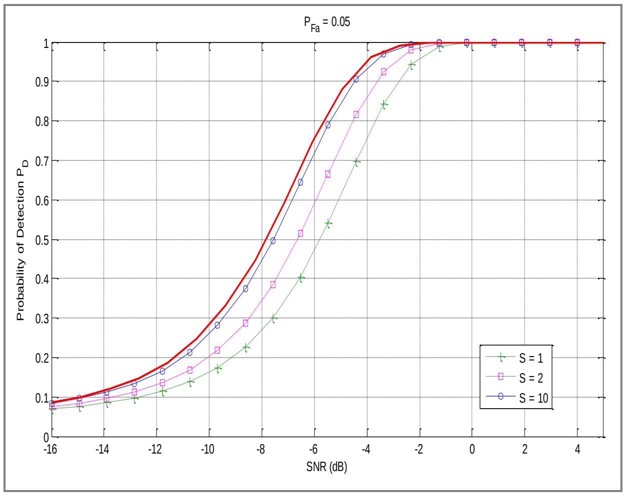

Figure 5: Probability of detection vs SNR for Hybrid Energy Detection

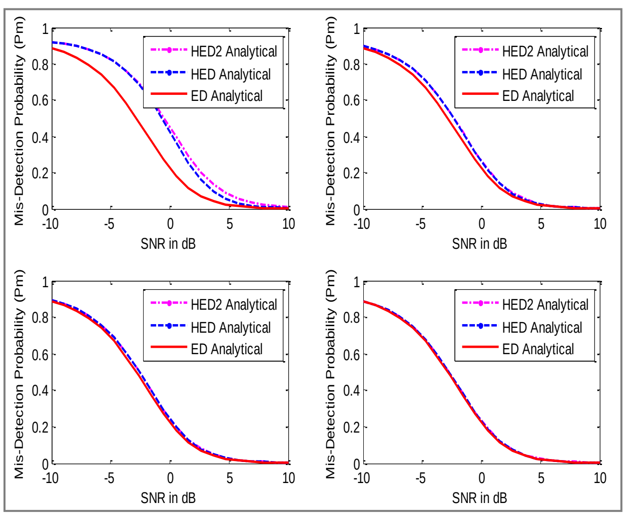

Figure 6: P_m vs SNR plot of Single Sensor Hybrid Energy Detection-2 for Gaussian Approximation of the Decision Statistics for N = 10, S = (2, 10, 20, 50), M = 10, SNR = -10dB to 10 dB, $h = 1$ and false alarm probability pf = 0.1.

Figure 6 illustrates the simulation of Single Sensor HED2 ROC curves when the noise variance is independently estimated by applying the obtained equation over S auxillary only noise slots determined by ED and the estimate $\hat{\sigma}_v^2$ is used in equation (3) for all other slots recursively. For generating the HED2 performance curve, ED parameters within HED2 are, N = 10, pd_ed = 0.5, assuming signal probability 0.5 and noise probability 0.5. Since, there is a chance of misdetection in case of HED2, performance of HED2 is slightly lower than HED but still no visible difference can be noted in extreme high or low SNR values. With the increase of the number of slots used for the estimation of the noise variance, HED and HED2 curves approximate the ED with known variance.

4. Conclusion

Different methods of existing spectrum sensing were studied and the performance of different channels is analysed in terms of Receiver Operating Characteristic (ROC) curves. Objective of every spectrum sensing scheme is to find out the detection statistic which can be used in the decision making by comparing the detection statistic with the threshold value. In context of Energy Detector, the detection statistic can be obtained by integrating the energy of the signal over certain time interval T. The analysis of semi-blind spectrum sensing algorithms, especially, ED is carried out in context to CRN. The analysis is then extended to hybrid approaches of ED with analytical expressions for the performance parameters, P_D and P_{Fa} is derived for each algorithms. Impact of noise variance estimation on ED was carried out based on ROC curves and Probability of detection vs SNR curves. The results showed that the effect of fluctuation of noise variance estimate from nominal value is severe in case of small number of auxiliary slots used for the estimation of noise variance. High detection probability is attained with higher number of samples taken to calculate decision statistics and the proper detection rate decreases simultaneously with lower number of samples considered to calculate the decision statistics. Increase in SNR also increases the detection probability but it is not always possible to have higher value of SNR in real scenario. Even at low SNR, the performance of ED, HED and HED2 is better in regards to probability of detection if higher number of samples is considered to calculate the decision statistic.

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Performance Evaluation of Commercial Banks in Nepal using Multi Criteria Decision Analysis

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***Abstract*: The objective of this study was to compare the financial performance of commercial banks in Nepal based on their financial characteristics and to identify the determinants of performance exposed by the financial ratios. After the financial liberalization in Nepal many commercial banks have started their operation. This has ushered choices among Investors and customers. Many financial factors are involved in determining the performance of commercial banks and there is an imperative need to prioritize these factors and ultimately evaluate banks according to the priorities derived. This paper identifies Bank selection as a Multi Criteria Decision problem and uses Analytical Hierarchy Process to evaluate 5 selected commercial banks. The financial parameters were derived by segregating 5 major criteria which were Liquidity, Efficiency, Profitability, Capital Adequacy and Assets Quality. These criteria were further classified into 21 hierarchical sub-criteria..The financial data for four years was derived from Annual Reports of the commercial banks and Nepal Rastra Bank Banking Supervision Report. It was evident that Liquidity in banks is the top ranked priority and maximum priority is given to Total Credit to Total Deposit Ratio. NMB Bank was the best out of the 5 Banks evaluated. The evaluation and ranking was performed using Expert Choice Software ver. 11.**

Keywords: Performance Evaluation, Commercial Banks, Multi Criteria Decision Analysis (MCDA), Analytical Hierarchy Process (AHP), Capital Adequacy Asset Quality Management Earnings Liquidity Sensitivity (CAMELS)

1. INTRODUCTION

Banking is one of the more closely supervised industries in the Nepal, reflecting the view that bank failures have stronger adverse effects on economic activity than other business failures. National economy is strongly dependent on commercial banks because, together with central banks they create conditions in which companies operate. There is a huge interest in bank business and there are many bank stakeholders, from the government to ordinary people. Each of them is interested in specific bank business segment and each of them requires specific information on bank business. There are many situations where the most suitable bank has to be chosen. Among the most important sources of information on bank business are financial. reports. Financial reports are generated yearly by the accounting department of a bank and present a synthesized picture of all business processes of a bank.

Effective bank supervision, therefore, requires accurate information about the condition of banks. On the basis of ownership, the commercial banks in Nepal can be categorized as public and private banks. As of mid July 2012 there are 3 public sector banks and 29 private sector banks.

The Banking Supervision department at the Nepal Rastra Bank assesses commercial banks by onsite and offsite supervision. The offsite supervision is done by analyzing the financial data in Capital Adequacy Asset Quality Management Earnings Liquidity Sensitivity (CAMELS) framework.

A sound banking system with wide spread of branches throughout the country with varieties of banking services to fulfill commerce trade, industry and agricultural needs of the country is of crucial importance for Nepal.

This paper develops Multi Criteria Decision Analysis (MCDA) framework called Analytical Hierarchy Process (AHP) to assess the financial criteria's and evaluate performance of 5 selected commercial banks in Nepal using financial data from 2008/09 to 2011/12.

2. OBJECTIVES OF THE STUDY

The basic objective of the study is to assess the competency of commercial banks in Nepal with respect to their financial performance. The main objectives of this study are given below:

a) To evaluate the priorities for liquidity management, efficiency, profitability, capital adequacy and asset quality of commercial banks.

b) To analyze the financial position of the relevant banks in terms of the priority derived by key financial indicators

c) To use a Multi Criteria Decision approach called Analytical Hierarchy Process to evaluate performance of the commercial banks and rank them.

3. LIMITATION

The study has been limited to the financial analysis only, and has not been rooted to management and sensitivity analysis as proposed in CAMELS. Further the assessment is done for years 2008 to 2012.

4. LITERATURE REVIEW

Public sector banks have substantial shares in the total assets of the industry and have huge branch networks around the country. Rastriya Banijya Bank (RBBL), Nepal Bank Limited (NBL) and Agriculture Development Bank (ADBL) are government owned banks. These banks have significant contribution on improving banking habit among the people at large and encourage entrepreneurship in both the urban as well as rural area. Nepal has a short history of the modern banking practices that starts from the establishment of Nepal Bank Limited as a first commercial bank in 1937. The establishment of Nepal Rastra Bank in 1956 as a central bank gave new dimension to Nepalese financial system. Nepal adopted financial sector liberalization process during 1980s. (Jha & Hui, 2012) state that the public sector banks are still the largest banks in all aspects from deposit and credit mobilization to the number of branches in operation.

The system that lays down the bank rating foundations was developed by the government Federal Deposit Insurance Corporation (FDIC) and is known as CAMELS (Capital, Asset, Management, Earnings and Liquidity). The essence of the system is for the bank rating to be done on the basis of five components reflecting the bank's performance: capital, assets, management, equity shares and liquidity. In Nepal, Nepal Rastra Bank (NRB) is the apex body which supervises banks in Nepal. The NRB uses on-site examination and off-site surveillance to identify the banks most likely to fail. There are significant papers which proposes Econometric and Multi Criteria Decision Models to evaluation process (Jha et al, 2012) have analyzed commercial banks in Nepal based on their financial characteristics and identified the determinants of performance exposed by the financial ratios, which were based on CAMELS Model also advocated by (Gilbert, et al, 20002), (Dang et al, 2011) as an efficient bank performance measurement tool. (Gajurel et al, 2011) have put forward a Structure Performance Model of banks in Nepal. (Sapkota, 2012) has done a trend analysis of commercial banks in Nepal from 2005-2010. (Thagunna et al, 2013) have used Data Envelopment Analysis (DEA) developed by (Cooper et al, 1978) to measure performance of banks in Nepal.

The specific literatures advocates the efficacy of Multi Criteria Decision models (MCDA) (Wua et al, 2009), (Doumpos et al, 2009) such as AHP (Saaty et al, 1980), (Javalgi, 1989) in commercial banks. The use of AHP in performance evaluation of banks in Nepal have been advocated by (Bhattarai et al, 2009), (Jabalameli et al, 2011) who has used AHP/DEA model, (Javalgi et al), (Hunjak et al, 2001), (Babic et al, 1999) have proposed AHP based performance evaluation model of commercial banks. (Chatterjee et al, 2010) in their paper have identified Fuzzy Analytical Hierarchy Process (FAHP) to examine banks.

5. METHODOLOGY

The purpose of this study is to evaluate the factors determining the performance of the Nepalese commercial banks. The data are mainly obtained from the Nepal Rastra Bank Bulletin (published by the Central Bank of Nepal), annual audited financial statements of commercial banks (published by the respective banks), and yearly economic survey. Average of four year ratios from 2008/09 to 2011/12 was evaluated to assess the financial performance of the commercial banks in Nepal. Five commercial banks, which have been established after 2007 in Nepal, were selected for the analysis in this study. The financial ratios used to assess bank performance were taken based on the AHP Framework in which hierarchical criteria's were determined based on CAMEL framework as capital adequacy, asset quality, management, earnings and liquidity. The specific financial indicators were also considered from the key financial indicators from Nepal Rastra Bank Annual Supervision Report, 2012.

It is evident from (Yalçın, Ali, & Cengiz, 2009) research which identifies financial criteria as (Capital adequacy, Assets Quality, Liquidity, Profitability, Income expenditure structure, Group share and sectoral share) (Samad & Hassan, 2000) have used Profitability; Liquidity and Risk and solvency to assess banks efficiency Profitability ratios (ROA) (ROE) Profit Expense Ratio (PER); Liquidity: Cash Deposit Ratio (CDR) Loan Deposit Ratio (LDR), Current Ratio (CR) ,Current Asset Ratio (CAR); Risk and insolvency indicators: Debt Equity Ratio (DER),Debt to Total Asset Ratio (DTAR) Equity Multiplier (EM),Loan to Deposit Ratio (LDR).

The selection of major criteria and sub criteria were based on literature findings, Nepal Rastra Bank's Key Performance Indicators for Commercial Banks and Delphi Method.

5.1. Analytical Hierarchy Process (AHP)

It is important to note that financial ratios of banks can be compared without any model. An expert can make comparisons of financial ratios of two or more banks and bring valuable conclusions. This is because financial ratios are absolute values and can be interpreted by experts. The problem arises when someone wants to compare banks according to more than a few financial ratios. It is easy to conclude which bank is better or best according to one financial ratio, but it is slightly more difficult to determine which bank is better or best in certain business segment or in general. The problem is considerably more complex when someone needs to compare several banks according to their businesses. For such complex problems a model has to be developed. In this paper we propose a model based on the Analytic Hierarchy Process.

The method application can be explained in five steps:

(1) The hierarchy model of the decision problem is developed in such a way that the goal is positioned at the top, with criteria and sub-criteria on lower levels and finally alternatives at the bottom of the model.

(2) On each hierarchy structure level the pair wise comparisons should be done by all possible pairs of the elements of this level. The decision maker's preferences are expressed by verbally described intensities and the corresponding numeric values on 1-3-5-7-9 scale (Saaty, 1980). For this research total of 5 experts performed the pair wise comparison for the hierarchies.

(3) On the basis of the pair wise comparisons relative significance (weights) of elements of the hierarchy structure (criteria, sub-criteria and alternatives) are calculated, which are eventually synthesized into an overall alternatives priority list.

(4) The sensitivity analysis is carried out.

Expert Choice ver. 11 is used to carry out the analysis.

The work on the AHP involves the estimation of priority weights of a set of criteria or alternatives from a square matrix of pair-wise comparison $A = [a_{ij}]$, which is positive and if the paired comparison judgment is perfectly consistent it is reciprocal, i.e., $a_{ij} = 1/a_{ji}$ for all ij = 1, 2, 3,.., n.

The final normalized weight of its i^{th} factor, w_i, is given by

$$w_i = a_{ij} / \left(\sum_{k=1}^{n} a_{kj} \right) \qquad (1)$$

$\forall$ i = 1, 2, ..., n.

In the real life judgment an error on the judgment is unavoidable. The suggested eigenvalue method computes w as the principal right eigenvalue of the matrix A or w satisfies the following system of n linear equations:

$A\,w = \lambda_{max}\,w$, where λ_{max} is the maximum eigenvalue of A.

This is to say that

$$w_i = \frac{\sum_{j=1}^{n} a_{ij} w_j}{\lambda_{max}} \qquad (2)$$

$\forall$i = 1, 2, ..., n.

The natural measure of inconsistency or deviation from consistency, called consistency index (CI) is defined as

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad (3)$$

The consistency index of a randomly generated reciprocal matrix from scale 1 to 9, with reciprocals forced, for each size of matrix called random index (RI) is presented in Table.

Table 1: Random Index (RI)

Matrix Order	RI
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

Then the consistency ratio (CR) is defined as the ratio of CI to RI for the same order of matrices, that is to say, CR = CI / RI. Value of CR < 0.01 is typically considered as an acceptable limit.

Table 2: Scale of Pair-wise Comparison

Intensity of Importance	Definition	Explanation
1 (equal)	Equal importance	Two activities contribute the equally to the objective.
3 (weak)	Weak importance of one over another	Experience and judgment slightly favor one activity over another.
5 (strong)	Strong importance	Experience and judgment strongly favor one activity over another.
7 (very strong)	Very strong importance	An activity is favored very strongly over another.
9 (absolute)	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values between adjacent scale value	When compromise is needed.

Higher values required to correct the consistency, normally it is the decision maker to reduce the inconsistencies by revising his judgments. The other task in the hierarchy is the synthesis of the judgments throughout the hierarchy in order to compute the overall priorities of the alternatives with respect to the goal or objectives. The weights are created by summing the priority of each elements according to a given criterion by the weights of that criterion. Pair-wise comparison scale for evaluation of relative importance of factors used in the AHP subjective judgment in accordance Saaty is given in Table.

5) Aggregation

The last step is to synthesize the local priorities across all criteria in order to determine the global priority. The historical AHP approach (called later distributive mode) adopts an additive aggregation with normalization of the sum of the local priorities to unity

$$Pi = j\sum Wj.\, lij \quad (4)$$

Where,

Pi = global priority of the alternative i

l_{ij} = local priority

w_{j} = weight of the criterion j

5.2. AHP Model

Based on the literature reviews and interviews with the Banking Experts based on Delphi method, the following hierarchy of Goals, Criteria, Sub criteria and Alternatives were modeled.

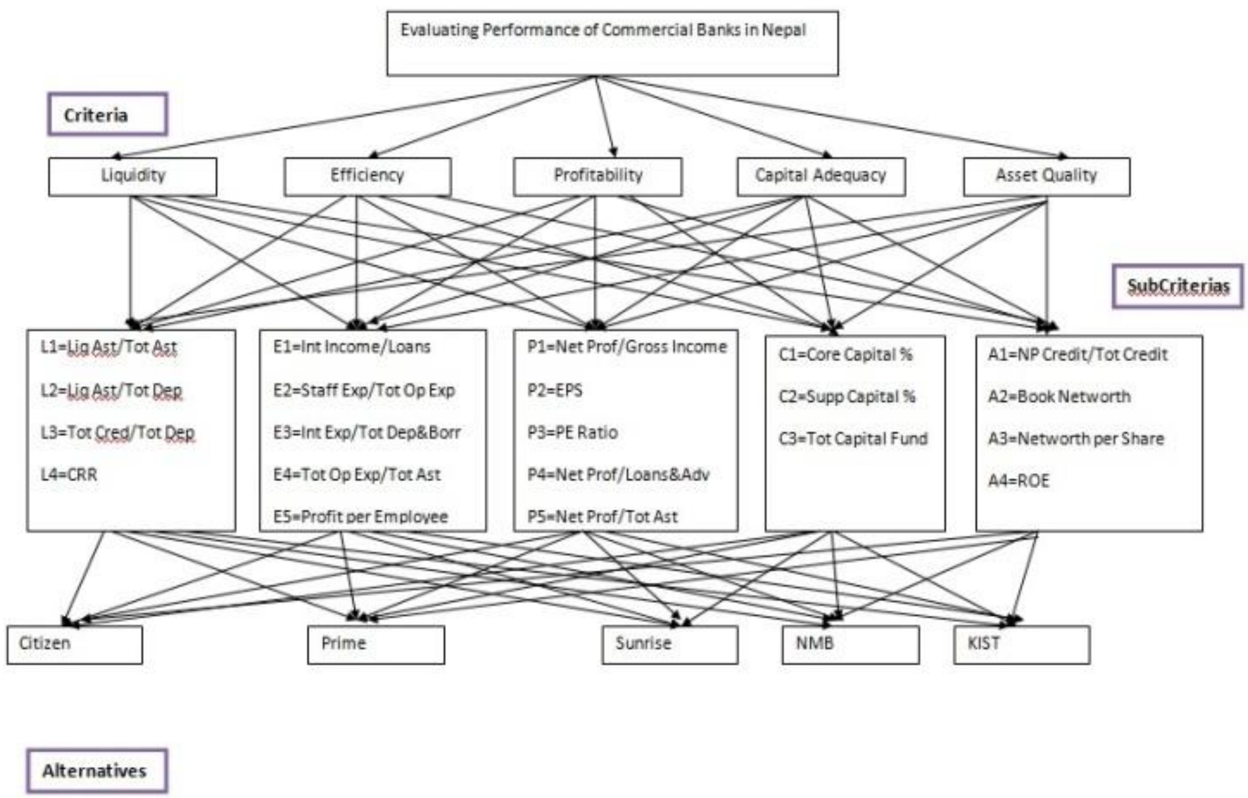


Figure 1: Figure showing the hierarchy of Goals, Criteria, Sub criteria and Alternatives

6. EMPIRICAL RESULTS AND DISCUSSION

The financial values were calculated from the Annual reports of the respective banks and the table below shows the data.

Table 3: Financial Ratios: Mean Values

		Sunrise	Prime	NMB	KIST	Citizen	Maximum	Minimum
Liquidity	1) L1=Liquid Assets to Total Assets	0.257	0.227	0.358	0.249	0.223	0.358	0.223
	2) L2=Liquid Assets to Total Deposit	0.319	0.259	0.602	0.299	0.260	0.602	0.259
	3) L3=Total Credit/Total Deposit	0.803	0.831	0.803	0.792	0.810	0.831	0.792
	4) L4=CRR	29.510	12.438	10.475	7.668	12.765	29.510	7.668
Efficiency	E1=Interest Income/Loans and Advancements	9.065	11.775	9.750	12.623	12.825	12.825	9.065
	E2=Staff Expenses/Total Operating Expenses	44.540	33.808	41.010	37.855	32.045	44.540	32.045
	E3=Interest Expenses/Total Deposit and Borrowings	6.800	7.240	6.153	7.505	7.128	7.505	6.153
	E4=Total Operating Expenses/Total Assets	1.930	11.105	1.290	2.048	3.793	11.105	1.290
	E5=Profit per Employee	288.066	1146.191	723.193	193.875	853.960	1146.191	193.875
Profitability	P1=Net Profit/Gross Income	8.243	13.690	11.068	17.468	11.348	17.468	8.243
	P2=Earning Per Share	7.713	19.493	7.190	4.850	14.190	19.493	4.850
	P3=Price Earning Ratio	29.183	12.585	56.795	48.363	32.798	56.795	12.585
	P4=Net Profit/Loan and Advances	0.940	1.813	1.395	0.880	1.590	1.813	0.880
	P5=Net Profit/Total Assets	0.006	1.323	0.820	0.570	1.078	1.323	0.006
Capital Adequacy	Adequacy of Capital Fund on Risk Weighted Assets							
	C1= Core Capital Percent	11.48%	11.390	16.655	14.453	12.390	16.655	11.48%
	C2=Supplementary Capital Percent	0.80%	0.918	0.598	0.765	0.875	0.918	0.80%
	C3=Total Capital Fund	12.27%	12.310	17.520	15.218	13.265	17.520	12.27%
Asset Quality	A1=Non-performing Credit/Total Credit	0.038	0.333	0.983	1.723	0.873	1.723	0.038
	A2=Book Net-worth	1747462.000	1433152.589	1977676.000	2117802.250	1737627.900	2117802.250	1433152.589
	A3=Networth Per Share	107.168	118.628	114.572	105.890	109.000	118.628	105.890
	A4=Return on Equity	0.077	0.315	0.071	0.049	0.114	0.315	0.049

Further to analyze the financial data through AHP, the financial ratios were segregated according to their efficacy as shown in table 4.

Table 4: Efficacy of different criteria

Criteria	Sub Criteria	INCR or DECR
Liquidity	L1=Liquid Assets to Total Assets	INCR
	L2=Liquid Assets to Total Deposit	INCR
	L3=Total Credit/Total Deposit	INCR
	L4=CRR	INCR
Efficiency	E1=Interest Income/Loans and Advancements	INCR
	E2=Staff Expenses/Total Operating Expenses	DECR
	E3=Interest Expenses/Total Deposit and Borrowings	DECR
	E4=Total Operating Expenses/Total Assets	DECR
	E5=Profit per Employee	INCR
Profitability	P1=Net Profit/Gross Income	INCR
	P2=Earnings Per Share	INCR
	P3=Price Earning Ratio	INCR
	P4=Net Profit/Loan and Advances	INCR
	P5=Net Profit/Total Assets	INCR
Capital Adequacy	C1= Core Capital Percent	INCR
	C2=Supplementary Capital Percent	INCR
	C3=Total Capital Fund	INCR
Asset Quality	A1=Non-performing Credit/Total Credit	DECR
	A2=Book Net-worth	INCR
	A3=Net worth Per Share	INCR
	A4=Return on Equity	INCR

6.1. Discussion

Financial performance, in general, indicate business security and business success. Consequently, the most important criteria according to the developed AHP model is Liquidity. The second most important criteria is Capital Adequacy. The following are the weights of the major criteria's

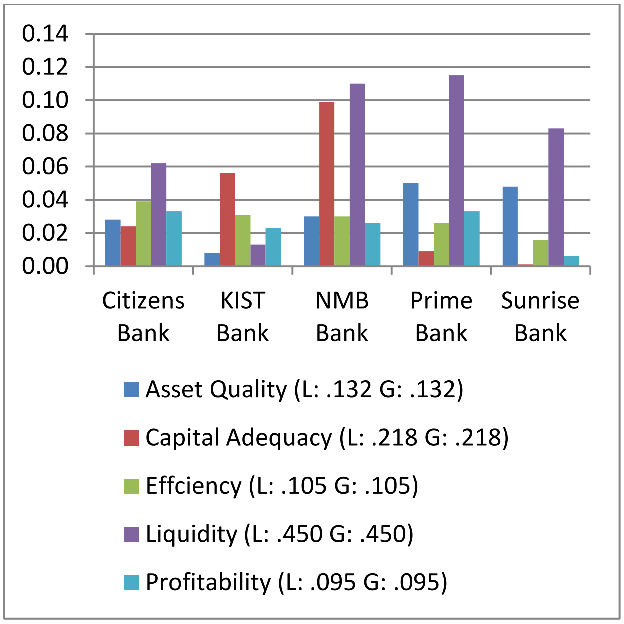
I. Liquidity: 0.450
II. Capital Adequacy: 0.218
III. Asset Quality: 0.132
IV. Efficiency: 0.105
V. Profitability: 0.095

The Overall Inconsistency (CI) = 0.08<0.1 (desirable value) so the Model is validated.

The criteria wise performance of the banks is shown in the following table

Table 5: Priorities of Criteria

	Liquidity	Efficiency	Profitability	Capital Adequacy	Asset quality
Sunrise	0.299	0.276	0.279	0.524	0.303
Prime	0.287	0.219	0.269	0.298	0.291
NMB Bank	0.217	0.208	0.212	0.128	0.181
KIST	0.162	0.182	0.191	0.046	0.173
Citizen	0.035	0.115	0.049	0.003	0.051
Total	1	1	1	1	1



The financial values have been calculated from the data obtained from Nepal Rastra Bank annual bank supervision report and respective bank's Annual reports.

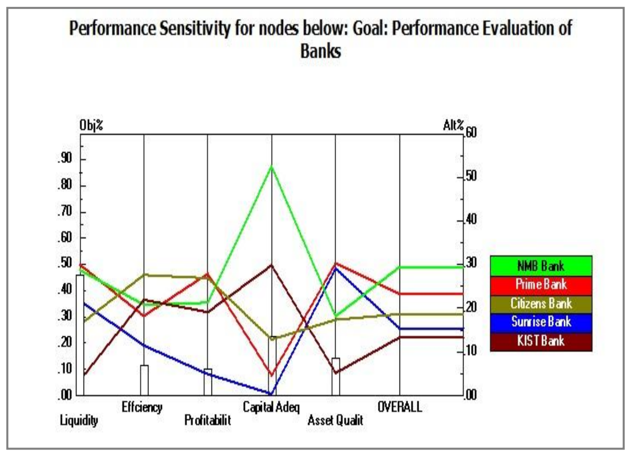
Alternative	Priority
L3=Total Credit/Total Deposit	0.21
C3=Total Capital Fund	0.123
L1=Liquid Assets Asset/Total Assets	0.088
A1=Non-performing Credit/Total Credit	0.085
L4=Cash Reserve Ratio	0.08
C1= Core Capital Percent	0.078
L2=Liquid Assets/Total Deposits	0.073
E1=Interest Income/Loans and Advancements	0.042
P5=Net Profit/Total Assets	0.028
E3=Interest Expenses/Total Deposit and Borrowings	0.025
E4=Total Operating Expenses/Total Assets	0.02
P3=Price Earning Ratio	0.02
P2=Earning Per Share	0.019
P1=Net Profit/Gross Income	0.018
A4=Return on Equity	0.018
C2=Supplementary Capital Percent	0.017
A2=Book Net-worth	0.017
A3=Net worth Per Share	0.012
E2=Staff Expenses/Total Operating Expenses	0.009
E5=Profit per Employee	0.009
P4=Net Profit/Loan and Advances	0.009

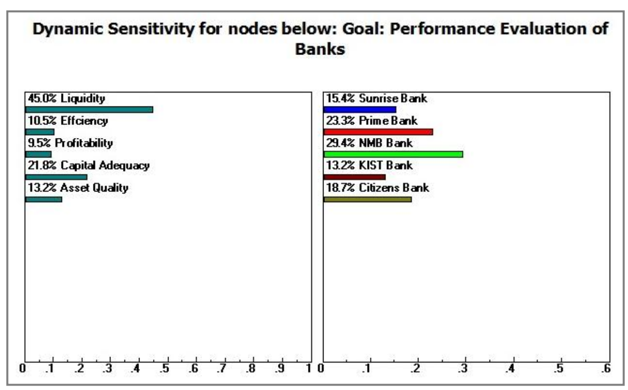
Weights of sub-criteria are also calculated upon pair-wise comparisons. When it comes to the Liquidity, the most important sub-criterion is Total Credit/Total Deposits. The sub-criteria with the highest weight among sub criteria of the Efficiency Criteria is Interest Income/Loans and Advancements. The most important sub-criteria of the Profitability Ratios Net Profit/Total Assets. The most important sub-criteria of Capital Adequacy criteria is Total Capital Fund.

According to the weights of criteria and sub-criteria and the local importance of every alternative, the application generates the overall priority list of banks

7. Performance Ranking of Commercial Banks

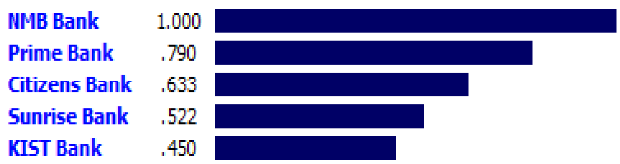
The results of the validation show that the highest overall priority was of NMB Bank. The main reason for such a result is the highest local priority of the Liquidity and Capital Adequacy of the Banks, which were recognized as the most important criteria's from the developed model. It is a great indicator that the Analytic Hierarchy Process enables users to have significant impact on final results in cases where both tangible and intangible criteria are involved. NMB bank has the best values of 8 out of 21 sub-criteria of the entire AHP Model.





Out of the 5 commercial banks NMB Bank (29.4%) is the most Efficient Bank while KIST Bank (13.2%) is deemed to be inefficient bank. The sensitivity analysis shows that KIST Bank has to increase Capital Adequacy (Core Capital) to improve its financial performance. The

Normalized performance scores of the banks is shown in the figure and shows KIST Bank an underperforming bank.



8. CONCLUSION

In this research an application for bank's performance based on the multi-criteria decision analysis method called the AHP was developed. Objectives (criteria and sub criteria) relevant to the bank's comparison and developed a hierarchy structure of the AHP model for the bank's financial values were modeled based on literatures and expert suggestions. The experts were high ranking bankers and financial analysts. The model for prioritizing banks that can be used as a tool for deciding which bank is better in respect to the criteria/sub criteria was modeled.

All the important criteria and sub-criteria for problem solving in the process of the bank's financial ratios comparison. Such a model for decision making enables multi criteria analysis, increases and systemizes the knowledge of the problem and speeds up the decision-making process. The validation we performed shows that in the case of comparing 5 commercial banks in Nepal, NMB Bank. is the best business bank from the standpoint of the central bank (criteria and sub-criteria from the model). The model presented here can be further developed and modified to reflect different environments and supporting systems.

9. FUTURE RESEARCH

The future research will be extended to scope of other larger commercial banks. The research will incorporate econometric and panel data models.

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Constitutive Modeling of Concrete Confined by FRP Composite Jackets utilizing Damage Mechanics Theory

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***Abstract*: A damage mechanics model for concrete confined by fiber reinforced polymer (FRP) composite jackets is developed using the general framework of thermodynamics in which dissipation inequality is established by the internal variable theory. Damage in concrete is reflected through the fourth – order elastic stiffness tensor involving a damage parameter whose evolution is determined from the damage surface. The model is capable of capturing the enhancement in compressive strength and ductility, and is checked against experimental results.**

Keywords: Damage mechanics, confinement modulus, response tensors, carbon fiber composites, damage surface

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1. INTRODUCTION

Confining concrete externally by providing jacket considerably improves its uniaxial compressive behavior in terms of strength and ductility. For the past few years, this concept has been used in retrofitting reinforced concrete columns generally in bridges and multistory buildings. Fiber reinforced polymer composites have become efficient retrofitting materials for reinforced concrete bridge columns due to its light weight, high specific stiffness, and high specific strength. The composite jacket is applied to the concrete surface in layers by using epoxy resin as a gluing agent. Carbon fiber and E-glass fiber composites are two commonly used polymer composites in retrofitting systems. The jacketing work with E-glass fiber polymer composite is more economical than that with carbon fiber polymer composite. The two types of retrofitting systems commonly in practice are in-situ fabricated jacketing and pre-fabricated retrofitting system. In terms of quality control and speed of installation, the pre-fabricated retrofitting system is superior to the in-situ jacketing system.

The confining stress induced in the confined concrete while resisting the transverse tensile strains by the jacket establishes a triaxial state of stress in concrete. It is well known that the state of triaxial compression enhances the strength and ductility of concrete as compared to that subjected to uniaxial compressive stress. The higher the level of longitudinal compressive stress is the higher the lateral confining stress, and vice-versa. At low level of longitudinal strain, concrete behaves elastically, and the FRP composite jacket provides little confining stress due to small transverse strains. At high level of longitudinal strain, the dilated concrete due to the formation of cracks significantly activates the composite jacket, and induces high level of confinement. However, the magnitude of lateral confining stress mainly depends upon the geometrical shape and size of the confined members, thickness, and the mechanical properties of the confining materials used. Youssef et al. [1] reported that confining stress concentrates at corners of the square or rectangular shaped columns, and failure takes place due to the rupture of FRP composite jackets at one of the corners. They also reported that composite jackets exert uniform confining stress on the circular column resulting in a great improvement in member's behavior under loading.

The purpose of applying polymer composite jackets in concrete columns is to improve the seismic performance of the reinforced concrete structure by making it strong and ductile. However, the compressive behavior of concrete column confined by FRP composites is still in research phase. Many researchers conducted experiments to understand the behavior of FRP confined concrete in uniaxial compression. Some of the experimental works and constitutive modeling works on FRP confined concrete are briefly discussed below.

Xiao and Wu [2] conducted uniaxial compressive tests on concrete cylinders confined by carbon fiber reinforced polymer (CFRP) composite jackets. Their test results revealed a significant increase in compressive strength and ductility due to the effect of lateral confinement by CFRP composite jackets (refer Figure 1). It is seen from their experimental stress-strain curve that the strength and ductility increase in confined concrete mainly depends on the unconfined compressive strength and the level of confinement (number of layers of jackets, which contribute to the confinement modulus of the composite jackets). It is also seen that as the stress reached the unconfined compressive strength, the stress-strain behavior of confined concrete becomes approximately bilinear. Failure of confined specimens were reported due to the rupture of composite jackets, and the failure strain of jacket is much lower than the uniaxial tensile rupture strain obtained by testing flat coupons. They proposed an analytical model to predict the mechanical behavior of concrete confined by carbon composite jackets. In their proposed model, the empirical equations obtained from the tests were combined with the equations derived based on the theory of elasticity. Xiao and Wu [3] further studied the uniaxial compressive behavior of concrete cylinder confined by various types of FRP composite jackets, and then proposed a new stress-strain model to predict the mechanical behavior. Their model was simple, but did not address the failure due to the formation of microcracks. The permanent deformation due to cracking and flow was not incorporated in the model.

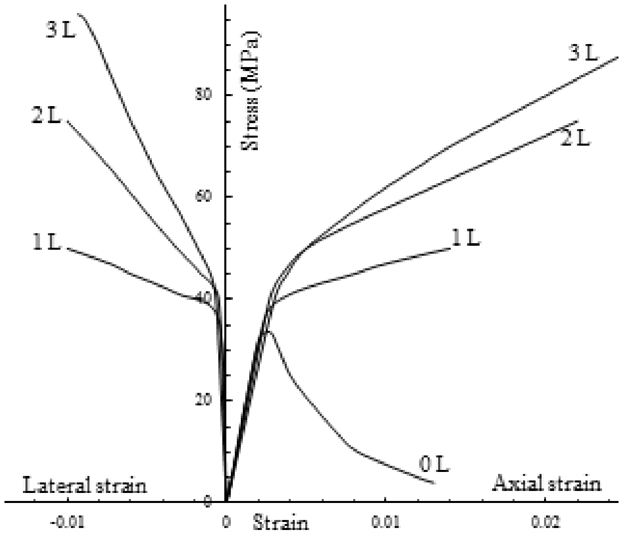

Figure 1: Stress-strain relationships for CFRP confined concrete, Ref. [2].

Berthet et al. [4] studied the compressive behavior of concrete short columns confined by E-glass fiber reinforced composite jackets. They also reported, in their experiments, the enhancement in compressive strength and ductility due to the effect of confinement. Their test results showed that the stress-strain curve has bilinear relation in which the first linear region nearly coincides with the stress-strain response of unconfined concrete and the second linear zone mainly depends on the jacket mechanical properties. The most influential factors affecting the ultimate strength and strain of the jacketed concrete are the ultimate strength of the jacket and the unconfined concrete strength. Their experimental work also revealed that the final failure of confined concrete occurs with the rupture of the composite jackets. However, the mechanisms of microcrack formation, both in concrete and in jackets, till the failure were not discussed in their work.

Youssef et al. [1] developed a theoretical stress-strain model for concrete confined by FRP composite jackets. The proposed model was then compared with the experimental stress-strain curves for the circular columns confined with carbon/epoxy jackets. The agreement between the model and the experiments were found to be good. However, their model was based on the experimental results of large number of circular, square and rectangular short concrete columns confined by carbon fiber and E-glass fiber reinforced polymer composite jackets. The theoretical model was developed by analyzing large-scale experimental stress-strain curves. For modeling purpose, the experimental stress-strain curve was divided into three stages. In the first stage, the stress-strain curve traces the path of the unconfined concrete. The confined concrete and the unconfined concrete have the same modulus of elasticity at this stage. The second stage belongs to the softening region of the stress-strain curve due to the formation of cracks, where the jacket starts activating. The third stage is the linear curve in which jacket is fully activated. The slope of this linear curve may be either positive or negative depending on the level of confinement.

In developing the model by Youssef et al. [1], the first part was modeled by using polynomial equations proposed by Hoshikuma et al. [5] for modeling concrete confined by steel. The second linear part was developed by using equation of straight line. The boundary conditions were then applied in these two equations. The model parameters, for both circular and rectangular columns, were then evaluated by using regression analysis. This is completely an empirical model based on experimental data. The degradation of elastic stiffness due to microcracks and cracks are not incorporated in the model. The proposed model was developed considering the path followed by the experimental curve rather than the physical evidence of progressive failure mechanism observed during the experiments.

A good understanding of the mechanical behavior of FRP jacketed concrete is important as a starting point as well as a guide for developing theoretical models for concrete confined by FRP composites. Experiments indicate that the composite jackets enhance the compressive strength and the permanent deformation in concrete. This is mainly because the activated jackets provide lateral confinement to concrete, and hence the formation of microcracks is inhibited leading to the development of inelastic deformation due to void closure, flow within aggregate particles, etc. However, the experimental observations do not provide detailed information concerning the mechanism of progressive microcracking in concrete as well as in composite jackets at different stages of stress-strain curve. This is essential for the development of theoretical models for FRP jacketed concrete. In general, the constitutive models for polymer composite confined concrete should address the following essential features: (1) the role of jacketing system in the process of microcracking of concrete; (2) combined energy dissipation during loading; (3) damaging behavior of jacketed concrete; and (4) void closure and inelastic flow of aggregates due to lateral confinement. Based on the experimental observations, damage mechanics approach can be considered an efficient tool for constitutive models of concrete confined by polymer composite jackets.

This paper presents a class of damage mechanics theory for modeling concrete confined by CFRP composite jackets. A mathematical framework of damage mechanics based on internal variable theory of thermodynamics is adopted for modeling behavior of confined concrete, whereas CFRP composite jackets are modeled as perfectly elastic material. Two variables – a damage parameter and a damage function – are established in the model to represent the damaging behavior of brittle materials in general and concrete in particular. Model predictions of confined concrete for uniaxial compression are compared with the available experimental results.

2. General Formulation

For a class of brittle solids like concrete whose microstructures are altered by the nucleation and growth of distributed microcracks, a continuum approach can effectively be taken in the constitutive modeling. The general formulation can conveniently be cast within the general framework of the internal variable theory of the thermodynamics [6,7,8,9]. For a strain space formulation, the Helmholtz Free Energy (HFE) per unit volume, A is given as

$$A(\boldsymbol{\varepsilon},k)=\tfrac{1}{2}\boldsymbol{\varepsilon}:\mathbf{E}(k):\boldsymbol{\varepsilon}+A^{i}(k) \tag{1}$$

Where the symbol ":" indicates tensor contraction. The strain tensor is given by $\boldsymbol{\varepsilon}$, and the material stiffness tensor is represented by $\mathbf{E}(\mathrm{k})$. The last term in Equation (1) represents the inelastic component of the Helmholtz Free Energy (HFE) and is associated with the surface energy of microcracks. The internal variable parameter k is a monotonically increasing scalar and is used to reflect the total dissipated energy associated with material damage. Assuming that only damage (microcracking) contributes to the alteration of elastic properties [10,11,12,13,14,15], the following decomposition of the stiffness tensor is adopted

$$\mathbf{E}(\mathrm{k})=\mathbf{E}^{0}+\mathbf{E}^{D}(\mathrm{k}) \tag{2}$$

where $\mathbf{E}^{0}$ and $\mathbf{E}^{D}$ denote the initial and degraded stiffness tensors, respectively. The dependence of $\mathbf{E}$ on k allows for the description of damage through the fourth order material stiffness tensor. For a purely mechanical process, the Clausius-Duhem inequality must be satisfied. This inequality is given as

$$-\dot{\mathrm{A}}+\boldsymbol{\sigma}:\dot{\boldsymbol{\varepsilon}}\geq 0 \tag{3}$$

where the super dots represent the rate forms. The substitution of the expression for A in the above stated inequality would lead to the following alternate form of the dissipation inequality

$$\mathrm{d}_{s}=(\boldsymbol{\sigma}-\frac{\partial \mathrm{A}}{\partial \boldsymbol{\varepsilon}}):\dot{\boldsymbol{\varepsilon}}-\frac{\partial \mathrm{A}}{\partial \mathbf{E}}::\dot{\mathbf{E}}-\mathrm{b}^{2}\dot{\mathrm{k}}\geq 0 \tag{4}$$

where the scalar function b^2 is given by $b^{2}=\partial A^{i}/\partial k$. Following the standard arguments [7,16] and assuming that unloading is an elastic process, the following relations are established for the elastic damaging process

$$\boldsymbol{\sigma}=\frac{\partial \mathrm{A}}{\partial \boldsymbol{\varepsilon}}=\mathbf{E}(k):\boldsymbol{\varepsilon} \tag{5}$$

Equation (6) indicates that, for a strain space formulation, the Helmholtz Free energy is a potential for the stress tensor, $\boldsymbol{\sigma}$, and that

$$\mathrm{d}_{s}=-\frac{\partial \mathrm{A}}{\partial \mathbf{E}}::\dot{\mathbf{E}}-\mathrm{b}^{2}\dot{\mathrm{k}}\geq 0 \tag{6}$$

Where d_s is the rate of dissipation indicating that the rate of work done by their thermodynamic affinities, $(\partial A/\partial \mathbf{E})$, and b^2 through their respective fluxes, $\dot{\mathbf{E}}$, and $\dot{\mathrm{k}}$, must be non-negative. The rate form of the stress tensor in terms of its components is expressed as

$$\dot{\boldsymbol{\sigma}}=\mathbf{E}(\mathrm{k}):\dot{\boldsymbol{\varepsilon}}+\dot{\mathbf{E}}(\mathrm{k}):\boldsymbol{\varepsilon}=\mathbf{E}(\mathrm{k}):\dot{\boldsymbol{\varepsilon}}+\dot{\mathbf{E}}^{\mathbf{D}}(\mathrm{k}):\boldsymbol{\varepsilon}=\dot{\boldsymbol{\sigma}}^{e}+\dot{\boldsymbol{\sigma}}^{i} \tag{7}$$

where $\dot{\boldsymbol{\sigma}}^{e}=\mathbf{E}(\mathrm{k}):\dot{\boldsymbol{\varepsilon}}$ is the rate of elastic deformation in the absence of any further damage, and $\dot{\boldsymbol{\sigma}}^{i}$ is the rate of stress decreased due to the formation of microcracks and cracks in the elastic damaging process. To progress further, evolutionary equations are needed for fluxes $\dot{\mathbf{E}}^{\mathbf{D}}(\mathrm{k})$. Consider the following relations

$$\dot{\mathbf{E}}^{\mathbf{D}}(\mathrm{k})=-\dot{\mathrm{k}}\,\mathbf{L}(\boldsymbol{\varepsilon}) \tag{8}$$

where $\mathbf{L}(\boldsymbol{\varepsilon})$ is fourth order response tensor that determine the direction of elastic damage process. With assumption that damage is irreversible, i.e, $\dot{\mathrm{k}}\geq 0$, Equation (6) in terms of $\mathbf{L}(\boldsymbol{\varepsilon})$ becomes

$$\mathrm{d}_{s}=\frac{1}{2}\boldsymbol{\varepsilon}:\mathbf{L}:\boldsymbol{\varepsilon}-\mathrm{b}^{2}\dot{\mathrm{k}}\geq 0 \tag{9}$$

For the onset of a rate-independent damaging process, a criterion is needed. Consider a state function $\Psi(\boldsymbol{\varepsilon},\mathrm{k})$ such that $\Psi\leq 0$ corresponds to nondissipative processes, $\Psi=0$ defines a surface (called the damage surface), and the condition $\Psi>0$ is not allowed. Such a criterion can be established by considering a hardening-softening function $t(\boldsymbol{\varepsilon},k)$ and using Equations (6) and (9) such that

$$\Psi(\boldsymbol{\varepsilon},\mathrm{k})=\frac{1}{2}\boldsymbol{\varepsilon}:\mathbf{L}(\boldsymbol{\varepsilon}):\boldsymbol{\varepsilon}-\frac{1}{2}\mathrm{t}(\boldsymbol{\varepsilon},\mathrm{k})=0 \tag{10}$$

with $(1/2)\mathrm{t}^{2}(\boldsymbol{\varepsilon},\mathrm{k})=\mathrm{b}^{2}+\mathrm{f}(\boldsymbol{\varepsilon},\mathrm{k})$ for some scalar function f. The loading unloading statement is given in the standard Kuhn-Tucker form

$$\psi \le 0, \quad \dot{k} \ge 0, \quad \dot{k}\psi = 0 \tag{11}$$

with the terms satisfying Equation (1) simultaneously. When energy is dissipated, $\dot{k} > 0$, which requires that ψ be zero. During elastic process, $\psi < 0$, indicating that $\dot{k} = 0$. For computational purposes, the rate of k and the tangent stiffness tensor are needed. $\dot{k}$ is obtained from the consistency condition of the damage surface as

$$\dot{k} = -\frac{(\partial\Psi/\partial\boldsymbol{\varepsilon}) : \dot{\boldsymbol{\varepsilon}}}{(\partial\Psi/\partial\boldsymbol{\varepsilon})} \tag{12}$$

The tangent stiffness tensor is obtained by considering the rate form of the stress tensor and substituting the expression for $\dot{k}$ from Equation (12) as

$$\dot{\boldsymbol{\sigma}} = \mathbf{E}^{(T)} : \dot{\boldsymbol{\varepsilon}} \tag{13}$$

where $\mathbf{E}^{(T)}$ signifies the tangent stiffness tensor and is given by

$$\mathbf{E}^{(T)} = E(k) - \frac{(\mathbf{L} : \boldsymbol{\varepsilon}) \otimes \frac{\partial\Psi}{\partial\boldsymbol{\varepsilon}}}{t\, t_k} \tag{14}$$

in which the scalar function t_k is defined as $t_k = (\partial t / \partial k)$. The symbol $\otimes$ represents the tensor product.

3. Development of Damage Model for Concrete

Two damage modes are usually identified in brittle solids like concrete. One is the cleavage cracking mode (mode-I), where the crack opening vector is parallel to the applied tensile stresses, and the second is the compressive mode (mode-II), which represents a combination of shear sliding and crack opening. These two modes of damage are incorporated into the formulation by performing the spectral decomposition of the strain tensor as

$$\boldsymbol{\varepsilon} = \boldsymbol{\varepsilon}^{+} + \boldsymbol{\varepsilon}^{-} \tag{15}$$

$$\mathbf{L} = \mathbf{L}_{\mathrm{I}} + \mathbf{L}_{\mathrm{II}} \tag{16}$$

where ε^{+} and ε^{-} are denoted as positive and negative cones of strain tensor, $\boldsymbol{\varepsilon}$. Subscripts I and II refer to the two damage modes-I and -II, respectively. To progress further, a particular forms of response tensors $\mathbf{L}_{\mathrm{I}}$ and $\mathbf{L}_{\mathrm{II}}$ must be specified. For the tensile mode (mode-I), the following expression for $\mathbf{L}_{\mathrm{I}}$ is proposed:

$$\mathbf{L}_{\mathrm{I}} = \frac{\boldsymbol{\varepsilon}^{+} \otimes \boldsymbol{\varepsilon}^{+}}{\boldsymbol{\varepsilon}^{+} : \boldsymbol{\varepsilon}^{+}}\alpha \tag{17}$$

where α is the material parameter that incorporates the effect of damage in tension from the lateral direction. The form for α is postulated to be:

$$\alpha = 1 + \beta(1 + H(\theta))\left(1 - \frac{\lambda}{\mathrm{tr}\boldsymbol{\varepsilon}^{+}}\right) \tag{18}$$

where λ is the maximum eigenvalue of $\boldsymbol{\varepsilon}^{+}$, and β is the material constant, $H(\cdot)$ denotes the Heaviside function, and θ is the minimum eigenvalue of $\boldsymbol{\varepsilon}$. On the other hand, the mode-II cracking is the combination of crack opening in lateral directions and the extension of cracks in the direction of applied compressive loads. Therefore, the complete response function for mode II damage can be developed by using the following response tensors:

$$\mathbf{L}_{\mathrm{II}} = \omega\left(\frac{\boldsymbol{\varepsilon}^{+} \otimes \boldsymbol{\varepsilon}^{+}}{\boldsymbol{\varepsilon}^{+} : \boldsymbol{\varepsilon}^{+}}\alpha + \frac{\tilde{\boldsymbol{\varepsilon}} \otimes \tilde{\boldsymbol{\varepsilon}}}{\tilde{\boldsymbol{\varepsilon}} : \tilde{\boldsymbol{\varepsilon}}}\right) \tag{19}$$

where ω is a material parameter which accounts for the relative strength of concrete in tension and compression, $\tilde{\boldsymbol{\varepsilon}} = \boldsymbol{\varepsilon}^{-} - \delta\,\mathbf{i}$ is a shifted strain tensor, δ is the maximum eigenvalue of $\boldsymbol{\varepsilon}^{-}$ and $\mathbf{i}$ is the second order identity tensor. The shifted strain tensor is used in order to preclude the prediction of damage under purely hydrostatic pressure.

Utilizing Equations (10), (15), and (16) through (19), the damage surface for uniaxial compressive stress path is given as:

$$\Psi(\boldsymbol{\varepsilon}, k) = \phi(2\alpha\, \boldsymbol{\varepsilon}^{+} : \boldsymbol{\varepsilon}^{+} + \boldsymbol{\varepsilon}^{-} : \boldsymbol{\varepsilon}^{-}) - t(\boldsymbol{\varepsilon}, k) = 0 \tag{20}$$

For uniaxial tensile stress path, the damage surface of Equation (10) is simplified to the form given as:

$$\varepsilon_1 = t(k) \tag{21}$$

which permits the identification of a single damage function $t(k)$ from simple uniaxial tensile loading test. The closed form solution can then be developed for the uniaxial tensile stress path as

$$\sigma_1 = (E^0 - k)\, t(k) \tag{22}$$

A specific form of damage function of the following form

$$t(k) = \varepsilon_u \left(\frac{k}{E^0 - k}\right)^{\frac{1}{2}} \tag{23}$$

can be proposed to describe the entire set of stress-strain curve for concrete. Here, ε_u denotes the strain associated with the uniaxial tensile strength of concrete, E^0 is the initial Young's modulus, and k is the cumulative damage parameter. Variation of this damage function with the scalar damage parameter k is shown in Figure 2.

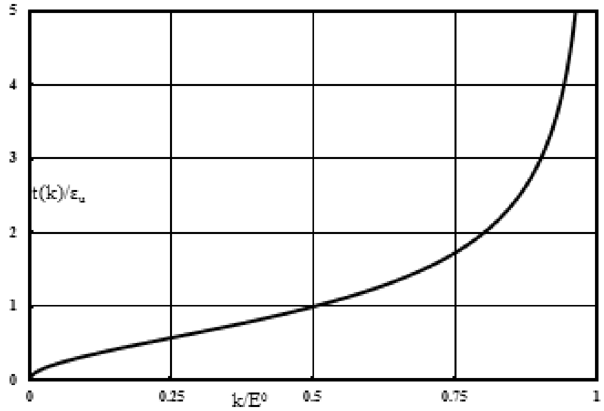

Figure 2: Variation of damage function with damage parameter k

4. APPLICATION TO CONCRETE CONFINED BY FIBER REINFORCED POLYMER (FRP) JACKETS

Concrete confined by fiber reinforced plastic (FRP) composite jackets exhibits enhancement in strength and ductility under uniaxial compression loading condition. The lateral confinement provided in concrete by the jacketing system establishes triaxial compression state of stress. In laterally confined concrete, formation of microcracks and microvoids is inhibited depending upon the level of lateral pressure induced in concrete due to confinement. This leads to the development of permanent deformations due to crack closer effect and the flow of aggregate particles within concrete specimen. However, plastic deformations are not considered in this paper.

In addition to the ultimate strength of concrete, the confinement modulus and confinement strength of the composite jacket are two main factors that affect the performance of confined concrete. The ratio of the increment of confinement stress to the increment of radial (or transverse) strain is defined as the confinement modulus, C_j. The confinement modulus of the jacket can be expressed as:

$$C_j = \frac{2t_j}{D} E_j \tag{24}$$

Where t_j = thickness of the jacket, $D =$ diameter of the concrete cylinder and E_j = tensile modulus of the composite jacket along the fiber direction. The composite jacket is assumed to be linearly elastic material. Equation (24) can be obtained by using the equilibrium condition and deformation compatibility condition in the cross section of the concrete cylinder. The confinement modulus C_j of the carbon fiber composite jacket is introduced into the constitutive relation $\boldsymbol{\sigma} = \mathbf{E}(k) : \boldsymbol{\varepsilon}$ for modeling confined concrete. Utilizing Equations (2), (5), (7), (8), (18) and (19) into the Constitutive relation, the following equations, based on damage theory, for confined concrete, in uniaxial compression can be obtained as:

$$\sigma_1 = \left[E^0\mu - k - \frac{2E^0\eta^2}{(\mu+\eta) + \frac{1}{E^0}(C_j - 2\alpha k)} \right] \varepsilon_1 \tag{25}$$

$$\varepsilon_2 = \varepsilon_3 = -\left[\frac{E^0\eta}{E(\mu+\eta) + (C_j - 2\alpha k)} \right] \varepsilon_1 \tag{26}$$

Where, $\mu = \frac{1-\upsilon}{(1+\upsilon)(1-2\upsilon)}$, $\eta = \frac{\upsilon}{(1+\upsilon)(1-2\upsilon)}$, $\alpha = 1 + \beta/2$ and υ is the Poisson's ratio for concrete. Using Equations (10), (15), (16), (18), and (19) and (23), the damage surface for the confined concrete in uniaxial compression is given by

$$\left[1 + \frac{4(E^0\eta)^2}{\{E(\mu+\eta) + C_j - 2\alpha k\}^2} \right] \varepsilon_1^2 - \frac{\varepsilon_u^2 k}{(E^0 - k)} = 0 \tag{27}$$

5. NUMERICAL EXAMPLES

In this section, the damage model of concrete confined by polymer composite jackets is illustrated for uniaxial compression path. Figure 3 corresponds to the predicted compressive stress-strain curves for concrete confined by different layers of FRP composite jackets. The experimental data of Xiao and Wu [2] are also plotted for comparison. The model shows the enhancement of strengths and ductility, which are obtained as a consequence of confinements. The confinement modulus, C_j, was taken as 525, 1050, 1580 MPa for the specimens with one-, two-, and three-layer jackets, respectively, for generating theoretical stress-strain curves with the corresponding material parameters for concrete given in Table 1.

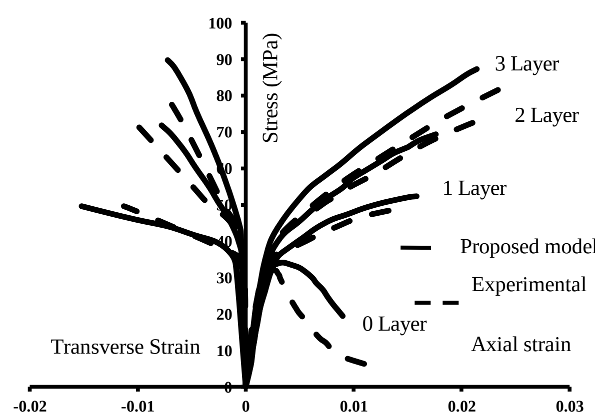

Figure 3: Theoretical Stress-strain relationships for CFRP confined concrete compared with experimental results of Xio and Wu [2].

Table 1: Material parameters for results shown in Figure 3

Parameters	Values
E^0	27468 MPa (Young's modulus)
ν	0.2 (Poisson's ratio)
ε_u	0.0003 (Strain corresponding to uniaxial tensile strength)
ε_c	0.0022 (Strain corresponding to uniaxial compressive strength)
β	0.75
ω	0.0049
λ	0.15 (Plastic cracking coefficient)

5. CONCLUSION

The behavior of concrete is highly influenced by the formation of microcracks and microvoids. These internal defects destroy material bonds and affects elastic properties. The progressive weakening of solids due to the formation and development of microcracks and microvoids is depicted by the continuous damage mechanics theory, which provides a natural basis for the constitutive modeling of brittle materials like concrete. In this paper, a damage mechanics model for CFRP confined concrete is established. In order to represent concrete behavior, a continuum damage mechanics formulation in strain-space is outlined wherein damage is recorded directly in the material's stiffness tensor. However, the behavior of CFRP composite jackets is assumed to be perfectly elastic. The damage mechanics formulation is cast within the general framework of the internal variable theory of thermodynamics, and the necessary conditions for satisfying the dissipation inequality are examined. Damage response tensors for mode-I and model-II cracking developed by Thapa and Yazdani [17] are used for modeling nonlinear behavior of confined concrete. Constitutive relations for CFRP confined concrete are established, and the model predictions of increase in strength and ductility are compared with the available experimental data. The model is capable capturing the compressive behavior of concrete confined by carbon fiber reinforced polymer composite jackets.

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Performance Analysis of Orthogonal Frequency Division Multiplexing Based on Channel Estimation Method

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***Abstract*: In order to achieve the potential advantages of Orthogonal Frequency Division Multiplexing (OFDM) based systems, the channel coefficients should be estimated with minimum error. Channel estimation plays a vital role in OFDM system. The channel estimation technique that can be pilot based or blind based can be helpful to improve the performance of OFDM system. The Performance comparison by measuring bit error rate for Least Square (LS) and Linear Minimum Mean Square Error (LMMSE) using modulation techniques like, Quadrature Phase Shift Keying (QPSK), and Quadrature Amplitude Modulation (QAM) is carried out under Additive White Gaussian Noise (AWGN) and Rayleigh fading. With different modulation schemes and channel estimation algorithm shows better results and improvement in terms of Bit Error Rate (BER).**

Keywords: Orthogonal frequency division multiplexing (OFDM), Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM), Bit Error Rate (BER).

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has recently been applied widely in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency and it robustness to multi-path delay. OFDM works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies to the receiver. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions as attenuation of high frequencies, narrowband interference, frequency-selective fading due to multipath etc. without complex equalization filters. OFDM has been adopted as the modulation method of choice for all the new wireless technologies being used and developed today. It is perhaps the most spectrally efficient method discovered so far, and it mitigates the severe problem of multipath propagation that causes massive data errors and loss of signal. OFDM systems are attractive for the way they handle ISI, which is usually introduced by frequency selective multipath fading in wireless environment. Each sub- carrier is modulated at a very low symbol rate, making the symbols much longer than the channel impulse response. In this way, ISI is diminished. Moreover, if a guard interval between consecutive OFDM symbols is inserted, the effects of ISI can completely vanish. This guard interval must be longer than the multipath delay. Although each-subcarriers operate at a low data rate, a total high data rate can be achieved by using a large number of sub-carriers. ISI has very small or no effect on the OFDM systems hence an equalizer is not needed at the receiver side. Cyclic Prefix (CP) is inserted between two successive symbols as guard interval which not only mitigates Inter Symbol Interference (ISI), but also converts the linear convolution between the transmitted OFDM symbol and channel impulse response to a circular one. At the receiver, the CP corrupted by ISI is generally discarded and the ISI free part of the OFDM symbol is used for channel estimation and data detection.

The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. The relative amount of dispersion in time caused by multipath delay spread is decreased because the symbol duration increases for lower rate parallel subcarriers. The other problem to solve is the inter symbol interference, which is eliminated almost completely by introducing a guard time in every OFDM symbol. This means that in the guard time, the OFDM symbol is cyclically extended to avoid inter carrier interference. An OFDM signal is a sum of subcarriers that are individually modulated by using phase shift keying (PSK) or quadrature amplitude modulation (QAM) [19].

The digital source is usually protected by channel coding and interleaved against fading phenomenon, after which the binary signal is modulated and transmitted over multipath fading channel. Additive noise is added and the sum signal is received [8].

A dynamic estimation of channel is necessary before the demodulation of OFDM signals since the radio channel is frequency selective and time-varying for wideband mobile communication systems [2]. The channel estimation can be performed by either inserting pilot tones into all of the subcarriers of OFDM symbols with a specific period or inserting pilot tones into each OFDM symbol [4]. The objective of Channel Estimation Technique is to compare the performance of LS and LMMSE for block pilot insertion technique using modulation techniques like BPSK, QPSK, and 16-QAM under AWGN noise and Rayleigh fading channel.

2. OFDM TRANSMISSION

Orthogonal Frequency Division Multiplexing (OFDM) is a multiplexing technique that divides a channel with a higher relative data rate into several orthogonal sub-channels with a lower data rate. For high data rate transmissions, the symbol duration Ts is short. Therefore ISI due to multipath propagation distorts the received signal, if the symbol duration Ts is smaller as the maximum delay of the channel. To mitigate this effect a narrowband channel is needed, but for high data rates a broadband channel is needed. To overcome this problem the total bandwidth can be split into several parallel narrowband subcarriers. Thus a block of N serial data symbols with duration Ts is converted into a block of N parallel data symbols, each with duration T = N×Ts. The aim is that the new symbol duration of each subcarrier is larger than the maximum delay of the channel, T > Tmax. With many low data rate subcarriers at the same time, a higher data rate is achieved [17].

A. Symbol Generation, Pilot Insertion and Transmission

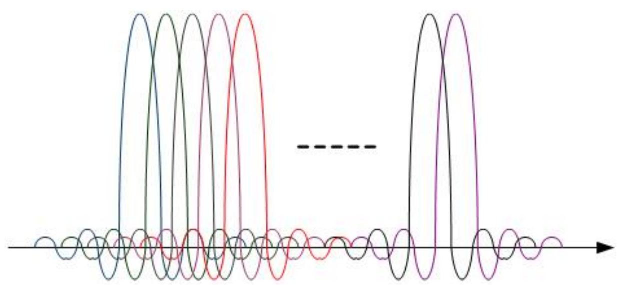

Figure 1: OFDM Symbol Transmission

An OFDM signal is a sum of subcarriers that are individually modulated by using phase shift keying (PSK) or quadrature amplitude modulation (QAM). The symbol can be written as:

$$s(t) = Re\left\{\sum_{i=-\frac{N_s}{2}}^{\frac{N_s}{2}-1} d_{i+\frac{N_s}{2}} \exp\left(j2\pi(f_c - \frac{i+0.5}{T}\right)(t-t_s)\right\},$$
$$t_s \le t \le t_s + T$$

$$s(t) = 0, t < t_s \; and \; t > t_s = T \qquad (1)$$

Where,

N_S is the number of subcarriers
T is the symbol duration
f_c is the carrier frequency

In order to create the OFDM symbol a serial to parallel block is used to convert N serial data symbols into N parallel data symbols. Then each parallel data symbol is modulated with different orthogonal frequency subcarriers, and added to an OFDM symbol, [18]. After conversion of symbol from serial to parallel symbols are inserted with different technique between the data symbol. Pilot bits are randomly generated and inserted between data bits. Finally OFDM symbols with pilots are transmitted over the multipath channel.

B. Inverse Fast Fourier Transform FFT to Create the OFDM Symbol

IFFT is a fast algorithm to perform inverse (or backward) Fourier transform (IDFT), which undoes the process of DFT. All modulated subcarriers are added together to create the OFDM symbol. This is done by an Inverse Fast Fourier Transformation (IFFT). The advantage of using IFFT is that the system does not need N oscillators to transmit N subcarriers [17].

C. Cyclic Prefix and Pilot Insertion a

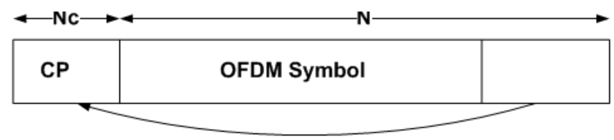

Figure 2: Cyclic Prefix adding process in OFDM symbol

The cyclic prefix is used in OFDM signals as a guard interval and can be defined as a copy of the end symbol that is inserted at the beginning of each OFDM symbol. Guard interval is applied to mitigate the effect of ISI due to the multipath propagation. Figure 1.2 shows the symbol and its delay. These delays make noise and distort the beginning of the next symbol as shown. To overcome this problem, one possibility is to shift the second symbol furthers away from the first symbol. But existence of a blank space for a continuous communication system is not desired. In order to solve this problem a copy of the last part of the symbol is inserted at the beginning of each symbol. This procedure is called adding a cyclic prefix. The Cyclic prefix is added after the IFFT at the transmitter, and at the receiver side the cyclic prefix is removed in order to get the original signal.

In orthogonal frequency division multiplexing (OFDM) systems over fading channels, channel estimation and tracking is generally carried out by transmitting known pilot symbols in given positions of the frequency-time grid. Pilots are subcarriers of known data (known modulation symbols),and are used to detect the channel changes and thus used for equalization, frequency offset estimation and many other baseband algorithms.

3. CHANNEL ESTIMATION

In any communication systems, channel estimation is a most important and challenging problem, especially in wireless communication systems. Usually, the transmitted signal can be degraded by many detrimental effects such as mobility of transmitter or receiver, scattering due to environmental objects, multipath and so on. These effects cause the signal to be spread in any transformed domains as time, frequency and space. To reduce these effects anyone must estimate the channel impulse response (CIR). Channel estimation has a long history in single carrier communication systems. In these systems, CIR is modelled as an unknown FIR filter whose coefficients are time varying and need to be estimated [21]. There are many channel estimation methods that can be used in multicarrier communication systems but the especial properties of multicarrier transmission systems give an additional perspective which forces to developing new techniques to channel estimation in wireless communication systems.

The channel estimation can be performed by either inserting pilot tones into all of the subcarriers of OFDM symbols with a specific period or inserting pilot tones into each OFDM symbol. There are basically two types of classification of Channel estimation in OFDM.

A. Blind Channel Estimation

A blind channel estimation method avoid the use of pilot symbols and thus is well motivated for applications requiring high spectral efficiency. No pilots are required in blind channel estimation. It uses some underlying mathematical properties of data sent. The Blind channel estimation methods are computationally complex and hard to implement. Blind approach may exhibits better performance as compared to the training-based one for the case of fast varying channels.The Pilot based channel estimation methods are easy to implement but they reduces the bandwidth efficiency.

B. Pilot Based Channel Estimation

Pilot based channel estimation can be of two types Block Pilot insertion and Comb Pilot Insertion. In pilot based channel estimation known symbol called pilots are transmitted.

Channel state varies continuously so channel state information needs to be estimated on short term basis. An approach of inserting training sequence (or pilot sequence), where a known signal is transmitted and the channel matrix H is estimated using the combined knowledge of the transmitted and received signal.

Let the training sequence be denoted by $P_1, \ldots \ldots \ldots \ldots . P_N$ where the vector P_i is transmitted over the channel as:

$$y_i = Hp_i + n_i \tag{2}$$

By combining the received training signals $y_i \, for \, i = 1, \ldots \ldots \ldots \ldots, N$ total training signaling becomes:

$$Y = [y_1 \ldots \ldots . . y_N] = HP + N \tag{3}$$

with the training matrix $P = [p_1, \ldots \ldots . p_N]$ and the noise matrix :

$$N = [n_1, \ldots \ldots . n_N] \tag{4}$$

With this notation, channel estimation means that H should be recovered from the knowledge of Y and P.

In order to estimate the channel at receiver side using the transmitted symbol of pilot two types of estimation techniques is used. The block-type refers to that the pilots are inserted into all the subcarriers of one OFDM symbol with a certain period. The block-type can be adopted in slow fading channel, that is, the channel is stationary within a certain period of OFDM symbols. Assuming that inter symbol interference is dropped by guard interval, we write output Y (k) as:

$$Y = Xh + nY \tag{5}$$

Where Y is the received vector, X is a matrix containing the transmitted signalling points on its diagonal, h is a channel attenuation vector, and n is a vector of i.i.d. complex, zero mean, Gaussian noise with variance ${\sigma^2}_n$. In the following the Linear Minimum Mean Square Error (LMMSE) and Least Square (LS) estimate in detail with channel attenuations h from the received vector **y** and the transmitted data X is described. It's assumed that the received OFDM symbol contains data known to the estimator - either training data or receiver decisions.

1) Block Type Pilot Insertion

OFDM symbols with pilots at all subcarriers (referred to as pilot symbols herein) are transmitted periodically for channel estimation. Using these pilots, a time-domain interpolation is performed to estimate the channel along the time axis. Since pilot tones are inserted into all subcarriers of pilot symbols with a period in time, the block type pilot arrangement is suitable for frequency-selective channels. For block type arrangements, channel at pilot tones can be estimated by using LS or LMMSE estimation, and assumes that channel remains the same for the entire block. So in block type estimation, we first estimate the channel, and then use the same estimates within the entire block.

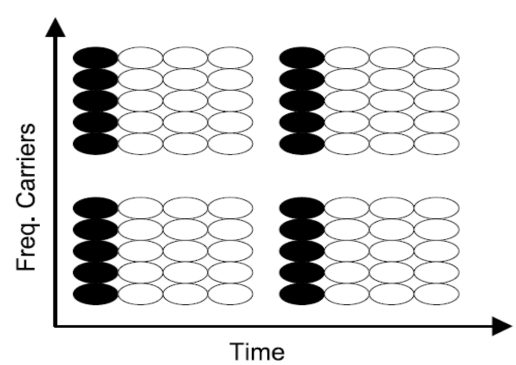

Figure 3: Block Pilot Insertion Method

- ***Least Square Estimation***

The LMS estimator uses a one-tap LMS adaptive filter at each pilot frequency. The first value is found directly through LS and the following values are calculated based on the previous estimation and the current channel output. The error signal e(k) is formed and plotted by taking the difference between the received pilot symbol Y(k) and transmitted pilot symbol X(k).

Let us Suppose pilot signals as *Mpi* with symbols as *Xpi(n), n=0,1,.....,Mpi-1* which are uniformly inserted into *X(k)* data signals. The OFDM signal modulated on the k^{th} subcarrier can be expressed as

$$(k\ ) = X\big((nLs + i)\big) = \begin{cases} X_{pi}(n), i = 0 \\ Source\ data, i = 1{,}2, \ldots\ldots, L_s - 1 \end{cases} \tag{6}$$

when the total *M* subcarriers are divided into *Mpi* groups, each with L_s=M /M_{pi} adjacent subcarriers. The estimate of pilot signals based on least squares (LS) criterion is given by [15],

$$\widehat{H}_{pi} = X_{pi}^{-1} Y_{Pi} \tag{7}$$

$$H_{pi} = \left[H_{pi}(0) H_{pi}(1) \ldots \ldots .. H_{pi}(M_{pi} - 1)\right]^T \tag{8}$$

the channel frequency response at pilot sub-carriers,

$$Y_{pi} = \left[Y_{pi}(0) Y_{pi}(1) \ldots \ldots .. Y_{pi}(M_{pi} - 1)\right]^T \tag{9}$$

received pilot signals vector which can also be expressed as,

$$Y_{pi} = X_{pi}. H_{pi} + I_{pi} + W_{pi} \tag{10}$$

$$\text{where } X_{pi} = \begin{pmatrix} X_{pi}(0) & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & X_{pi}(M_{pi} - 1) \end{pmatrix}$$

$I_p\ and\ W_{pi}$ are the intercarrier interference (ICI) vector and the Gaussian noise vector in pilot subcarriers, respectively.

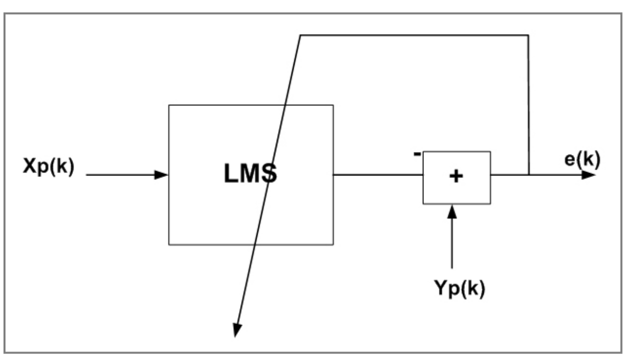

Figure 4: Least Square Estimation

- ***Linear Minimum Mean Square Error Estimation***

The linear minimum mean square error (LMMSE) estimate has been shown to be better than the LS estimate for channel estimation in OFDM systems based on block type pilot arrangement. The LMMSE estimate has about significant gain in SNR over LS estimate for the same MSE values in low SNR regions. The major drawback of the LMMSE estimate is its high complexity, which grows exponentially with observation samples. In a low rank approximation is applied to a linear minimum mean squared error estimator (LMMSE estimator) that uses the frequency correlations of the channel [14].

Let us denote the error of channel estimation as

$$e = H - \widehat{H} \tag{11}$$

Where H is actual channel estimation and is raw channel estimation, respectively. And the MSE of channel estimation is [16]

$$\mathrm{E}\{[|\mathrm{e}^2|\} = \mathrm{e}\left\{\left|\mathrm{H} - \widehat{\mathrm{H}}\right|^2\right\} = \mathrm{e}\left\{\left(\left|\mathrm{H} - \widehat{\mathrm{H}}\right|\right) \left(\left|\mathrm{H} - \widehat{\mathrm{H}}\right|^{\mathrm{H}}\right)\right\} \tag{12}$$

Where E{} is the expectation. Since the channel and AWGN are not correlated, we can rewrite Equation 3.7 as:

$$\widehat{H}_{MMSE} = R_{HY} {R_{YY}}^{-1} Y \tag{13}$$

Let us denote the auto-covariance matrixes of H, Y by $R_{HH,} R_{YY,}$ respectively, and cross covariance matrix between H and Y byR_{HY}. Let ${\sigma^2}_N$ is the noise-variance, since the channel and AWGN are not correlated, we could get:

$$\begin{aligned} R_{HY} &= E\{HY^H\} \\ &= E\{H(HX + W)^H\} \\ &= E\{HH^H X^H + HW^H\} \\ &= R_{HH} X^H \end{aligned} \tag{14}$$

$$\begin{aligned} R_{YY} &= E\{YY^H\} \\ &= E\{(HX + W)(HX + W)^H\} \\ &= E\{HXH^H X^H + HXW + WX^H H^H + WW^H\} \\ &= XR_{HH} X^H + {\sigma_N}^2 I_N \end{aligned} \tag{15}$$

If $R_{HH}\ and\ {\sigma_N}^2$ are known to the receiver, so channel impulse response could be calculated by LMMSE estimator as below:

$$\begin{aligned} \widehat{H}_{MMSE} &= R_{HY} {R_{YY}}^{-1} Y \\ &= R_{HH}(R_{HH} + {\sigma_N}^2 (X^H X)^{-1})^{-1}\ \widehat{H}_{LS} \end{aligned} \tag{16}$$

So from equation (16), A simplification of MMSE estimator is to replace the $(X^H X)^{-1}$ by its expectation $\mathrm{E}\{(\mathrm{X}^\mathrm{H}\mathrm{X})^{-1}\}$, which means the average power of all subcarriers replace the instantaneous power of each subcarrier in order to reduce the computation,

Assuming the same signal constellation on all tones and equal probability on all constellation points, we get

$$E\{(X^H X)^{-1} = E\left\{\frac{1}{|X_k|^2}\right\} I \quad (17)$$

where I is the identity matrix.

Average of SNR is given by,

$$\overline{SNR} = \frac{E\{|X_k|^2\}}{\sigma_N{}^2} \quad (18)$$

The term $\sigma_N{}^2 (X^H X)^{-1}$ is computed by $\frac{\beta}{SNR} I$

Where β is defined as,

$$\beta = \frac{E\{|X_k|^2\}}{E\left\{\frac{1}{|X_k|^2}\right\}} \quad (19)$$

Thus, modified equation can be written as:

$$\hat{H}_{LMSE} = R_{HH}(R_{HH} + \frac{\beta}{SNR} I)^{-1} \quad \hat{H}_{LS} \quad (20)$$

2) Comb Type Pilot Insertion

The comb type pilot arrangement is suitable for fast-fading channels, but not for frequency selective channels. To achieve high data rates as well as good performances, coherent detection is commonly used in most existing OFDM Systems. Coherent detection relies on knowledge of channel state information. One simple approach to obtain channel state information is to send some pilot symbols at the transmitter. Pilot subcarriers are often interlaced with data subcarriers. Comb-type pilot insertion has been shown to be suitable for channel estimation in fast fading channels [1].

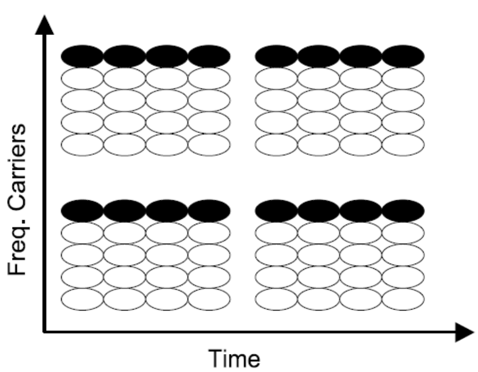

Figure 5: Comb Pilot Insertion Method

4. SIMULATION

A. Description of simulation

1) Simulation Parameters

OFDM system parameters used in simulation are indicated in Table I. We assume to have perfect synchronization since the aim is to observe channel estimation performance. Simulation parameters chosen for analysis are the standard specification for Mobile WiMAX based on the IEEE 802.16e-20055 standard. In mobile WiMAX the FFT sizes can vary from 128 bits to 2,048 bits. We have analysed with FFT size 128. The parameters are shown here for only a limited set of profiles that are likely to be deployed and do not constitute an exhaustive set of possible values.

WiMAX, or IEEE 802.16, is an internet communications protocol specifically designed to provide internet access across long wireless communications links. WiMAX boasts data throughputs of up to 75 Mbps. In addition, it fully utilizes the OFDM approach to a communications channel. For this reason, it is more resilient to multi-path symbol interference and can be used to transmit data distances of up to 30 miles.

In addition, WiMAX utilizes each channel's sub-carriers in three specific ways. First, the data sub-carriers are used for data transmission. Second, WiMAX implements pilot sub-carriers which are used for channel estimation and synchronization. Finally, several sub-carriers are designated as null sub-carriers which are used as guard bands.

Table I: Simulation Parameters

PARAMETER	SPECIFICATION (Mobile WiMAX)
Bandwidth	1.25MHZ
Frequency of Carrier	1.9 GHZ
Number of sub-carriers	128
Number of symbols per carrier	100
Interval of sub-carriers	7.8125 KHz
Number of multipath	5
Block Pilot position	8
Cyclic Prefix length	16
Signal constellation	16-QAM,QPSK
Channel	AWGN, Rayleigh

2) Channel Estimation Based on Block-Type Pilot Arrangement

For channel estimation technique, basically two types of channel estimation technique: least square and linear minimum mean square error is studied. Performance of both algorithms is analysed based on Bit Error Rate calculation under modulation schemes QPSK and 16 QAM.

From the simualtion in figure 5 the BER performance of LMMSE is better than that of LS at the presence of AWGN noise. As SNR goes high both the algorithm has similar performance. The estimation technique which shows less error at different SNR can be used to estimate the channel.

Similarly the simulation under Rayleigh channel has been carried out for QPSK modulation to observe performance.

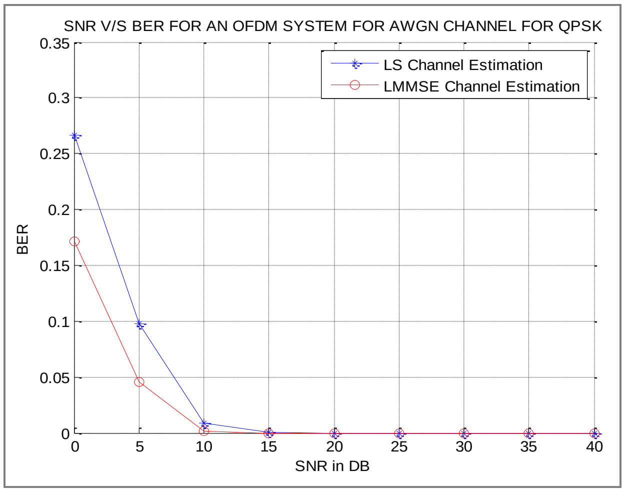

Figure 6: Comparison of Estimation technique under block pilot insertion under AWGN Channel, QPSK

Table 2: BER table for AWGN under QPSK modualtion

SNR (DB)	LMMSE BER	LS BER
0	0.1711	0.2670
5	0.0451	0.0977
10	0.0012	0.0088
15	0.0000	0.0000
20	0.0000	0.0000
25	0.0000	0.0000
30	0.0000	0.0000
35	0.0000	0.0000
40	0.0000	0.0000

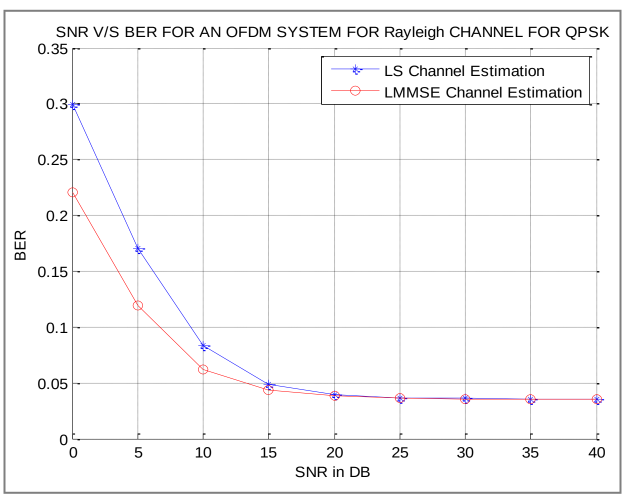

Figure 7: Comparison of Estimation technique under block pilot insertion under Rayleigh Channel, QPSK

Simulation has been carried for the BER performance of LMMSE under Rayleigh fading. From the simulation garpth also what can be oberved is as SNR goes high both the algorithm has similar performance. For of the simualtion result BER table comparing LMMSE BER and LSE BER has been drawn.

Table 3: BER table for Rayligh fading under QPSK modualtion

SNR	LMMSE BER	LSE BER
0	0.2209	0.2989
5	0.1197	0.1704
10	0.0623	0.0834
15	0.0432	0.0485
20	0.0379	0.0393
25	0.0361	0.0368
30	0.0358	0.0358
35	0.0355	0.0353
40	0.0357	0.0356

From the simulation result for QPSK modulation under AWGN and Raleigh fading channel, it has been observed that under QPSK modulation at AWGN noise the performance is better as compared to the QPSK under Rayleigh fading.

For more analysis of the OFDM performance simulation has been carried out under for 16-QAM modulation also. BER performance of LS and LMMSE is analysed under AWGN noise and Rayleigh channel. Keeiping simulation paramter constant the anaalysis has been done vaarying channel conditon and modulation technique. Simulastion results and tabular form of BER and SNR shows the detail for performance comparison.

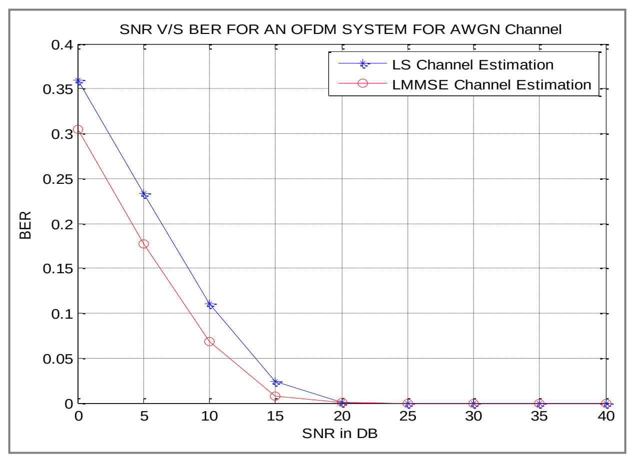

Figure 8: Comparison of Estimation technique under block pilot insertion under AWGN Channel, 16-QAM

Table 4: BER table for AWGN noise under 16-QAM modualtion

SNR DB	LMMSE BER	LSE BER
0	0.304	0.360
5	0.178	0.233
10	0.069	0.110
15	0.007	0.024
20	0.000	0.000
25	0.000	0.000
30	0.000	0.000
40	0.000	0.000

From the simualtion observed in Figure8. the BER in case of 16-QAM modualtion technique performance of LMMSE is better than that of LS at the presence of AWGN noise. When SNR goes high both the algorithm has similar result. The result is somehow in correspondence with QPSK modulation. But as when we compare BER rate, QPSK modulation has better result as compared to 16-QAM under same channel impairment.

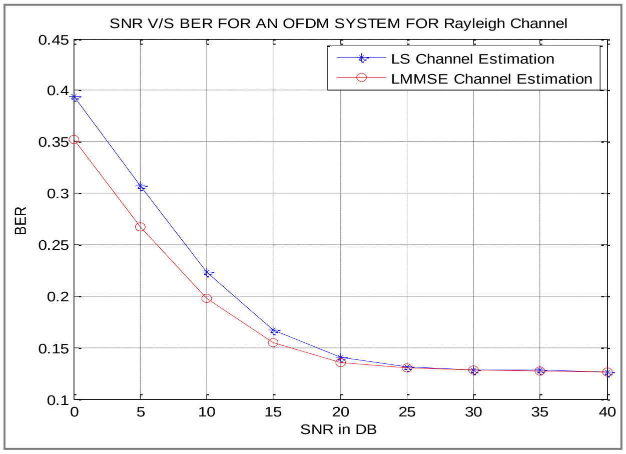

Figure 9: Comparison of Estimation technique under block pilot insertion under AWGN Channel, 16-QAM

Table 5: BER table for Rayligh Fading under 16-QAM modualtion

SNR DB	LMMSE BER	LSE BER
0	0.3521	0.3943
5	0.2677	0.3072
10	0.1980	0.2237
15	0.1544	0.1675
20	0.1355	0.1408
25	0.1297	0.1317
30	0.1280	0.1283
35	0.1275	0.1278
40	0.1260	0.1259

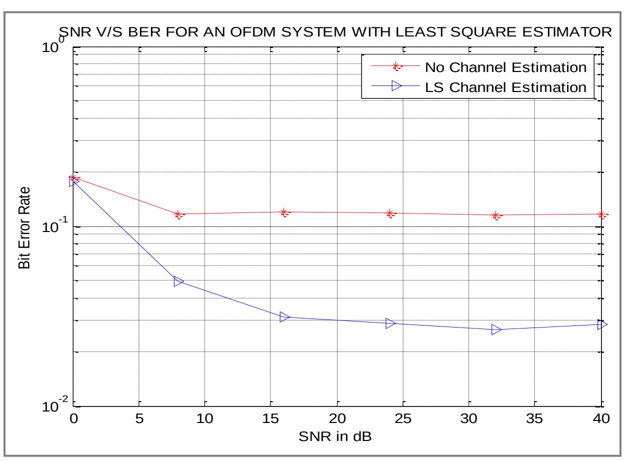

Figure 10: Comparison of Estimation technique under block pilot insertion under AWGN Channel, 16-QAM

From the simation result for QPSK and 16-QAM modultaion it has been confirmed that QPSK modulation gives better result as compared to 16-QAM for LMMSE. Also simulation has been carried out with channel estimation using LS and no channel estimation to observe the performance.

From the simulation result improvement in BER rate is observed as compared with no channel estimation. So it is necessary to perform channel estimation for signal passing through fading channel to obtain better performance.

5. Conclusion

From the simulation plots and observed BER data it can be confirmed that OFDM under AWGN channel has better performance as compared to Rayleigh channel. The BER rate of QPSK under AWGN channel has better result as compared to AWGN channel under 16-QAM modulation. Also from simulation results i.e. BER caluclation, confirms that LMMSE has better estiamtion as compared to LSE estiamtion under QPSK modulation scheme at lower values of SNR. However as we go to higher SNR values both the algorithm has similar results. As least square estimation does not consider SNR so it shows better result at greater SNR values.

From the simulation resuslt with estimation and no estimation it can be confirmed that with channel estiamtion has markable imporvement in BER as compared with no channel estimation.

6. Limitations and Future Enhancement

The algorithm LMMSE gives better result as compared to LSE but it requires the knowledge of channel autocorrelation matrix in frequency domain and the signal to noise ratio (SNR). Although the system can be designed for fixed SNR and channel frequency autocorrelation matrix, the performance of the OFDM system will degrade significantly due to the mismatched system parameters. Also another algorithm LS found to be better at higher SNR values but it does not consider noise ratio (SNR).

In Future the complexity of LMMSE algorithm can be further be minimized so that better result can be made with less complexity. Also simulation work can be further enhanced by estimating the channel using comb type pilot insertion technique at different channel condition.

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MapReduce Based Approach to Sequence Comparison using Longest Common Subsequence

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Abstract: **Sequence alignment is one of the most important tasks in bio-informatics or computational biology field. It helps identifying the similarity between the biological sequences. Longest Common Subsequence is the fundamental problem for sequence alignment techniques. Due to the emerging growth in bio-informatics applications, new biological sequences with longer length have been used for processing. Sequential algorithmic implementations take more time to find Longest Common Subsequence. Sequential implementations sometimes become intractable for longer biological sequences. To compute Longest Common Subsequence of longer biological sequences more efficiently and quickly, parallel algorithms are used. In this paper, a Map Reduce based parallel algorithm for comparing genetic sequences using the Longest Common Subsequence (LCS) between genetic sequences is presented.**

Keywords— *Bio-informatics, Sequence Alignment, Longest Common Subsequence, MapReduce, Hadoop*

1. Introduction

A. Background

A fundamental operation in bioinformatics involves the comparison of genetic (DNA) sequences. Similarity between genetic sequences is a strong indicator of evolutionarily preserved characteristics.

Among the many sequence comparison tools for mining genetic information, one extremely common technique includes the alignment-based methods. These involve aligning the entire (global alignment, Needleman-Wunsch[1]) or smaller sections (local alignment, Smith-Waterman[2]) of the genetic sequences. The choice of global or local alignment is based on the type of analysis desired. However, both these methods are heavily dependent on the quality of sequence data. Even slight discrepancies resulting from experimental or technical limitations, can significantly affect the comparison results.

Alternative approaches of sequence analysis are becoming increasingly important in dealing with the exponential growth of genetic sequence data, and the classification and the grouping of organisms based on these sequences. Such alternative approaches include the alignment-free methods, which match the relative (as opposed to the exact) order of the base pairs in the sequence.

Advancements in sequencing technology have provided a deluge of genetic data. The Genbank, a public repository of genetic sequence data, reported 164136731 sequence records in its 195th release in Apr 2013. Analyzing such large datasets, including the 3 billion bases of the human reference genome, on uniprocessor machines is an extremely time consuming process. It is imperative therefore, to harness the power of high performance computing to facilitate our understanding of this high throughput data.

2. Literature Review

The Needleman–Wunsch[1] algorithm was the first application of dynamic programming which provides a global alignment between two sequences. This algorithm leads to the evolution of various efficient LCS algorithms. It is only suitable if the two sequences are of similar length. The Smith- Waterman [2] algorithm evolved from Needleman- Wunsch algorithm provides a local alignment of biological sequences.

Various parallel algorithms like CREW PRAM model, Systolic arrays have been proposed in the earlier days to reduce the computation time. In the recent time Wan, Liu, Chen proposed Fast LCS algorithm [3] with time complexity |LCS(X, Y)|. Fast LCS's efficiency has been further improved by EFP_LCS [4].

Recent developments in open source software Hadoop[5] project and associated software provide a foundation for scaling to petabyte scale data warehouses on Linux clusters, providing fault-tolerant parallelized analysis on such data using a programming style named MapReduce[6]. MapReduce is the software framework invented by and used by Google to support parallel execution of their data intensive applications. MapReduce being new technology there are very few works accomplished in bioinformatics using it. Due to increasing number of gene sequences MapReduce would be good choice to process large gene data.In this paper, MapReduce based approach to compute Longest Common Subsequence is presented.

A. Needleman–Wunsch algorithm

The Needleman–Wunsch algorithm performs a global alignment on two sequences. It is commonly used in bioinformatics to align protein or nucleotide sequences. The algorithm was published in 1970 by Saul B. Needleman and Christian D. Wunsch.

The Needleman–Wunsch algorithm is an example of dynamic programming, and was the first application of dynamic programming to biological sequence comparison. It is sometimes referred to as the Optimal matching algorithm.

This global sequence alignment method explores all possible alignments and chooses the best one (the optimal global alignment). It does this by reading in a scoring matrix and a gap penalty (penalties) that contains values for every possible residue or nucleotide match and summing the matches taken from the scoring matrix.

B. Smith–Waterman algorithm

The Smith–Waterman algorithm performs local sequence alignment; that is, for determining similar regions between two strings or nucleotide or protein sequences. Instead of looking at the total sequence, the Smith–Waterman algorithm compares segments of all possible lengths and optimizes the similarity measure.

The algorithm was first proposed by Temple F. Smith and Michael S. Waterman in 1981. Like the Needleman–Wunsch algorithm, of which it is a variation, Smith–Waterman is a dynamic programming algorithm. As such, it has the desirable property that it is guaranteed to find the optimal local alignment with respect to the scoring system being used (which includes the substitution matrix and the gap-scoring scheme). The main difference to the Needleman–Wunsch algorithm is that negative scoring matrix cells are set to zero, which renders the (thus positively scoring) local alignments visible. Backtracking starts at the highest scoring matrix cell and proceeds until a cell with score zero is encountered, yielding the highest scoring local alignment.

C. Fast LCS algorithm

The algorithm first constructs a novel successor table to obtain all the identical pairs and their levels. It then obtains the LCS by tracing back from the identical character pairs at the last level. The key technique of this algorithm is the use of several effective pruning operations. In the process of generating the successors, pruning techniques can remove the identical pairs which cannot generate the LCS so as to reduce the search space and accelerate the search speed.

This algorithm is developed on an MPP parallel computing model.

D. MapReduce

MapReduce is a programming model and an associated implementation for processing and generating large data sets. Users specify a map function that processes a key/value pair to generate a set of intermediate key/value pairs, and a reduce function that merges all intermediate values associated with the same intermediate key.

Programs written in this functional style are automatically parallelized and executed on a large cluster of commodity machines. The run-time system takes care of the details of partitioning the input data, scheduling the program's execution across a set of machines, handling machine failures, and managing the required inter-machine communication. This allows programmers without any experience with parallel and distributed systems to easily utilize the resources of a large distributed system.

A typical MapReduce computation processes many terabytes of data on thousands of machines. Programmers find the system easy to use: hundreds of MapReduce programs have been implemented and upwards of one thousand MapReduce jobs are executed on Google's clusters every day.

MapReduce provides an abstraction that involves the programmer defining a "mapper" and a "reducer," with the following signatures:

- Map: (value 1, key1) → list (key2, value2)
- Reduce: (key2, list (value2) → list (value2).

E. Hadoop and the Hadoop Distributed File System

Hadoop is a popular open source implementation of MapReduce, which is a powerful tool designed for deep analysis and transformation of very large datasets which is inspired by Google's MapReduce and Google File System. It enables applications to work with thousands of nodes and petabytes of data.

Hadoop uses a distributed file system called Hadoop Distributed File System (HDFS), which creates multiple replicas of data blocks and distributes them on computer nodes throughout a cluster to enable reliability and has extremely rapid computations to store data as well as the intermediate results. The Hadoop runtime system coupled with HDFS manages the details of parallelism and concurrency to provide ease of parallel programming with reinforced reliability. In a Hadoop cluster, a master node controls a group of slave nodes on which the Map and Reduce functions run in parallel.

3. METHODOLOGY

A. Sequence Comparison Using LCS

The longest common subsequence algorithm finds the longest subsequence between two strings. In contrast to the substring, the subsequence denotes a series of letters from the string which while being in order, need not be consecutive. For example, between ATCG and CTCAG, the longest common substring is TC, while the longest common subsequence is TCG.

LCS can help to identify the key nucleotides across genetic sequences and is considerably less affected by the occasional sequencing error. This method is also useful for identifying potential regions of small mutations by analyzing the portions of the string not present in the LCS.

B. Computing the LCS

The algorithm presented in this paper is mainly inspired by the paper "A Parallel Non-Alignment Based Approach to Efficient Sequence Comparison using Longest Common Subsequences" [7] which is inspired by FAST_LCS method. This involves creating position pairs of identical letters in the sequence and combining them to potential LCS strings as long as their relative order is maintained across the pairs. Given two position pairs (i,j) and (k,l), the corresponding letters would be a potential candidate for LCS only if i<k and j<l.

The position pairs of the two strings ATCG and CTCAG are represented as vertices of the graph. An edge connects vertex (i,j) to (k,l) if (i<k) and (j<l). The diameter of the tree gives the longest common subsequence.

In the sequences given above; the position pairs are; A:(0,3); C:(2,0) and (2,2); T:(1,1) and G:(3,4). Some strings preserving the relative order are:

(i) AG: (0, 3) → (3,4)

(ii) TG: (1,1) → (3,4)

(iii) TCG: (1,1) → (2,2) → (3,4)

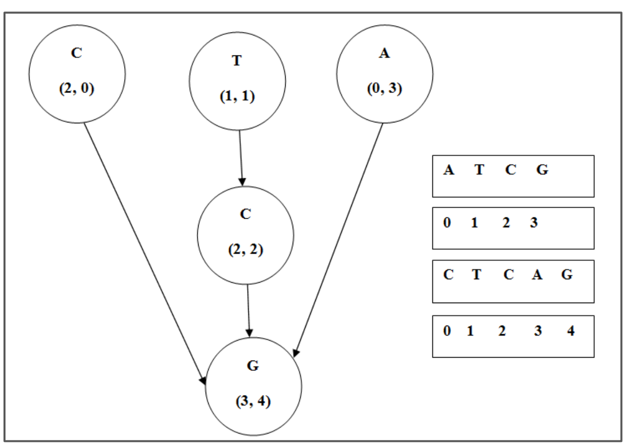

Figure 1: An example of computing LCS using position pairs

The algorithm consists of obtaining these position pairs and then creating a tree where the vertices represent the position pairs and the edges, their order in the subsequences. The diameter of the tree provides the LCS, as shown in Figure 1.

C. Parallel Implementation of LCS

Algorithm:

- Create positional pairs(nodes) of all the characters in sequence

  [Single Map Reduce]

- Create Sub Sequence Tree (Multi Level Map Reduce)
  - At each level:
    - Compare two nodes, let X(i,j), Y(k,l)
    - Combine connecting nodes to make new node
  - If i<k and j<l, create XY
  - Pass XY to next level
  - Stopping Criteria

    count(nodes) = 1

D. Map Reduce Strategy

First of all two input files containing DNA sequences are loaded to HDFS. Input files are text files which contain combinations of characters A, T, C and G.

1) *Create positional pairs*: This single Map Reduce task is to create all positional pairs of similar characters in both input sequences. For this the Map and Reduce tasks are defined as follows:

Map Procedure:

Input(k,v) = (line_number, String)

Output(k,v) = (String, String)

For each line in value

- Extract each character
- Set extracted character as output key
- Set position of extracted character as output value

Reduce Procedure:

Input(k,v) = (String, String)

Output(k,v) = (String, String)

For each position values of characters

- Create position pair of each characters with corresponding position in two input files

- Set thus created position pair as output value of reducer
- Character value will remain output key of reducer

2) *Create Sub Sequence Tree*: This is Multi Level Map Reduce task. Input to the First level Map Reduce task to create sub sequence tree are the position pairs created previously. For this the Map and Reduce tasks are defined as follows:

Map Procedure:

Input(k,v) = (line_number, String)

Output(k,v) = (one, String)

For each line in value, pass the content in line (position pair) to the reducer as it is.

Reduce Procedure:

Input(k,v) = (one, String)

Output(k,v) = (String, String)

For each position pairs

- Compare two position pairs
- If they follow relative order, combine them and create new node
- Set newly created node as key of reducer output
- Create position pair of newly created node and set it as value of reducer output
- Thus created new node with position pair is passed to next level

Next level Map Reduce task uses the output of previous level Map Reduce task as input. Multi level Map Reduce task is repeated unless there is single node is left.

4. Output and Discussion

The basic MapReduce Model for computing the Longest Common Subsequence has been developed.

The calculation of Positional Pairs of each character in gene sequences has been computed using single Map Reduce model. The solution is scalable and efficient.

Subsequence tree has been created using Multi level MapReduce model in which output of one level is input to another level. This MapReduce model is run iteratively for number of levels. The number of levels to run is obtained dynamically based on the number of pairs combined at each stage.

To speed up computation, position pairs are sorted in each level so that vertex appearing later in string is not visited earlier.

A. Sample Output

1) Input Directory in HDFS

Figure 2: Input Directory in HDFS

2) Input Files in HDFS

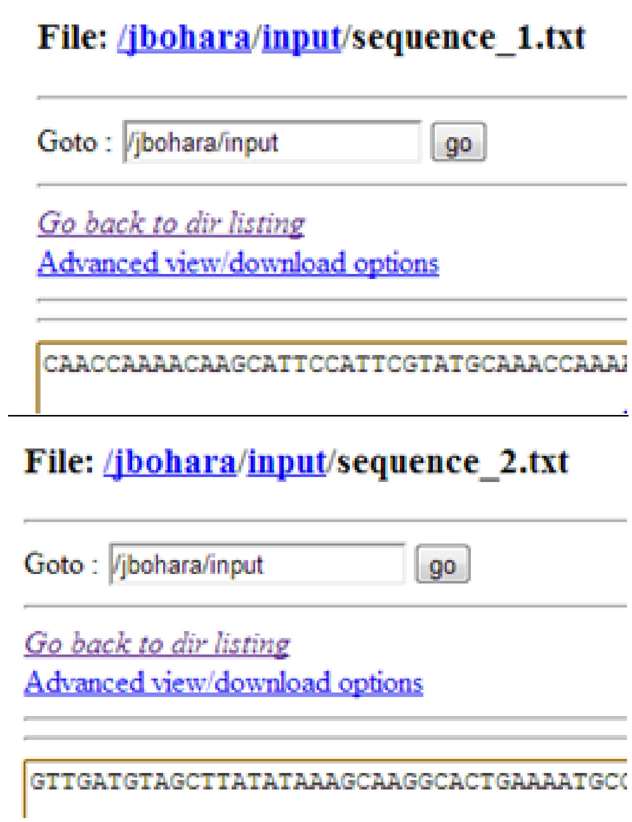

Figure 3: Input Files in HDFS

3) Output Directory in HDFS

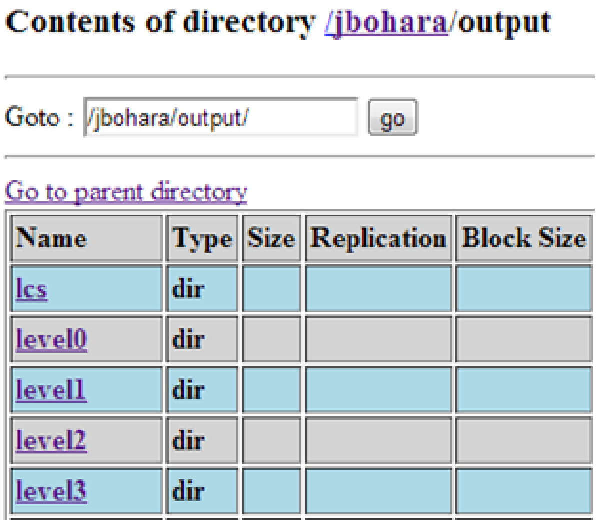

Figure 4: Output Directory in HDFS

4) Output of Level 0(Position Pairs Creation)

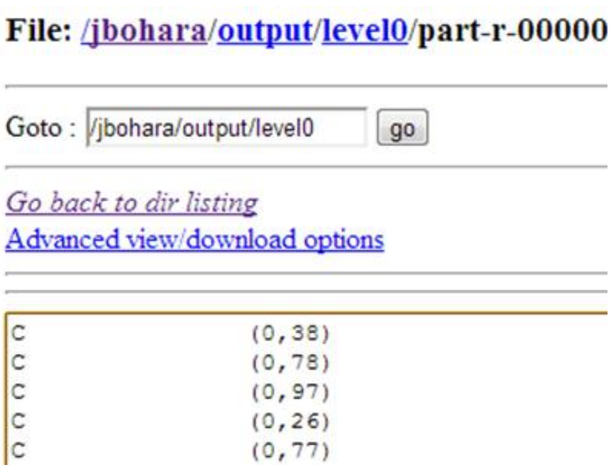

Fig. 5: Output of Level 0(Position Pairs Creation)

5) Output of Level 1(Sub sequence Tree Formation)

Figure 6: Output of Level 1(Sub sequence Tree Formation)

6) Output of Level 2(Sub sequence Tree Formation)

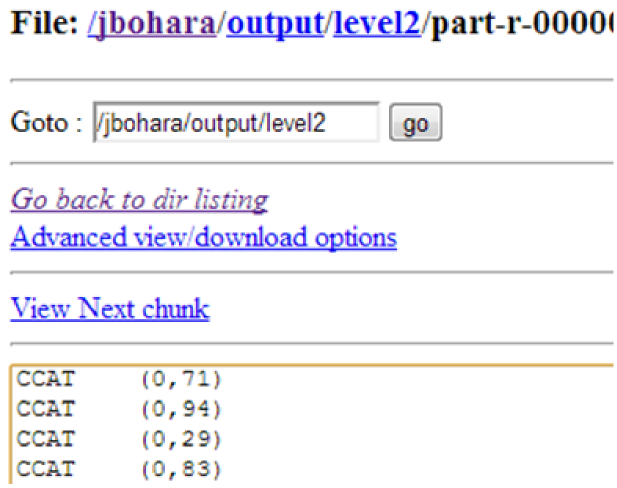

Figure 7: Output of Level 2(Sub sequence Tree Formation)

7) Final Output (Longest Common Subsequence)

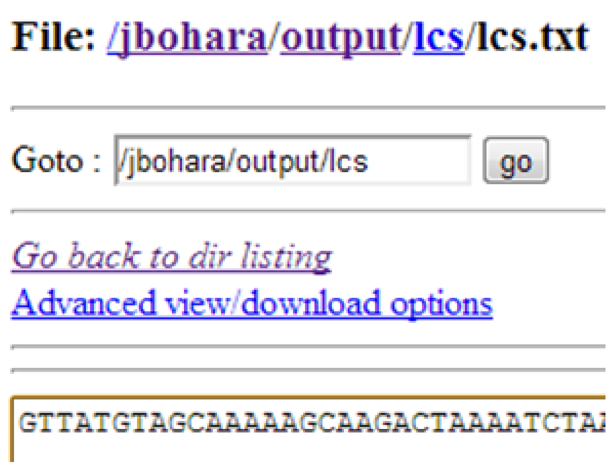

Figure 8: Final Output (Longest Common Subsequence)

5. Conclusions

A basic model for MapReduce based approach to Longest Common Subsequence has been developed. This model is designed in such a way that it is not only useful for gene sequence comparison but also useful for any file comparison .Yet there is much room for optimization and improvements for better accuracy and efficiency. Benchmarking is to be done with other existing algorithms.

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Dynamic Utilization of WRAN with Co-operation for Performance Enhancement of Wireless Communications

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***Abstract*: Modern wireless applications demand the higher data rates and that led to the problem of scarcity of spectrum. According to Federal Communication Committee 70% of statically allocated spectrums are underutilized and thus it had given legal permission for unlicensed operation for the Television White Space (TVWS). The concept of TVWS is due to the shifting of analog TV to Digital TV, traditionally reserved frequency bands in the range of 54 MHz to 698 MHz with 700 MHz band. Field surveying during this research work within the range of 0.1 MHz to 3 MHz also supports the FCC data because just 16.83% of spectrum is used and apart from FM radio and GSM band, other licence band are almost void. In such a scenario dynamic spectrum allocation got the higher priority and new concept based on cognitive radio technology emerged. Cognitive radio technology is an innovation software defined radio design that is proposed to increase the spectrum utilization by exploiting unused spectrum dynamically changing environment. This paper envisions the current scenario of spectrum utilization and proposed a model for the secondary user which is not only an opportunistic user but also a co-operative user of primary user and assist for the transmission of data packet of primary user according to MG1 queuing theory. Paper focus the dynamic spectrum allocation for Wireless Regional Area Network (WRAN)- IEEE 802.22, which is the first worldwide standard on cognitive radio because this WS offer ten times the coverage and three times better the capacity of current Wi-Fi spectrum. Secondary user uses the channel to transmit its own packet if and only if, the packet of primary data is empty. The hypothesis, performance is increased due to sharing of resource is became true by assuming the upper bound of 1 GB primary's data on queue and on sharing of about 50% of this data by the secondary transmitter as co-operative user, performance is increased by 9.45% to 40.85% as normalized traffic load increased from 0 to 0.98. Since, the data rate is set according to WRAN parameter to get optimum performance of resource sharing is about 41% is achieved at traffic load 0.98.**

Keywords: Cognitive Radio, Dynamic Spectrum Allocation, MG1 queue, Opportunistic User, White Space.

1. INTRODUCTION

High data rate demands the modern wireless applications and that led to a problem of scarcity of spectrum. According to the Federal Communication Commission (FCC), the current static frequency allocation schemes leave approximately 70% of the allocated spectrum are underutilized [1]. In order to increase the spectrum usage efficiency, new policies have emerged, that suggest the coexistence and share of resources between the users. Dynamic Spectrum Access (DSA) is one of the proposed solutions that consists a new spectrum sharing algorithm where unlicensed Secondary Users (SU) access the spectrum holes or White Space (WS) opportunistically from the licensed Primary Users (PU) [2].

Cognitive Radio (CR) is an intelligent wireless communication system capable of obtaining information from its surrounding environment and, by adjusting its radio operating parameters, increasing the communication channel reliability and accessing dynamically the unused resources, leading to a more efficient utilization of the radio spectrum [3]. The networks of cognitive radio do the following four functions intelligently [4*].

- It continuously observes the unused spectrum called as ‘white space’ or ‘spectrum hole’. This property of cognitive radio is termed as *spectrum sensing.*
- When white spaces are found, cognitive network selects best available white space. This property of cognitive radio is termed as *spectrum management*.
- Cognitive radio network intelligently allocates these white spaces or channels to the secondary users. This property of cognitive radio is termed as *spectrum sharing*.
- When primary user is detected in the network, Cognitive radio network vacates the channel for the licensed or primary users. This property of cognitive radio is termed as *spectrum mobility*.

2. WRAN - IEEE802.22

Wireless Regional Area Network (WRAN) is the first worldwide standard on CR whose physical layer is based on Orthogonal Frequency Division Multiple Access (OFDMA) for multiple access and Quadrature Phase Shift Keying (QPSK), 16-QAM and 64-QAM modulation schemes,

- 64 QAM – for distance (D)<15 Km
- 16 QAM – for 15≤(D)≤22 Km
- QPSK – for D≥ 22 Km

i.e. adaptive with respect to communication distance and spectrum sensing in WRAN requires number of inputs to be given to the sensing equipment out of which the most important are channel number is an 8 bit long number in the range 0 to 255. Since, the coverage range of WRAN is significantly large with respect to 802.16 (WiMax) is the core difference between these two IEEE projects. But the 802.22 MAC has followed the design of 802.16 WiMax network including CR capabilities such as frequency management and self-coexistence management.

In CR network, performance of the system is measured in terms of

- Delay analysis. i.e., average waiting time of packets
- Average number of packets arrived in the system
- Idle time of the server
- Busy time of the server
- System utilization

For these proposed, prior knowledge of queuing theory is essential. Hence, M/G/1 queue is a single server system with Poisson arrivals and general arbitrary service-time distribution. The MG1 queue is a single server system with Poisson arrivals and general (orbitary) service time distribution denoted by $F(X)$ and service time probability density function denoted by $f(x)$. In MG1 queue, consideration for analysis is that every call arrives according to Poisson arrival process whose distribution function is $A(t) = 1 - e^{-\lambda t}, t \geq 0$, with rate λ and they are treated in order of arrival. Service time is independent and identically distributed (i.i.d) function $F(.)$ and density $f(.)$.

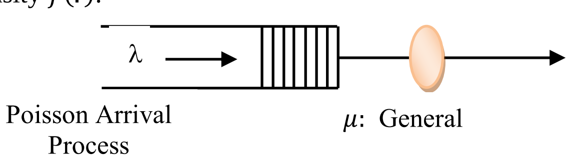

Figure 1: Queuing Theory

The Pollaczek-Khintchine (PK) mean value formula provides the statement of the average number of data packets in a service period is equal to ρ. In the Bounded Pareto-distribution, probability density function (PDF) of the file size is gien by,

$$f_X(x) = \frac{\alpha k^\alpha x^{-\alpha-1}}{1-(\frac{k}{p})^\alpha}, k \leq x \leq p \qquad (1)$$

where α, the shape parameter, k, the minimum file size and p, the maximum file size.

First moment (Mean of this distribution):

$$E_X(x) = \int_{-\infty}^{\infty} x.f_X(x)dx = \int_k^p x.f_X(x)dx$$

$$= \frac{\alpha k^\alpha}{1-\left(\frac{k}{p}\right)^\alpha} \int_{-\infty}^{\infty} x.x^{-\alpha-1}dx$$

$$= \frac{\alpha k^\alpha}{1-\left(\frac{k}{p}\right)^\alpha} \left[\frac{1}{-\alpha+1} x^{-\alpha+1}\right]_k^p$$

$$E_X(x) = \frac{\alpha k^\alpha}{1-\left(\frac{k}{p}\right)^\alpha} \frac{\alpha}{\alpha-1} (k^{-\alpha+1} - p^{-\alpha+1}) \qquad (2)$$

Second moment of this distribution:

$$E_X(x^2) = \int_{-\infty}^{\infty} x^2.f_X(x)dx$$

$$= \int_k^p x^2.f_X(x)dx$$

$$= \frac{\alpha k^\alpha}{1-\left(\frac{k}{p}\right)^\alpha} \int_{-\infty}^{\infty} x^2.x^{-\alpha-1}dx$$

$$= \frac{\alpha k^\alpha}{1-\left(\frac{k}{p}\right)^\alpha} \left[\frac{1}{-\alpha+2} x^{-\alpha+2}\right]_k^p$$

$$= \frac{\alpha k^\alpha}{1-\left(\frac{k}{p}\right)^\alpha} . \frac{\alpha}{\alpha-2} . (k^{-\alpha+2} - p^{-\alpha+2}) \qquad (3)$$

Variance of the file-size distribution:

$$\sigma_X^2 = \int_{-\infty}^{\infty} \left(x - E_X(x)\right)^2 f_X(x)dx$$

$$\sigma_X^2 = E_X(x^2) - (E_X(x))^2 \qquad (4)$$

In an MG1 system where the arrival rate is λ and X is a random variable representing the service time, then the average waiting time in the system $E[W_q]$

$$E[W_q] = \frac{\lambda.E[X^2]}{2(1-\rho)} \qquad (5)$$

where $E[X^2]$ is the second moment of the service time distribution and ρ is the system load,

$$\rho = \lambda.E[X^2] \qquad (6)$$

Using the file-size distribution specified in equation (1) and link capacity, C, we can have $E[X]$ and $E[X^2]$ has follows,

$$E[X] = \frac{E_X(x)}{C} \qquad (7)$$

$$E[X^2] = \frac{E_X(x^2)}{C^2} \quad (8)$$

The average time delay through the system, $E[T]$, is the sum of $E[W_q]$ and $E[X]$. i.e

$$E[T] = E[W_q] + E[X] \quad (9)$$

3. LITERATURE REVIEW

In cognitive radio networks, spectrum sensing is one of the most important components in cognitive radio networks. It enables a secondary user equipped with cognitive radio to be able to locally indentify the presence of the primary user signal and thus access spectrum properly. There are many spectrum sensing methods proposed in the literature such as energy detection, matched filter and cyclo-stationary detection.

Cooperative sensing refers to a method of gathering spectrum sensing information from such secondary user before making a final decision on the presence of the primary user based on the collected information. Cooperative sensing is seen as a solution for a local spectrum sensing problem that a node may incorrectly detect the presence of primary signal due to fading, nose or shadowing.

Several cooperative sensing techniques are proposed in the literature for centralized [4]-[7] and [8] [9] for the decentralized networks. In centralized network, all the data sensed by the secondary users are fed to base station for the final decision. Where as in decentralized, local sensing data is needed to exchange among cognitive devices in the networks.

Since, this thesis is focused on the layer above the physical layer i.e. medium access control (MAC) protocol for cooperative communication, resource allocation and performance evaluations, some short of MAC protocols for cognitive radio networks are taken into account.

In [10] Carrier Sense Multiple Access (CSMA) based medium access control protocol for multihop wireless networks that uses multiple channels and selection of clearest channel for the data transmission is proposed which is similar with [9]. The clearest channel is defined as the channel that has the least interference sensed at the receiver.

This proposed protocol uses one control channel and N data channels for the dynamic channel selection. For the performance evaluation of cognitive radio networks, [11] [12] has been studied. In these papers, analyses of secondary users coexist with primary users with opportunistically accessing the unutilized spectrums have been simulated. Primary users own a band of channels, i.e. N channels. When a secondary user detect the presence of an arriving primary packet on its current channel, it vacates that channel and moves its transmission to another available channel, if any found in networks. If all channels are busy, the secondary packet remaining in a queue are served on First- Come, First-Served (FCFS) basis.

In [13] both primary and secondary users are modeled as M/G/1 queue with general service time as well as exponential average time with mean time. This paper also analyzes the performance considering with multiple primary users as well as multiple antenna for reduction of interference. The paper describes that only secondary user can co-operate the primary user’s data. So, lack of cooperation from the primary user’s side is seen.

In [14] the primary user is modeled as M/G/1 queue with general service time distribution and the secondary user queue is assumed to be saturated. The paper also provides the performance results of multiple secondary users by simulation with collision probability and overlaps between primary and secondary users in order to protect primary user and determines throughput of secondary users.

Similar model is proposed in [15], where both primary and secondary data is queued as M/G/1 queuing theory. Though, the performances on decreased mean waiting time as the secondary user is sharing primary's job is discussed, data rate of 10 Gbps is not seen practical.

4. PROPOSED MODEL

The proposed model is concentrate on the maximum sharing of resources, which means secondary user supports primary users by transmitting primary user's data as an incentive. Figure 2 would try to answer the raised question by the community that what is the incentive for primary users for sharing spectrum by secondary users.

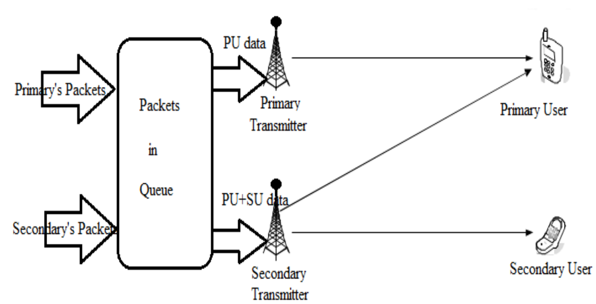

Figure 2: Physical architecture of proposed model

In CRNs, there exist two main challenges:

i. How to sense the spectrum and model behavior of the primary license to identify available frequency channels.

ii. Management of available spectrum resources among secondary users to satisfy their Quality of service requirements while limiting the interference to primary user.

Since, primary user has higher priority than the secondary user, we utilize priority queuing to model co-operate cognitive radio system. If primary user arrive, secondary user has to leave to transmits own packet rather it needs to co-operate to transmit primary users data.

Figure 3: Priority based packet transmission

Figure 3 shows the packet transmission structure for co-operative cognitive radio and need to broken into three segments for detail discussion.

- Packets arrival: data is arrived to the queue as Poisson process.
- Queuing: Service or queuing of data on the system.
- Packet departures: Departure or the transmission of data is based on priority basis. Secondary data is transmitted if and only if there is no primary data on the service queue.

Let the data packets P1, P2, are the primary packets and S1, S2, are secondary packets arrival to the queuing in random process. Since, priority queuing system is used for the packets to the departure, P3 is departed before S3 although S3 packet is arrived first. Hence, waiting time of a packet consists of three parts:

- Time until beginning of the next slot.
- Time spent in a queue waiting time for the service to begin
- Average Service (transmission) time.

5. NUMERICAL RESULT

Numerical results are analyzed in three sections as discussed below.

5.1. Spectrum Surveying

The received power of the signal was measured at the 'Repair and Maintenance Lab' of Western Region Campus,, Pokhara-16, Nepal in terms of 'dBμV′ using spectrum analyser at noon time. For the proper reception of signal, three different antennas like dipole, wired and Wi-Fi antennas were used. Since, noise presense at the lab was measured about 32 dBμV, received power in terms of ' dBm′ can be dtermined using equation [16],

$$E\left(\frac{dB\mu V}{meter}\right) = E(dB\mu V) - Gr(dBi) + 20\log f(MHz) - 29.8 \qquad (10)$$

where, Gr is the isotropic gain of receiving antenna and substituting, average 615 MHz of frequency for WRAN, in eq. (10), it is reduced to,

$$P(dBm) = E(dB\mu V) - 106.98 \qquad (11)$$

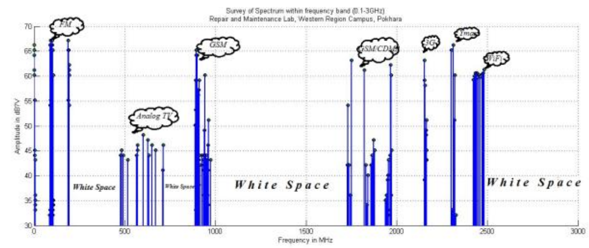

Figure 4: Survery of spectrum utilization within frequency range 0.1-3 GHz

Figure 4 illustrates the utilization of frequency within the given range is can be classified in three categories,

- Black Utilization: If the given bandwidth is densely utilized, it is called as black utilization of spectrum. Normally, 900 MHz of GSM spectrum and 2.4 GHz range of Wi-Fi can be considered in this category. So, total black utilization is from the survey is obtained about 5.78%
- Brown Utilization: The spectrum used by terrestrial TV, Analog TV and GSM band of 1800 MHz with CDMA and 3G are rarely found in air and called as brown utilization of spectrum. So, total brown utilization is about 11.03%
- White Utilization: The spectrum allocated for specific purpose but not properly utilize is known as white utilization of spectrum hole.

From the survey data, most noisy reception of spectrum is from the FM radio stations located about 8 Km to 40 Km of radio distance and 3G/WiMAX service of Nepal Telecom. These spectrums are found with very low signal power and almost with the equal level of noise presence at the survey lab. Interesting thing is that the FM radio having tranmitting station about 40 Km radio distance lacated at Tanahu District (Damauli) is possible to receive with alomost equal strength, having FM stations located very near (about 8 Km) from the surverying location.

Similarly, excellent reception of spectrums are found from the NTV signal that is transmitting from Sarangkot which is just 1 Km of air distance with line of sight. Some of FM radio stations which were located about 2 Km to 4 Km of radio distance and even some of the spectrum from WiMAX service of Nepal Telecom is also significantly remarkable. GSM channel of Ncell also found within the top ten categories of good signal reception.

5.2. Utilization of Spectrum

For the demonstration of utilization of spectrum at vacant bands,

- Five channels of primary users, $x(t) = \cos(2\pi f_{cn} t)$ where n=1,2…5 with five carrier frequencies are frequency modulated over the respective frequency band before transmission.
- Additive white gaussian noise can be added because of noise contamination in the channel during the transmission.
- The energy is measured to find the presense or absence of primary signal.
- If primary user/s is/are absent, spectrum hole is fullfilled dynamically.

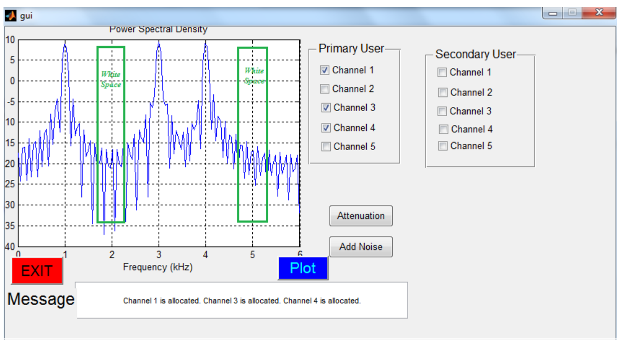

Figure 5: GUI illustration of primary signal transmission.

The Figure 5 clearifies the three primary signal channel 1, channel 3 and channel 4 are transmitting while channel 2 and channel 5 are free and considered as white space. In such a case, dynamic spectrum allocation (DSA) system plays the vital role to use this white space by transmitting secondary's signal opportunistically through these spectrum holes.

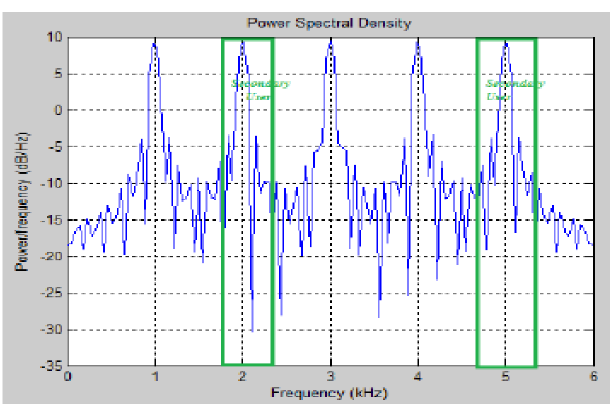

Figure 6: Opportunistic transmission of two channels.

Figure 6 illustrates the dynamic spectrum allocation system that allocates automatically 2 channels of secondary (Channel 1 and Channel 2) to the white space available at channel 2 and channel 5 of primary user.

This methodology try to solve the problem of in-efficient spectrum utilization found in repair and maintenance lab by maximizing the utilization using DSA. PSD parameter is varied so that the portion of spectrum which is not used by primary user is allocated to secondary users. This dynamic allocation of the secondary user to the carrier frequency of 2 KHz and 5 KHz is determined by the PSD data analysis which is programed in Matlab after analysing its peaks dynamic selection of vacant channel is done by the calculation of power spectral density (PSD) data of periodogram as shown in Figure 7 below.

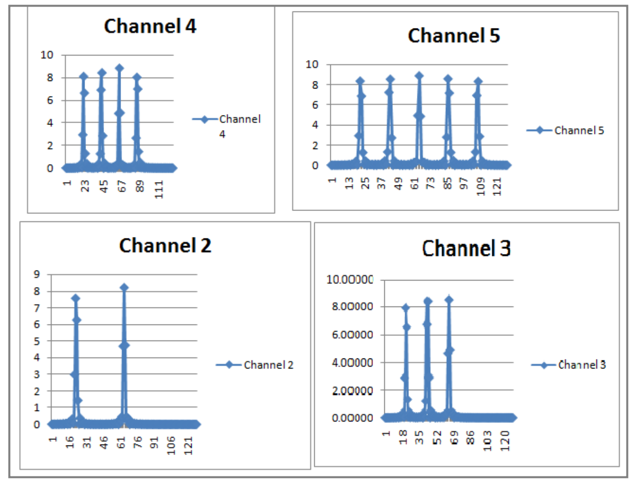

Figure 7: Detection of thresold level for the presence of primary user

If the primary channels are not transmitting the signal from proper channel, their PSD value is less than that of threshold value. The different threshold value for individual channel is according to their PSD is illutrates from the graphs above in Figure 7.

5.3. Peroformance Measurement

To measure the performance, mean of MG1 queue with PDF given by Bounded Pareto distribution is derived as in equation (2), (3), (5) and (6). Mean waiting time of data can be analysed by varying upper bound of file size. And this paper analyse the performance within the WRAN parameter mentioned below.

Table 1: WRAN parameter

s. n.	parameter	specifications
1.	frequency range	54-862 mhz (with 700 mhz band)
2.	bandwidth	6, 7 and /or 8 mhz
3.	spectral efficiency	0.25 to 5 b/s/hz
4.	data rate	1.5 – 40 mbps
5.	transmit eirp	4 watts
6.	service coverage	33 km
7.	digital modulation	qpsk, m-qam
8.	fft size	2048

Suppose, the mean of spectral efficiency is about 3 b/s/Hz, then for 8 MHz Bandwidth, data rate would be 24 mbps. Similarly, sharing of queued data is assumed as keeping lower bound data constant as about 4 MB and making the variation in upper bound data. For this, lets set upper bound data as 1 GB before sharing and 50 MB after the sharing data by 50%. Since, Upper bound data which is transmitting by the server in the rate of 24 mbps, then from the equations (5) and (9), tabulated data is as below.

Table 2: Tabulated data of waiting time and total delay for 1 GB data without co-operation at 24 mbps of data rate.

Performance without Co-operation of 1 GB data at 24 mbps data rate					
Traffic Load	Waiting Delay (Sec)	Total Delay (Sec)	Traffic Load	Waiting Delay (Sec)	Total Delay (Sec)
0	0	0.78211456	0.5	3.17669071	3.95880527
0.02	0.06483042	0.84694498	0.52	3.44141494	4.22352949
0.04	0.13236211	0.91447667	0.54	3.72915866	4.51127321
0.06	0.20276749	0.98488205	0.56	4.0430609	4.82517546
0.08	0.27623397	1.05834853	0.58	4.3868586	5.16897315
0.1	0.35296563	1.13508019	0.6	4.76503606	5.54715062
0.12	0.4331851	1.21529965	0.62	5.18302168	5.96513624
0.14	0.5171357	1.29925025	0.64	5.64745015	6.42956471
0.16	0.60508394	1.3871985	0.66	6.16651726	6.94863182
0.18	0.69732235	1.47943691	0.68	6.75046776	7.53258231
0.2	0.79417268	1.57628723	0.7	7.41227832	8.19439288
0.22	0.89598969	1.67810424	0.72	8.16863325	8.95074781
0.24	1.00316549	1.78528004	0.74	9.04135048	9.82346504
0.26	1.11613457	1.89824913	0.76	10.0595206	10.84163514
0.28	1.23537972	2.01749428	0.78	11.2628125	12.04492707
0.3	1.36143888	2.14355343	0.8	12.7067628	13.48887739
0.32	1.49491328	2.27702783	0.82	14.471591	15.25370557
0.34	1.63647703	2.41859159	0.84	16.6776262	17.45974078
0.36	1.78688852	2.56900308	0.86	19.5139572	20.29607177
0.38	1.94700398	2.72911854	0.88	23.2957319	24.07784643
0.4	2.11779381	2.89990836	0.9	28.5902164	29.37233094
0.42	2.30036224	3.08247679	0.92	36.5319432	37.31405771
0.44	2.49597127	3.27808583	0.94	49.7681545	50.550269
0.46	2.70606986	3.48818442	0.96	76.240577	77.02269158
0.48	2.93232989	3.71444444	0.98	155.657845	156.4399593

The Tab. 2 above is the tabulated data of mean waiting time and total delay time to transmit 1 GB of data by the server whose rate of service (transmission data rate) is considered as 24 mbps on the basis of increased traffic load from 0 to 0.98. Since, lower bound data indicates the average data that arrives on the server, upper bound data is the maximum data found in server. As, the service time for the data transmission is 24 mbps, 1 GB data which is in queue can be transmitted within 0.7821 sec if there is no traffic load.

This traffic load from equation (6) is the product of arrival rate of data packet and the second moment of the PDF of file size. During low normalized traffic load let's assume at 0.8, mean waiting time found to be increased very slow rate to 13.48 sec. from 0 with the increment of traffic load, but then after, significant increment is seen to peak value of 155.65 sec. in mean waiting time as well as total delay time to 156.439 sec. as traffic load tends to 0.98 from 0.8.

If we talk about the tabulated data of mean waiting time and total delay time (Table 3) to transmit 50 MB of data (50% fo data is sharing) by the server whose rate of service (transmission data rate) is considered as same WRAN parameter of 24 mbps, 50 MB data which is in queue can be transmitted within 0.038239 sec which is almost 50% less time if there is traffic load of 0.02 and with the increment of traffic load, mean waiting delay as well as total delay time is increased according to MG1 queuing theory.

Table 3: Tabulated data of waiting time and total delay for 50 MB data (50% Co-operation) at 24 mbps data rate

Performance with Co-operation of 50 MB data (50%) at same data rate					
Traffic Load	Waiting Delay (Sec)	Total Delay (Sec)	Traffic Load	Waiting Delay (Sec)	Total Delay (Sec)
0	0	0.70819009	0.5	1.873714	2.58190425
0.02	0.038239	0.74642915	0.52	2.029857	2.73804709
0.04	0.078071	0.78626151	0.54	2.199577	2.90776758
0.06	0.119599	0.82778886	0.56	2.384727	3.0929172
0.08	0.162932	0.87112175	0.58	2.58751	3.29570012
0.1	0.20819	0.91638055	0.6	2.810571	3.51876133
0.12	0.255506	0.96369656	0.62	3.057113	3.76530267
0.14	0.305023	1.01321332	0.64	3.331047	4.03923748
0.16	0.356898	1.06508802	0.66	3.63721	4.34539993
0.18	0.411303	1.11949319	0.68	3.981643	4.68983268
0.2	0.468429	1.17661863	0.7	4.372	5.0801898
0.22	0.528483	1.23667357	0.72	4.818122	5.52631222
0.24	0.591699	1.29988929	0.74	5.332879	6.04106885
0.26	0.658332	1.36652209	0.76	5.933428	6.64161826
0.28	0.728667	1.4368567	0.78	6.643168	7.35135848
0.3	0.80302	1.51121044	0.8	7.494857	8.20304673
0.32	0.881748	1.58993793	0.82	8.535809	9.24399904
0.34	0.965247	1.67343678	0.84	9.836999	10.5451894
0.36	1.053964	1.7621543	0.86	11.50996	12.2181485
0.38	1.148405	1.85659554	0.88	13.74057	14.4487606
0.4	1.249143	1.95733286	0.9	16.86343	17.5716175
0.42	1.356828	2.06501758	0.92	21.54771	22.2559029
0.44	1.472204	2.18039407	0.94	29.35486	30.0630453
0.46	1.596127	2.30431696	0.96	44.96914	45.67733
0.48	1.729582	2.43777239	0.98	91.81199	92.520184

The hypothesis to take decision of performance measurement is made as follows;

Accept: H_1, if $t_p < \delta$: Hypothesis is TRUE

Accept: H_0, otherwise : Hypothesis is FALSE

Where, δ is the threshold value of the delay time. If the value of t_p: which is estimated time to transmit primary data with co-operation is less than that of threshold value, hypothesis H_1 is accepted. Otherwise, H_0: as null hypothesis, which states that assumed hypothesis become false i.e not accepted.

Since, the meaning of decreasing upper bound in the queue is the co-operation by secondary user, and if waiting time is decreased by decreasing the upper bound of data to be transmission, hypothesis H_1would be validate.

From the tabulated data of Tabs. 2 and 3, let us take the value of waiting time for traffic load 0.5. Withou co-operation, waiting delay is found to be 3.9588 sec. where as during co-operation, it is found to be 2.5819 sec. i.e with sharing of data as co-operation by secondary, reduced delay is about 1.37 sec. Hence the hypothesis H_1 is true and accepted.

Plotting these values to get the graphs using Matlab R2013a tool, significant meaning of optimization can be abstracted.

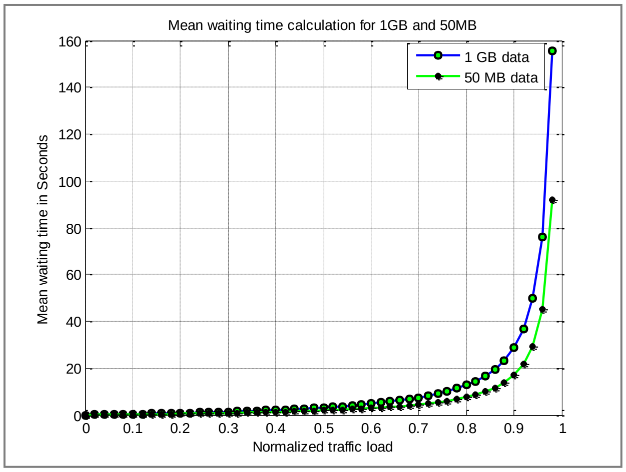

Figure 8: Graphical representation of mean waiting time for 1 GB and 50 MB of data

The graphical Figure 8 provides the comparative delay analysis for 1 GB data with respect to 50 MB of data. The significant meaning of analysing waiting time for 50 MB data transmission when the trafic load increase, reflects the waiting time for 50% cooperation of primary users' data by the secondary user . Figure 9 also illustrates the similar nature of both curves for the waiting time but this waiting time rise sharply in case of 1 GB data if the traffic load crosses normalized value of 0.8 and 0.88 in case of 50 MB data.

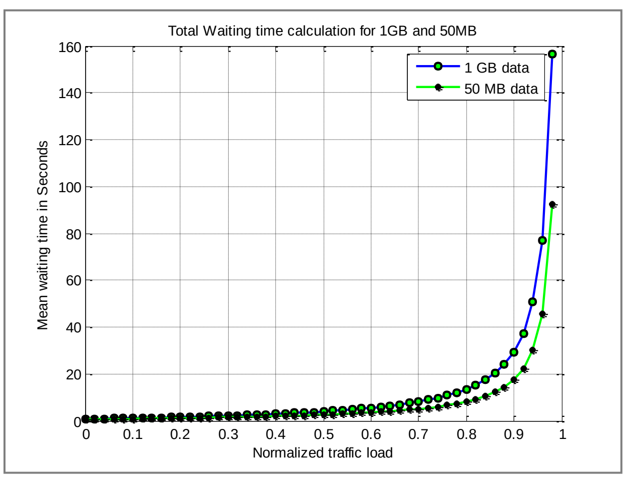

Figure 9: Graphical representation of total waiting time for 1 GB and 50 MB of data

Similarly, the graphical Figure 9 provides the comparative delay analysis for 1 GB data with respect to 50 MB of data in terms of total delay. Since, total delay is the sum of waiting delay and service time of its own packet, comparative analysis of total delay must have similar characteristics and is almost true from the above Figs 8 and 9.

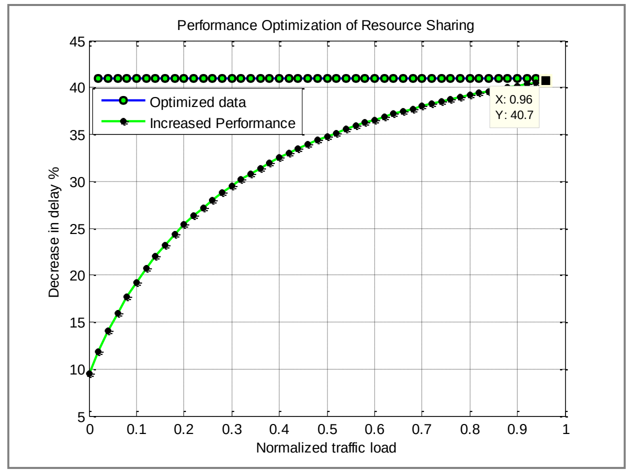

Figure 10: Illustration of increment in performance due to co-operation of data.

It is not difficult to say as a layman that when secondary user share the load of primary user, performance would be increased. And Figure 10 also support the hypothesis that when 50% of data is shared by the secondary user, performance of the system has increased from 9.45% to 40.85% as normalized traffic load increased from 0 to 0.98. When arrival rate starts increasing, performance also increased significantly till the traffic load reached to 0.5 and soon after this the increased performance is settled to 40.85% for traffic load 0.98. Since, 41% is the optimized value of performance increased due to sharing of 50% of data which is obtained at every point using MG1 queuing theory, is supported by the Figure 10 when traffic load reached to 0.98.

6. CONCLUSION

The aim of this paper is to measure the performance of CRN when secondary user is considered as co-operative to primary user. So, whole work is broken into three sections. To verify the necessity cognitive radio, research work begun with the survey of spectrum detection. This survey clearifies that only 16.83% of allocated spectrums are fully used as there is the scarcity of new spectrum for allocation. Due to this under utilization of spectrum, cognitive radio with dynamic spectrum allocation got the priority and made possible here to demonstrate using Matlab simulation with user friendly GUI design envirionment.

In the literature, cognitive users are treated as opportunistic user as they use vacant bands of primary user. This thesis work tries to verify that the cognitive users are not only opportunistic users but also co-operative users. In such a case, while primary user is transmitting its own data, secondary user is also take part to transmit primary's data as a co-operation. From the comparative study of simulated data from 1 GB primary user's data without co-operation and with co-operation, performance of primary user is increased about 9.45 % to 40.85% as traffic load increased from 0 to 0.98. i.e performance is increased if the traffic load is increased to achieve the optimized performance of 41% at 0.98.

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Analysis of Twin Tunnel Wall Thickness by Elasto-Plastic Approach

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***Abstract*: This paper deals with the modeling and its analytical solutions for the prediction of displacements between twin tunnel wall by using method of Mohr–Coulomb, non-associated flow condition. Two dimensional analyses are carried out to provide new findings on the Twin Tunnels wall thickness optimization. The analysis is based on laboratory testing data for material model preparation. It finds the wall thickness of tunnel openings which is prepared at varying spaces between twin tunnels in the computer software Phase-II, 7.0. The overburden depth, extraction ratio and factor of safety are considered for model analysis. It focuses on Elasto-Plastic rock masses with non-linear failure criteria and non-associated flow laws by the rock mass residual and peak value analysis.**

Keywords: Modified D-Shape twin tunnel, Mohr-Coulomb failure criteria, elastic-Plastic analysis, Brittle rock

1. INTRODUCTION

The displacements of twin tunnels wall all over the opening in the rock mass at great depth is an important problem in underground excavation for geotechnical and mining engineering. A large number of analytical solutions for this opening problem have been presented by considering different material models behavior, such as the elastic-perfectly plastic, elastic–brittle–plastic and elastic-strain softening models, with the different yield criteria, like the linear Mohr–Coulomb (M–C) and non- linear Hoek–Brown (H–B) criteria.

Brown et al., gives the displacement of wall in an elasto–plastic model and which presented closed to solutions for the displacements of a circular opening in the H–B media. This solution included a simplifying assumption for elastic strains in the formulation for displacement in the plastic region. The strength of the rocks does not increase linearly with the level of stresses; non-linear criteria have to be used if the behavior during the failure of a rock mass is to be modeled.

There are different criteria, the proposal originally put forward by Hoek and Brown [1] has been selected with its subsequent developments. This criterion allows making a simple assessment of the failure in a rock medium by introducing the main geological and geotechnical features that characterize it. The computing programmers are used by Mohr–Coulomb linear failure criterion, for the analysis of the rock mass in residual and peak parameters.

This paper presents 2D numerical analysis conducted in Phase 7.0, II version, to investigate the influence of twin tunnel spacing. The wall analysis is carried out for three different tunnel distances namely 1D, 1.2D, 1.4D, 1.6D, 1.8D, 2.0D and 2.4D where D is the tunnel's diameter.

2. PROBLEM DESCRIPTION

2.1. Objectives

The use of underground spaces for transportation purpose is required in development of large cities. The geotechnical and underground conditions must be required for the construction of new tunnels close to existing ones. In other cases, the solution of twin tunnels presents major advantages, such as reduction of both tunnels diameter and rock movement resulting from the tunnel construction.

The interaction of twin tunnels by numerical modeling and in situ observations are used. Also results and interaction could largely affect the rock deformation that the design of twin tunnels requires numerical analysis associated to monitoring during the design phase. The construction stage is considered at one for modeling but actual this is difficult for excavation.

2.2. General Hypothesis

The problem of rock behavior in strains of the rock mass around an excavation is treated as a plane strain problem of a model cross section under the influence of a continuous reduction in the radial stress (internal pressure) exercised on the excavation walls from the initial value (hydro- static stress field) up to zero. The fundamental objective of this paper is to create a mechanical convergence forecast model that includes non-linear plasticity criteria and non-associated flow laws. The problems integrating the differential equations that define the convergence curve.

2.3. Failure Criteria

The rock mass failure criterion depends on the type of rock and the quality of the rock mass. Transformed failure criteria are used for this work that allow obtaining more compact systems of equations (easier to handle) and eliminating material parameter dependencies. The stresses are in a standardized form, i.e. divided by the so-called resistant module. Thus the results are more compact. Subsequently, the failure criteria that are most used today is the Mohr–Coulomb failure criterion and the Hoek–Brown failure criterion.

3. Stress and Displacement Around Circular Excavation

When an underground excavation is made in a rock mass, the stresses which previously existed in the rock are distributed, and new stresses are induced in the rock at the immediate vicinity of the opening. It can be represent by means of principle stress trajectories, which are imaginary lines in a stressed elastic body along which principle stresses act.

3.1. Stress in Elastic zone

Before opening the tunnel, the stresses in the rock mass, expressed as Lambe variables and standardized, are in equilibrium and are the same as the mountain load ($p_o = \gamma z/\beta$):

Where, po is hydro-static stress field.

$P* = p_o$; $q* = 0$ in the infinite

$$P* = po;\ q* = q^*_{RP}\left(\frac{R}{r}\right)^2 \text{ in the interface} \tag{3.1}$$

$$q*RP = q*(p_o) \tag{3.2}$$

Where R is the radius of the elasto-plastic interface, r the radius of any point located on the elastic zone and q^*_{RP} the peak semi deviatoric in the elasto-plastic interface that must verify the failure criterion the general expression of which is as follows.

The main stresses for a point located at a distance r are

$$\sigma_r = p* - q* = po - q^*_{RP}\left(\frac{R}{r}\right)^2 \tag{3.3}$$

$$\sigma_\theta = p* - q* = po - q^*_{RP}\left(\frac{R}{r}\right)^2 \tag{3.4}$$

Where radial (σ_r)and transverse stresses (σ_θ)

3.2. Stress in Plastic zone

The equations that govern the stress-strain behavior (in plane strain and axial symmetry) are as follows. Internal equilibrium equation of stresses expressed in Lambe variables:

$$2\frac{dr}{r} = Br\,(q*)\,dq* \tag{3.5}$$

Where the function Br(q*), characteristic of each material, plays a very important role in the mechanical behavior of plastic strip in particular, in the convergence calculation as follows:

$$Br\,(q*) = \left(\frac{dp*}{dq*} - 1\right)\frac{1}{q*} = \left(\frac{1}{\sin\rho} - 1\right)\frac{1}{q*} \tag{3.6}$$

Failure criterion expressed in-terms of Lambe variable

$$q* = q*(p*) \tag{3.7}$$

The solution of differential Eqs. (3.9) and (3.11) is obtained by integrating between r = R (point BR of the interface where the semi-deviatoric is known as q^*_{Rr}) and the generic point M of the plastic strip located between BR and A at a distance r of the excavation centre:

$$\ln\left(\frac{r}{R}\right)^2 = \int_{q_R}^{q^*} Br(q*)dq \tag{3.8}$$

It is from this expression that the standardized stresses can be obtained at any point of the plastic strip as well as the plastification radius depending on the semi-deviatorics stresses q^*_a and q^*_{Rr} , existing in the tunnel contour and in the interface, respectively.

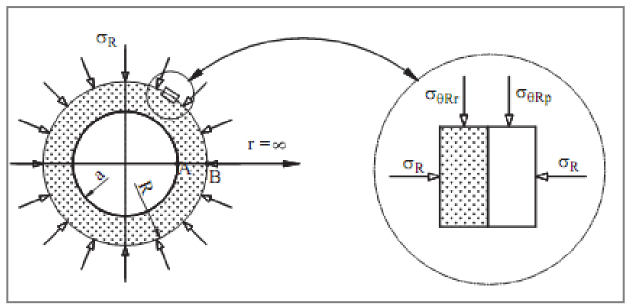

Figure 3.1: Details of stresses in elasto-plastic interface (Source: International Journal of Rock Mechanics & Mining Sciences 48 (2011) 878–887)

3.3. Displacement Analysis

Stress is directly propositional to strain in elastic limit and after it reaches plastic region or break the surface the stress is released. In circular excavation, the break part released the stress and creates the plastic region around the boundary. The displacement of excavation boundary is maximum and continuously reducing beyond the boundary. The displacement is varying from plastic zone to elastic zone. The expressions indicated below are shown in general terms:

3.3.1 Displacement in Elastic zone

The variations in stress (before and after opening the tunnel) produce strains that are determined with the Hook equations:

$$V = \frac{\Delta p^*}{G^*} = 0 \tag{3.9}$$

$$\gamma = \frac{\Delta q^*}{G^*} = \frac{q^*_{RP}}{G^*}\left(\frac{R}{r}\right)^2 \tag{3.10}$$

In the elasto-plastic interface (r = R) the intrinsic strains are:

$$v_R = 0 \tag{3.11}$$

$$v_R = \frac{q^*_{RP}}{G^*} \tag{3.12}$$

and the main strains are as follows:

$$\epsilon_{\gamma R} = \frac{V_R - \gamma_R}{2} = \frac{q^*_{RP}}{2G^*} \tag{3.13}$$

$$\epsilon_{\theta R} = \frac{V_R + \gamma_R}{2} = \frac{q^*_{RP}}{2G^*} \tag{3.14}$$

The circumferential strain defines the radial convergence, uR, in the interface:

$$\epsilon_{\theta R} = \frac{u_R}{R} = \frac{q^*_{RP}}{2G^*} \tag{3.15}$$

When $\sigma_a > \sigma_R$ there is no plastified zone and the entire mass behaves elastically where the strains are as follows:

$$v = 0$$

$$\gamma = (po - \sigma^*_a)\left(\frac{a}{r}\right)^2 \frac{1}{G^*} \tag{3.16}$$

2.3.2. Displacement in Plastic zone

In order to calculate the plastic strains, the path of the stresses suffered by the rock mass elements must be known and therefore there must be a constructive process. The circumferential strain ε_θ results from the differential Eq. (3.16) when considering the function γ obtained previously:

$$\varepsilon_\theta - \varepsilon_{\theta R} = -\int_{q^*_{Rr}}^{q^*} \frac{B_r(q^*)}{2} \gamma dq^* \tag{3.17}$$

Where $\varepsilon_{\theta R} = \gamma^*_{RP} / G^* = q^*_{RP} / 2G^*$

The "Relative Failure Convergence" Ω is defined by the expression:

$$\Omega = \frac{\varepsilon_\theta}{\varepsilon_{\theta R}} - 1 \tag{3.18}$$

And the real tunnel convergence is

$$u = r(1 + \Omega)\, \varepsilon_{\theta R} \tag{3.19}$$

The convergence function Ω depends on the flow law considered and on the failure criterion selected. The formulation presented above has been universally developed and, as such, it is valid both for any failure criterion and any flow law. The following are presented as appendices to this paper: the expression to be used when applying the Mohr-Coulomb failure criterion.

4. ANALYSIS APPROACH

4.1. Data Collection and Estimation

In this research paper the rock mass properties is taken as a depth of 1000 m in a good quality rock mass composed of conglomerate, sandstone and mudstone, corresponds to the CG2 domain at the Kannagawa site.

The peak and residual parameters estimated from the GSI system given by Cal et al. (2007) are shown in Table 4.1. Note that due to the good quality of rock mass there were large difference between the peak and residual strength parameters (around 80% in cohesion and over 15% in friction).

Table 4.1: Hard rock mass geomechanical parameters

Parameter	Unit	Value
GSIpeak		64.9
GSIres		27.8
σci	MPa	162
mi	MPa	19
ϒ	kN/m3	26
E	GPa	24
ν		0.25
Cpeak	MPa	3.7
φpeak	o	57.8
Cres	MPa	0.96
φres	o	51

4.2. Materials Model Properties

Two different properties, modulus of elasticity and poisson's ratio as elastic nature is assigned for the model preparation.

After classifying the materials characteristics as Linear, Elastic and Isotrophic in the Phase II material model properties is adopted for analysis. The Cohesion and angle of friction are applying in terms of peak and residual values for the elasto-plastic analysis. The rock mass behavior models are based on rock types: for a good quality rock masses with GSI value (50<GSI<70). The other parameters are obtained with the aid of the RocLab program (Rocscience, 2002), which produced a completed set of geomechanical data for rock mass.

4.3. Preparation of Geometric Model

The Geometric model is prepared by using software Phase-II 7.0 version. It can prepare the size of model, discretization, boundary condition and FEM analysis. The two dimensional model of twin tunnel wall thickness interaction is analyzed and to interact different parameters.

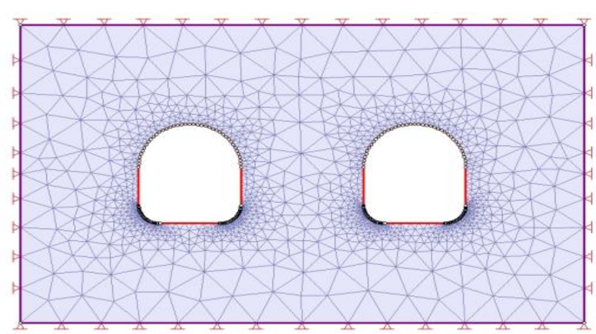

Figure 4.1: Boundary Condition of model

4.4. Analysis of Model

The rock mass failure criterion depends on the type of rock and the quality of the rock mass. Transformed failure criteria are used for this work that allow obtaining more compact systems of equations (easier to handle) and eliminating material parameter dependencies. The stresses are in a standardized form, thus the results are more compact. Subsequently, the failure criteria that are most used today is the Mohr–Coulomb failure criterion.

The Mohr–Coulomb linear failure criterion is expressed as follows:

$$\sigma = \frac{1+\sin\emptyset}{1-\sin\emptyset}\,\sigma_3 + \frac{2c\cos\emptyset}{1-\sin\emptyset} \qquad (4.1)$$

In terms of the Lambe variables, standardized by the resistant module, this can be written as $q* = (p* + 1)\sin\emptyset$; $q* = q/\beta$; $p* = p/\beta$. Where the resistant module is $\beta = c\cot\emptyset$, and $q* = (\sigma_1^* + \sigma_3^*)/2$.

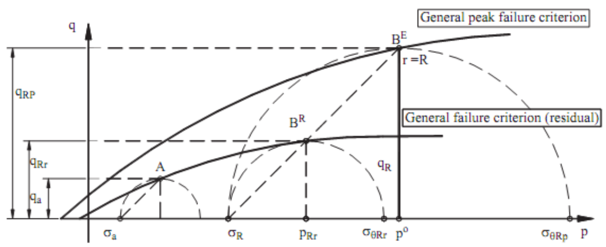

Figure 4.2: Stress path as represented in Mohr Diagrams

The criteria indicated are specified for the peak and residual conditions. For convenience in an elasto-plastic rock mass residual parameters are specified.

5. Analysis, Result and Conclusion

The research work has performed on two-dimensional model of modified D-shape twin tunnels, in Phase-II, software. The material properties are assigned for the analysis of stress and total deformation as shown in figure 5.1 and 5.2. The analysis data are taken at site specific and the composite sample contained as conglomerate, sandstone and mudstone and properties shown in table 4.1. The size of tunnel section is taken from 5TH edition of Green Book (ASTHO 2004), in single and double lane transportation tunnel. The model is analyzed in elasto-plastic approach in Mohr failure criterion. After analysis, the different result is concluded as:

- The rock mass property is important for Twin tunnels wall thickness optimization due to causes of stability and support structure cost.
- The rock mass model is prepared and applying different Stress ratio (K) (1.0, and 1.5) values where simultaneously changing overburden, width between twin tunnels and lane (single and double).
- The wall stresses and displacement contour are obtained after analysis of twin tunnels.
- The overburden depth of tunnel is varied also the stress and displacement pattern is obtained and simultaneously changing with width of tunnel and Stress ratio (K).
- Stress/displacement pattern contour are obtained in between twin tunnels wall that's differ to the other symmetric part of the tunnel.
- In both single and double lane, the stresses and displacement contour pattern at the wall are nearly similar during the variation of Stress ratio (K), over burden depth and twin tunnels wall thickness.
- Stress is found at a large variation and spot stress also appears at the wall surface randomly.

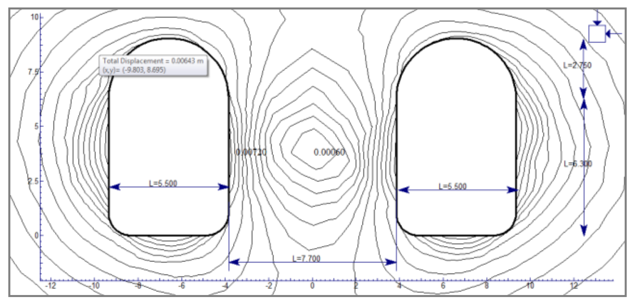

Figure 5.1: Displacement between tunnel walls (1000m depth K=1.0, width=1.4*Width of one tunnel)

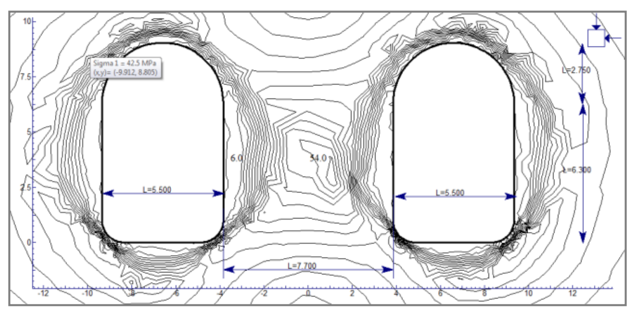

Figure 5.2: Stress on wall (1000m depth K=1.0, width=1.4*width of each

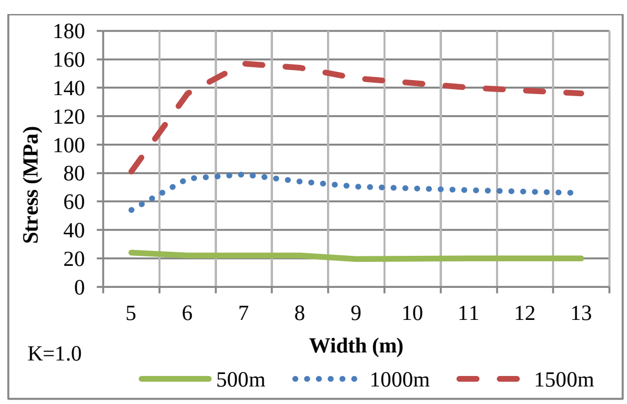

Figure 5.3: Stress – Width curve (Single Lane Width=5.6m)

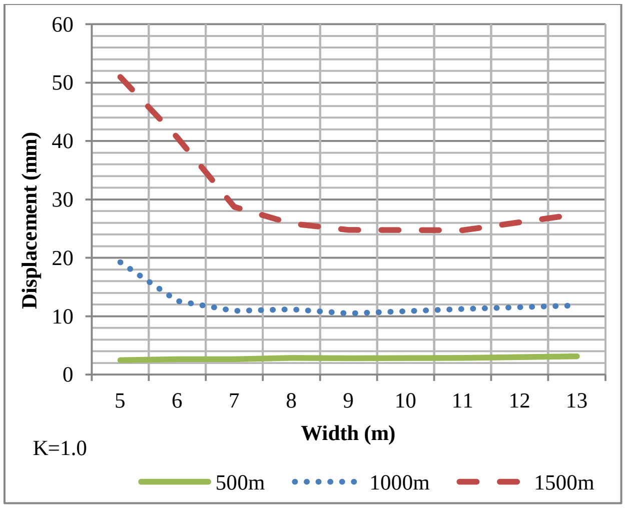

Figure 5.4: Displacement-Width curve (Single Lane Width=5.6m)

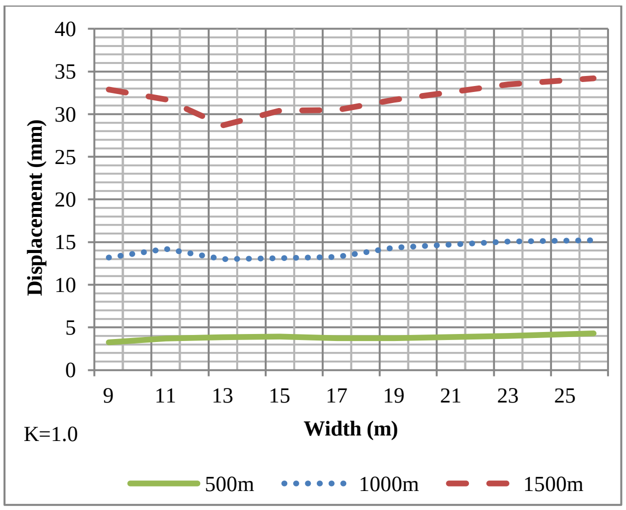

Figure 5.5: Displacement-Width curve (Single Lane Width=5.6m)

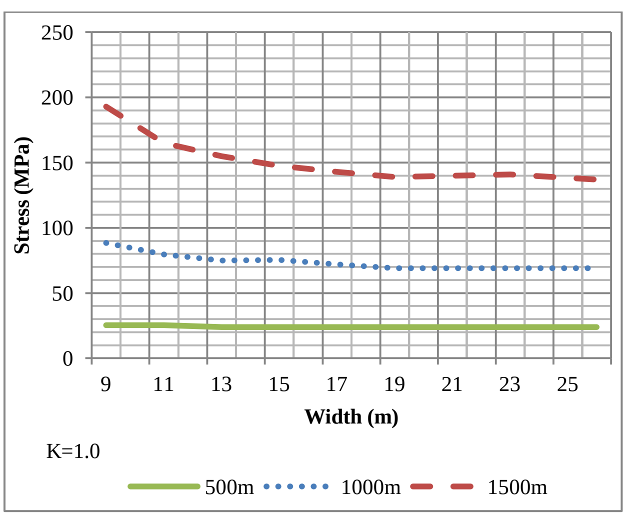

Figure 5.6: Stress – Width curve (Single Lane Width=5.6m)

The general conclusion is concluded from the above preceding analysis and results in rock mass.

- The rock mass property is important for Twin tunnels wall thickness optimization due to causes of stability and support structure cost. Good quality rock is favorable as compare to poor and average quality rock mass.
- The stress and displacement curves are plotted in graphically in Figure 5.3, 5.4, 5.5 and 5.6. The conclusion of this graph shows 1.2, 1.4 and 1.6 time's width of tunnel for 500m, 1000 and 1500m overburden depth corresponding varying value of K 0.5, 1.0 and 1.5.
- The model analysis approach is Elasto-plastic method which is economical as compare to elastic method of analysis.
- The large number of model (sample) gives reliable result. Only one data is used for analysis which may slightly variation in stress contours around the boundary of opening.
- The stress and displacement pattern in opening is same but not in magnitude of the stress and displacements.
- In single lane tunnel, the stress and displacement shows inverse relation at the width 1.0 to 1.4 times width of tunnel and afterward both have similar variation in magnitude.
- The total deformation is increased with increasing value of K (Horizontal/Vertical stress).

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Operation Optimization and Performance Evaluation of Devighat Hydropower Plant

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***Abstract*: Hydropower plant optimization is to maximize electrical energy production depending on the natural water inflows of a river. Two different types of optimization were carried out in Devighat Hydro Power Plant (DHPP). Among different possible optimization methods, Type I and Type II optimization were carried out in DHPP. Type I optimization deals with enhancing the efficiencies of individual units of the plant with help of overhauling or rehabilitation process resulting in enhancement of generation. Type II optimization deals with modeling an optimal hydro unit commitment and loading for maximizing generation. The results from Type I and Type II optimization justify the efficient generation in terms of effort, time and money invested.**

Keywords: Optimization, Generation, Efficiency, Units

1. Introduction

Electrical energy being the cleanest form of energy, there is an increasing demand for it. Rapid urbanization, population growth and technological development enhance to further increase the demand. Almost 90% of demand of electricity in Nepal is met by electricity produced by Hydropower Plants. But, total installed capacity of Hydropower Plants in Nepal of 750 MW is very low and inadequate to meet the demand of electricity which is 950MW. So there is shortage of electricity. For the fiscal year 2011/12, the total Annual Energy Demand was estimated to be 5194.78 GWh and annual Peak Power Demand was estimated to be 1026.65 MW with NEA able to supply only 4178.63 GWh. The annual increase in total Annual Energy Demand was 7.48% and the annual increase in Peak Power Demand was 8.5% as compared to previous year (NEA, 2012). From this scenario of power supply and demand situation of Nepal it is clear that there is generation shortage**.** Except Kulekhani Ist and IInd Hydro Power Plant, all Hydropower Plants of Nepal are Run of River (ROR) type, so due to low river discharge in dry seasons, this capacity shortage is further exacerbated resulting in high load shedding hours.

The best option to meet growing demand is to improve capacity of NEA either by installation of new Hydropower Plant or by improving efficiency of existing plants. Hydroelectric generation is a function of discharge, net head and efficiency factor of generating units. Efficiency factor is in turn a function of the flow and available net head.

The problem of the optimum management of hydropower plants includes the determination, for each unit in the hydropower plant, whether it is in operation under the given operating conditions, i.e. in which operating regime it operates.

The optimization of hydropower systems can be conveniently performed by the means of overhauling or rehabilitation process and simulation of their operation. The simulations are based upon the simulation mathematical models, whose technical task is to describe as accurate as possible the properties of physical objects.

2. Data for Performance Analyses

This study is based on both qualitative and quantitative information. The data is based on both primary and secondary data field. Primary data were taken from Devighat Hydro Power Plant. Secondary data were collected from other various sources.

2.1. Primary Data Collection

The primary data needed for performance analysis include unit characteristics data, facility operational data, and facility hydrological data.

The primary data was measured by using various equipments located in the Power Plant. Devices such as flow meter, level sensor, energy meters etc. were used to measure different outputs. Data were collected from various displays located at different panels of control room. Data stored on memory of control room computers were also collected. The hourly analogue data maintained by Shift In-charge on daily log sheets were taken and upgraded to digital data.

Plant was shut down from Magh 2067 to Ashad of 2068. So analysis of generation during this duration could not be performed. DHPP being cascade plant of THPP, discharge was regulated by THPP. So in month of Ashad 2069, even during wet season generation from DHPP was similar to dry season generation due to unit shutdown in THPP. This resulted in slight deviation from general pattern during analysis.

2.2. Collection of Secondary Data

Secondary data was collected from different offices of Nepal Electricity Authority (NEA) such as Load Dispatch Centre (LDC) and Office of Generation, Operation and Maintenance. Various related publications, reports, literatures, studies, etc. have been collected from different related offices. Beside these, related information was also collected from related web sites.

2.3. Performance Analysis of Hydro Power Plant

All the quantitative data obtained have been encoded in Microsoft Excel program and driving variable were analysed. For the performance optimization of hydro power plant, it is necessary to analyse existing performance of hydro power plant such as power output of Hydro Power Plant with variable discharge, head, and efficiency.

Different performance indices, such as overall plant efficiency, individual unit efficiencies, availability of units, availability of plant, plant capacity, capacity factor, MTTR, MTBF, etc., have been calculated before and after Type I optimization.

2.4. Devighat Hydropower Plant

Devighat Hydropower Plant with an installed capacity of 14.1 MW (3 x4.7 MW) is located at 70 km Northwest of Kathmandu on the right bank of Trishuli river. It is a tailrace development of Trishuli Hydropower Plant. It was commissioned in the year 1984. The average (Designed) annual generation of this power plant is 114 GWh.

The hydropower plant consists of three units of 5 MW each. Its power generating capacity has been rehabilitation from initial 14.1 MW (3 x4.7 MW) to 15 MW (3 x 5 MW). The three units have been upgraded with state-of-the-art system.

Figure 1: Satellite view of Devighat Hydropower Plant

3. Optimization and Model Development

3.1. Type I optimization

Type I optimization was carried out in DHPP from Magh of 2067 to Ashadh of 2068. So, for comparison, only six-month data were available for fiscal year 2067/68 (i.e. before rehabilitation). During the rehabilitation, all electro-mechanical components were replaced with state-of-art technology. Different power plant performance indices before and after rehabilitation were analysed (Type I Optimization).

Plant capacity is a measure of energy the plant is capable of generating. It is dependent on power generation of the plant and the corresponding running hours. The total plant capacity of Devighat Hydro Power Plant, as follows:

PC = Installed Power (MW) × Running Hours (H)

Before T1 Optimization,

PC = 14.1MW × 24hrs × 365 (days)

PC = 123,516 MWh

After T1 Optimization,

PC = 15MW × 24hrs × 365 (days)

PC = 131,400 MWh

Plant capacity of DHPP has been increased from 123,516MWh to 131,400MWh due to T1 optimization. This was possible due to efficiency enhancement of power plant after T1 optimization.

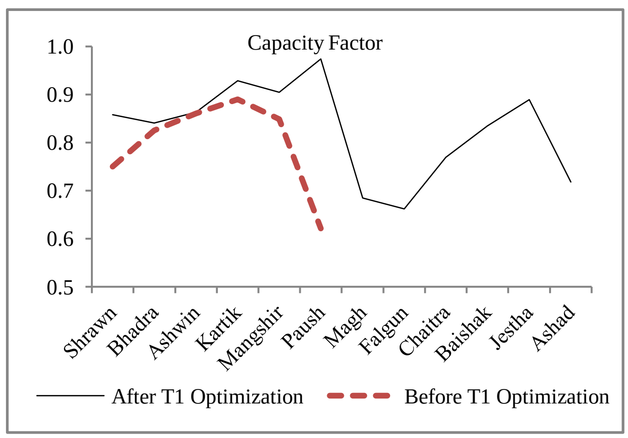

Figure 2: Comparison of Capacity Factor before and after T1 Optimization

This shows that after T1 optimization, the average capacity factor for DHPP is 82.73%, with a minimum of 66.19% for the month of Falgun and a maximum of 97.38% in the month of Poush. Before T1 optimization, the average capacity factor for DHPP was 79.94%, with a minimum of 62.15% for the month of Poush and a maximum of 88.97% in the month of Kartik. These capacity factors are within and above utility best practice of between 50% and 80%. Capacity factor of the plant after T1 optimization is enhanced for every months considered during analysis. This indicates that after the optimization, failure rate and downtime of the plant/units have significantly reduced with increase in generation.

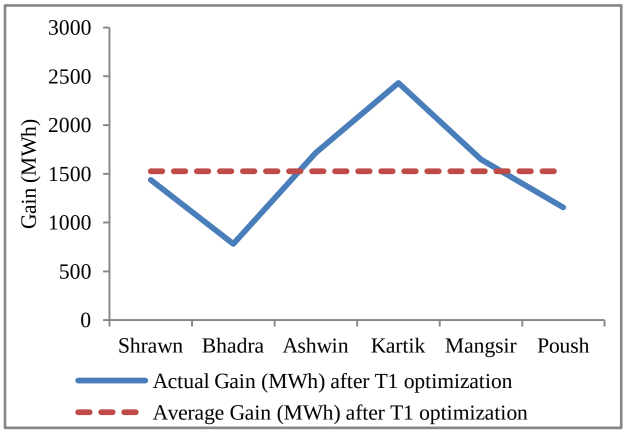

Figure 3: Actual and Average gain after T1 Optimization

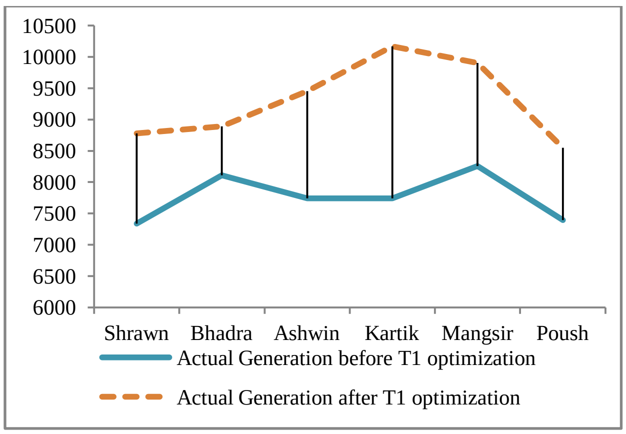

Figure 4: Actual generation before and after T1 Optimization

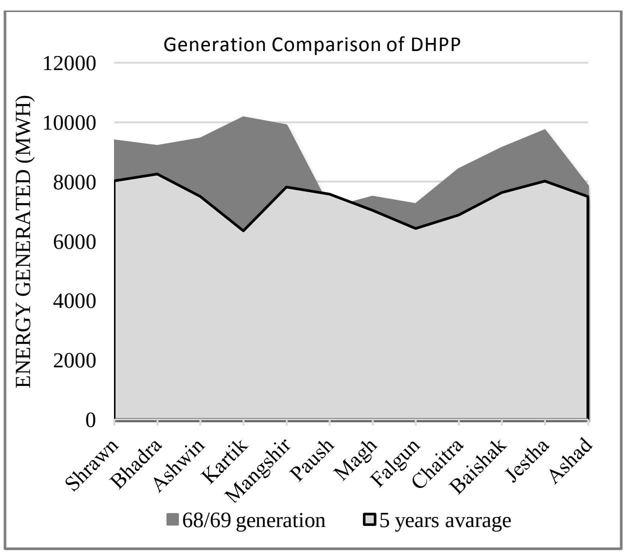

Figure 5: Comparison of 68/69 generation
5 years average of DHPP

From Figure 3 and Figure 4, it is clearly seen that gain is always positive and generation after T1 optimization is higher than that before T1 optimization for all months under consideration. This validates the effort taken for rehabilitation. Figure 5 and Figure 6 also justify generation enhancement due to T1 optimization.

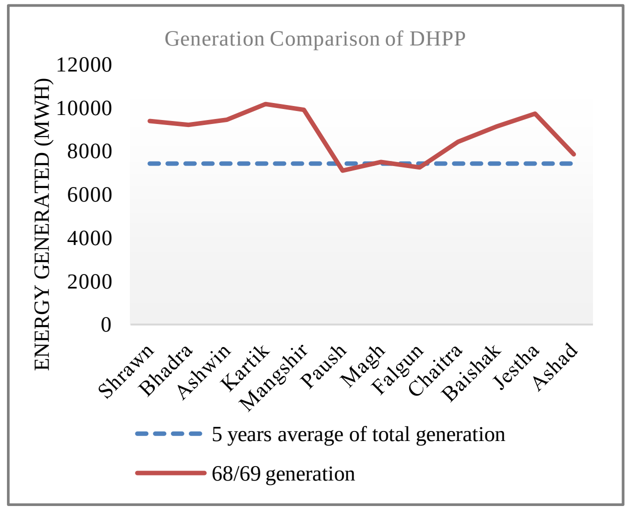

Figure 6: Comparison of 68/69 generation with 5 years average of Total Generation of DHPP.

Table 1: Monthly performance indices before and after T1 Optimization

	Plant Use Factor (PUF)		Load Factor (LF)	
	067/68	068/69	067/68	068/69
Shrawn	77.74%	84.05%	77.37%	93.07%
Bhadra	81.96%	86.56%	85.50%	91.22%
Ashwin	80.82%	90.55%	81.58%	93.68%
Kartik	80.82%	95.16%	81.58%	100.76%
Mangsir	96.54%	95.63%	87.03%	98.12%
Poush	83.62%	98.92%	77.92%	70.44%
Magh	-	81.69%	-	74.30%
Falgun	-	74.36%	-	71.82%
Chaitra	-	82.67%	-	83.48%
Baisakh	-	83.49%	-	90.56%
Jestha	-	86.30%	-	96.47%
Ashadh	-	73.61%	-	77.31%

Both PUF and LF have been enhanced due to Type I optimization, except for month of Mangsir where PUF is slightly reduced after rehabilitation. Maximum generation before optimization is in the month Mangsir with utilization factor of 80.22%. After optimization, maximum generation is in month Kartik with utilization factor of 92.88% which is significantly higher than that before optimization.

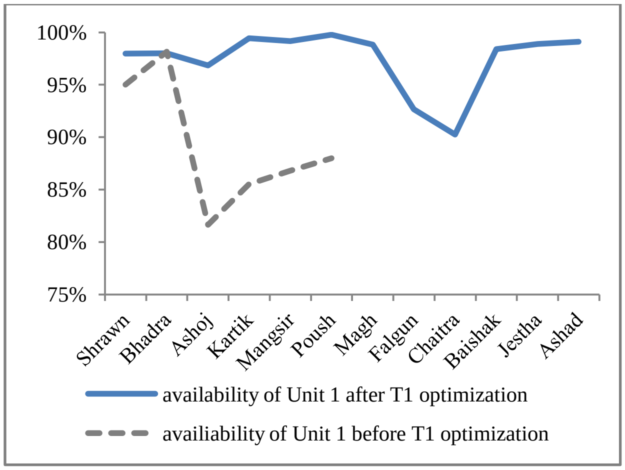

Figure 7: Availability of Unit 1 before and after Type1 Optimization

Figure 7 shows availability of the unit 1 before and after optimization. It is seen that the availability before the optimization was very low which have been significantly improved by the optimization.

3.2. Type II Optimization

Unit efficiencies were calculated for a constant high head (40m) at varying discharge for individual unit with the help of discharge measurement, head measurement and unit energy generation measurement. Mathematical model of efficiency versus discharge was developed for each unit. This mathematical model was used to optimize total power generation of the plant over total discharge regime using Solver function in MS Excel. The Solver function was used to optimize total power by distributing discharge and committing unit with maximum efficiency in the discharge range. The results of Solver function was also verified using a mathematical optimization program developed in C programming language.

3.3. Optimization System Design

The developed optimization system is applied to Devighat Hydropower Plants, which is composed of three generating units. The aim of this optimization process is to allocate the demand power for each unit from the total plant dispatched power, in order to obtain the maximum power plant efficiencies.

Power Plant Efficiency

The efficiency of each unit (η) is the electrical power output (P) to the hydraulic input power (P_h).

$$\eta = \frac{P_e}{P_h}$$

A second order polynomial is often used to represent the generated power efficiency behaviour, that is:

$$\eta = aP^2 + bP + c$$

Considering P_{ei} as the hydraulic power in the i-th turbine and η_G as the global efficiency, yields:

$$\eta_G = \frac{P_{e1} + P_{e2} \dots \dots P_{e(n-1)} + P_{en}}{P_{h1} + P_{h2} \dots .. P_{h(n-1)} + P_{hn}}$$

Using above equation we can obtain:

$$\eta_G = \frac{P_{e1} + P_{e2} \dots \dots P_{e(n-1)} + P_{en}}{\frac{P_{e1}}{\eta_1} + \frac{P_{e2}}{\eta_2} \dots .. \frac{P_{e(n-1)}}{\eta_{n-1}} + \frac{P_{en}}{\eta_n}}$$

where, η_i is the efficiency of the i-th unit.

From above two equations we can realize that η_G will result in different values depending on the allocation of the dispatched power among the n available units. For any dispatched power, there always will be one optimal power distribution among the available units to obtain the maximum global efficiency or, in other words, the global optimum.

The Offline Procedure

The aim of the optimization is to obtain a maximum global efficiency of the power plant through the optimal power allocation among the available units. In the off-line procedure, the solution of this problem is a mathematical use of non-linear mathematical programming developed in MS Excel with help of Solver. The knowledge of the efficiency curve of each unit has to be obtained from previous field tests. Therefore, the formulation of the optimization problem, including the objective function and the constraints is given by

$$\eta_G = \frac{P_{e1} + P_{e2} \dots \dots P_{e(n-1)} + P_{en}}{\frac{P_{e1}}{\eta_1} + \frac{P_{e2}}{\eta_2} \dots .. \frac{P_{e(n-1)}}{\eta_{n-1}} + \frac{P_{en}}{\eta_n}}$$

$$\text{s.t.} \sum_{j=1}^{n} P_j = P_d$$

$$P_{jmax} \geq P_j \geq P_{jmin}$$

where, η_j and P_j are the efficiency and the delivered power of the j-th unit, respectively; P_d is the total dispatched power; and P_{jmin} and P_{jmax} represent the operating region of the j-th unit defined by its lower and upper generating power, respectively. It is considered in this model that the net head does not vary.

The Online Procedure

The online procedure is not based on a specific model, but on real time measurement of some important system variables that will be used in system optimization. Considering that models are simplified representations of the real world, certainly the results of online procedures will be often better than those obtained with offline procedures, because they are based on real-time and real world measurements. The real-time represents the periodical interventions of an agent on the system, in accordance with the available data at that measurement moment, which are applied until the convergence to a considered optimal value.

In the hydro power plant optimization, the load allocation between the available units is changed in a periodic way in accordance with the measurements variation, that could be efficiency, flow or pressure measurements. The great advantage of the online procedure is that its results will be better than the offline procedures, due to operational conditions and simplifications applied to the mathematical model used in the optimization process.

Optimization Using Efficiency Measurement

The optimization of the power generation must follow an objective function and some variables should be provided to the controller responsible for the units loading allocation. The necessary information is the individual power (P_j) and efficiency (η_j), and the dispatched power (P_d). The variable P_d must be provided only once and the variables P_j and η_j, must be provided by specific sensor devices, in real time, at an adequate update rate. The variable P_j can be provided to the system using specific device meters or digital relay outputs, while variable η_j must be obtained using specific device meters.

Optimization Using Flow Measurement

For a given constant power output, the efficiency is inversely proportional to the input power, i.e., for a given dispatched power, the maximum efficiency will be reached when the summation of the hydraulic power at the turbines input is minimized. The hydraulic power (in kW) is given by:

$$P_h = g.H_N.\ Q$$

$$Q = P_h/(g.H_N)$$

Where, g is the gravitational constant (m/s²), Q is the input flow (m³/s), and H_N is the net head (m) obtained as the difference between the gross head and the friction losses in the hydraulic system.

As long as the hydraulic power is proportional to the input flow, and that the maximum efficiency is obtained when the flow is minimum, the optimization system can be rewritten as follows:

$$\min Q_T = \sum_{j}^{n} Q_j$$

$$\text{s.t.} \sum_{j=1}^{n} P_j = P_d$$

$$P_{jmax} \geq P_j \geq P_{jmax}$$

where, Q_j is the input flow in the j-th unit, and Q_T is the total flow given by the summation of the n individual flows.

The controller must search the power allocation between the units aiming at minimizing the total flow. Therefore, the user has access neither to the unit efficiency nor to the overall efficiency, but is sure that it is operating over the most economical point by minimizing the amount of the necessary water energy, for a given dispatched power.

The model developed during this research is based on offline optimization process using flow measurement. Offline optimization model was developed using Solver in MS Excel. The objective function to be maximized was developed with help of efficiency characteristic against percent discharge of each unit. Efficiency characteristic was developed using data from field test. From regression analysis of field test data, smoothened efficiency characteristics of Unit 1, Unit 2 and Unit 3 were obtained as follows:

$$\eta_1 = 0.9474\ Q_1^3 - 2.8708\ Q_1^2 + 2.9368\ Q_1 - 0.0906 \quad (1.1)$$

$$\eta_2 = 0.9357\ Q_2^3 - 2.8713\ Q_2^2 + 2.9598\ Q_2 - 0.0937 \quad (1.2)$$

$$\eta_3 = 0.8352\ Q_3^3 - 2.6771\ Q_3^2 + 2.8494\ Q_3 - 0.0820 \quad (1.3)$$

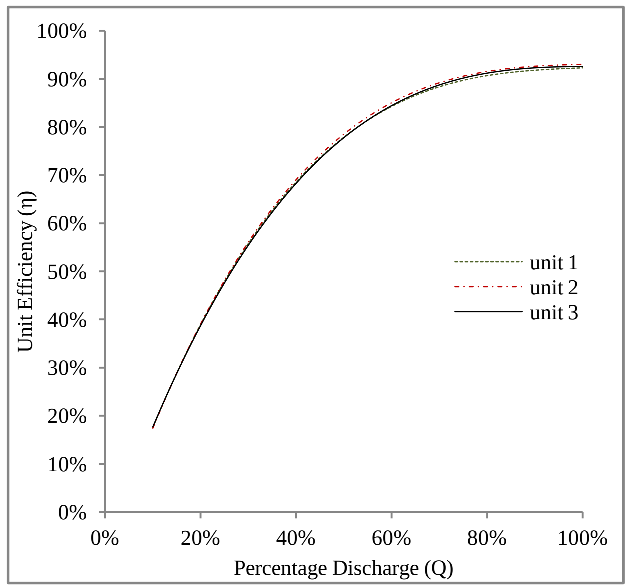

Figure 8: Efficiency Characteristics of Units

With aid of above mentioned three equations, equation for unit power and total power output of the plant were obtained to be

$$P_1 = 9.81 * 40 * Q_1 * \eta_1 \quad (1.4)$$

$$P_2 = 9.81 * 40 * Q_2 * \eta_2 \quad (1.5)$$

$$P_3 = 9.81 * 40 * Q_3 * \eta_3 \quad (1.6)$$

$$P_{total} = P_1 + P_2 + P_3 \quad (1.7)$$

Combining equations (1.1) to (1.7), we get,

$$P_{total} = 9.81 * 40 * (0.9474\ Q_1^4 - 2.8708\ Q_1^3 + 2.9368\ Q_1^2 - 0.0906\ Q_1 + 0.9357\ Q_2^4 - 2.8713\ Q_2^3 + 2.9598\ Q_2^2 - 0.0937\ Q_2 + 0.8352\ Q_3^4 - 2.6771\ Q_3^3 + 2.8494\ Q_3^2 - 0.0820\ Q_3) \quad (1.8)$$

Equation (1.8) represents total power produced for the plant at any instant which is a function of discharge only. It has been assumed that head is constant throughout the optimization process. This is the objective function for the optimization which is subjected to following constraints:

Non-negativity constraints:

$$Q_1, Q_2, Q_3, \eta_1, \eta_2, \eta_3, P_1, P_2, P_3, P_{total} \geq 0$$

Bounding constraints:

$$Q_1, Q_2, Q_3 \leq 14.34 \text{ m}^3/\text{s}$$

$$\eta_1, \eta_2, \eta_3 \leq 100\%$$

This mathematical model represents actual physical behaviour of power production in DHPP.

An offline model for Type II optimization of unit commitment and discharge distribution for optimal power generation has been developed. This model has been verified using generation and discharge measurement of fiscal year 2068/69 and calculations have been done to find out the results that would have been gained if Type II optimization had been implemented.

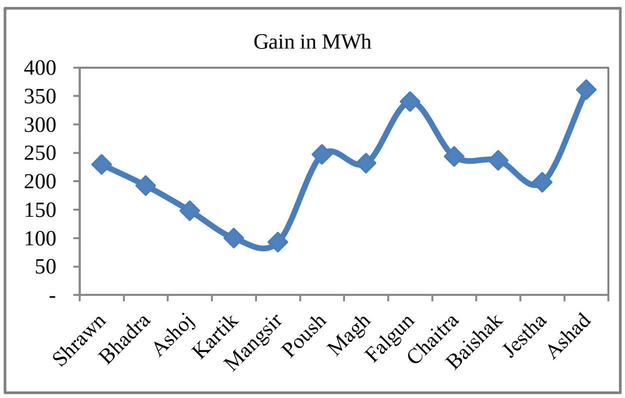

Figure 9: Monthly Gain (in MWh) for Type II Optimization

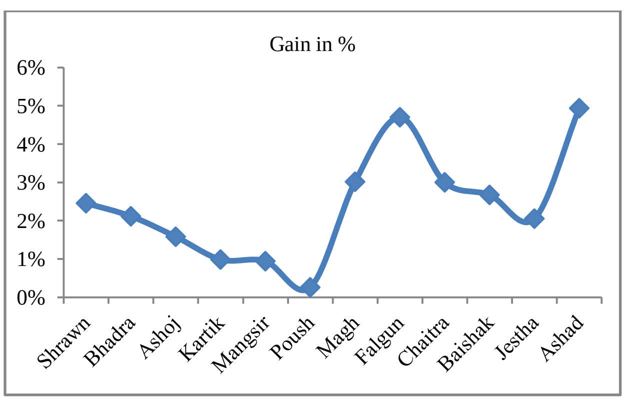

Figure 10: Monthly Gain (in percentage) for Type II Optimization

Figure 9 and figure 10 shows the optimized monthly gain trend along the year. Low discharge month had high gain indicating high optimization potential during low discharge period and high discharge month had low gain indicating low optimization potential but for the month of Ashad high gain for high river discharge period is due to the fact that two units of THPP were out of operation for 2068 Ashad, which resulted in low discharge for DHPP.

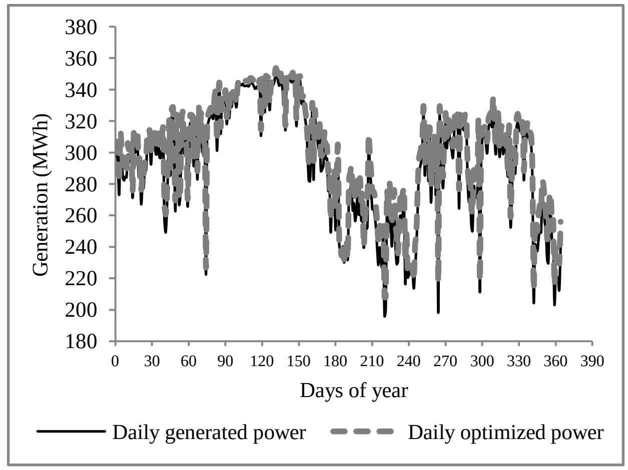

Figure 11: Comparison of daily generation before and after Type II Optimization

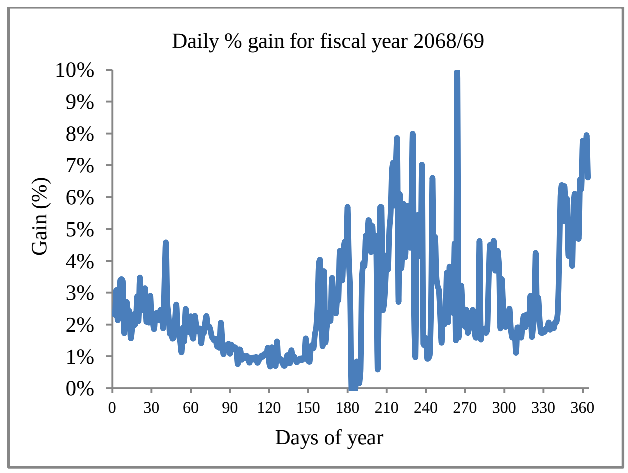

Figure 12: Daily gain (%) for a year under review

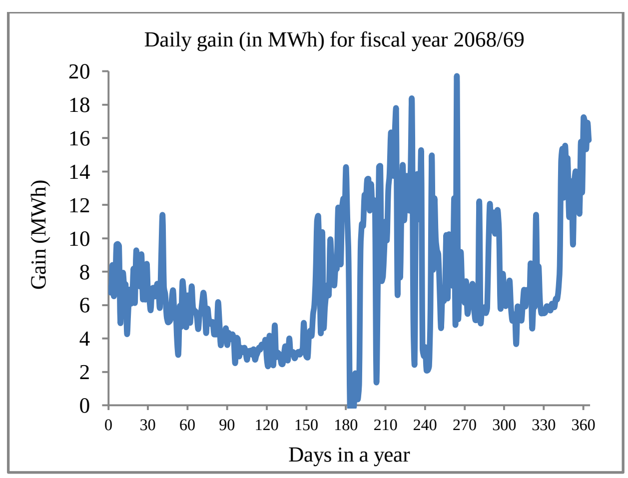

Figure 13: Daily gain (MWh) for a year under review

Figure 11, Figure 12 and Figure 13 indicate that there exists possibility of online Type II optimization in DHPP.

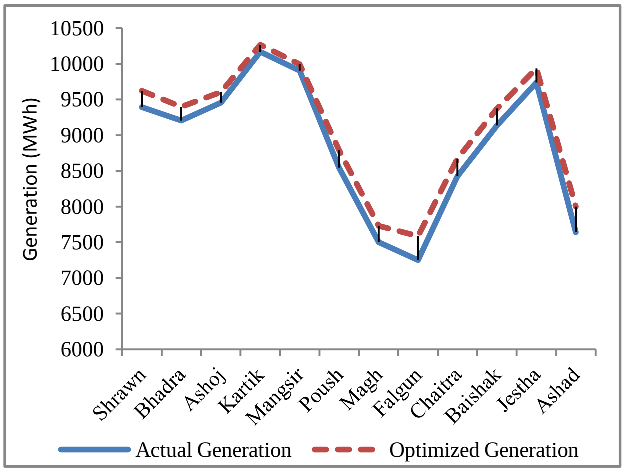

Figure 14: Monthly comparison between actual and optimized generation

Figure 14 proves that total generation from equal distribution of discharge between units is always less than the total generation by allocation of discharge to the units obtained from Type II optimization.

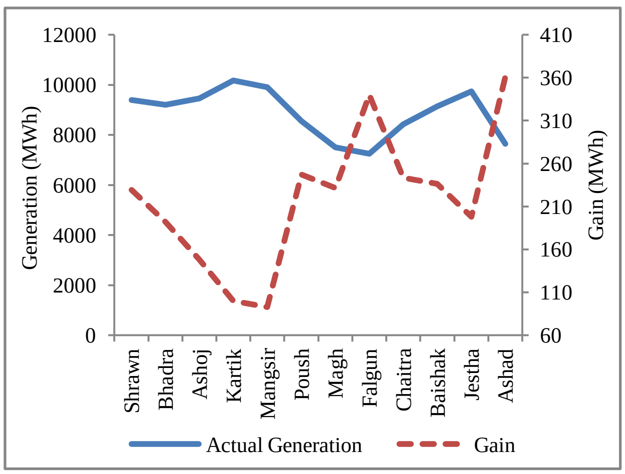

Figure 15: Monthly gain compared to actual generation

Figure 15 shows that during dry months or when discharge is low, gain is maximum. This is especially important as demand is high and overall generation is low during this period. So optimization is effective and relevant during dry months. In month of Ashad, even though flow in river is high, due to unit breakdown in THPP, DHPP received a reduced discharge which is responsible for low generation and high gain.

Comparison of daily actual and optimized power generation of Two representative months, one with most favourable condition for optimization (low discharge condition) month of Falgun and another with least favourable condition for optimization (high discharge with high head and clean water) month of Kartik are shown i Figure 16 to 19.

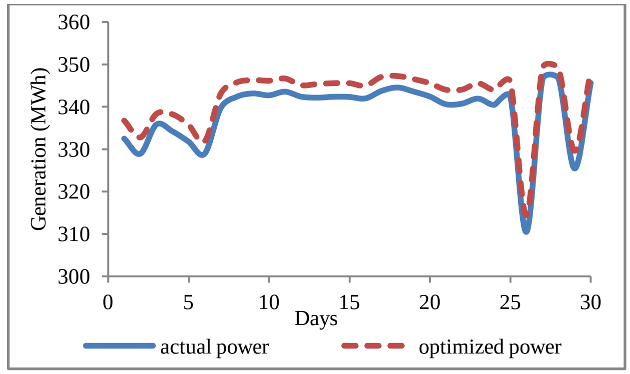

Figure 16: Comparison of daily actual and optimized power generation of Kartik

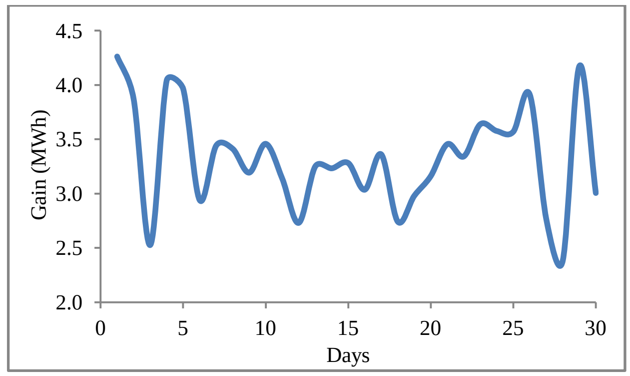

Figure 1: Daily gain of Kartik

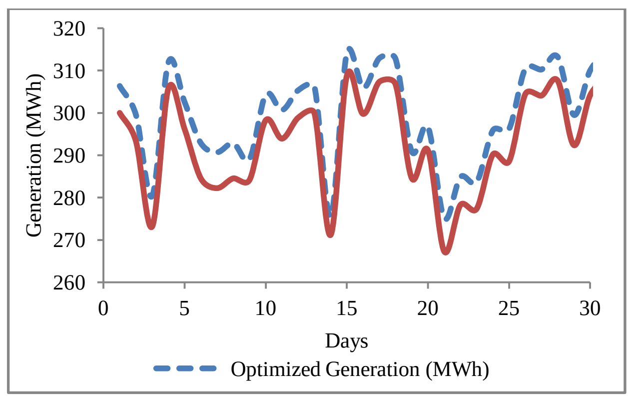

Figure 2: Comparison of daily actual and optimized power generation of Falgun

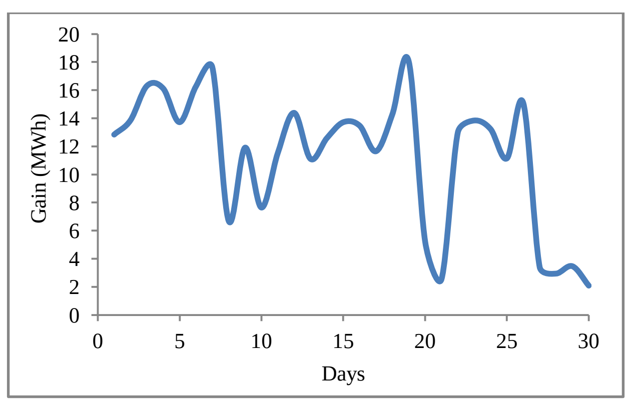

Figure 3: Daily gain of Falgun

Gain due to optimization during dry months compared to wet months is high which can be verified by comparing Figure 17 and Figure 19.

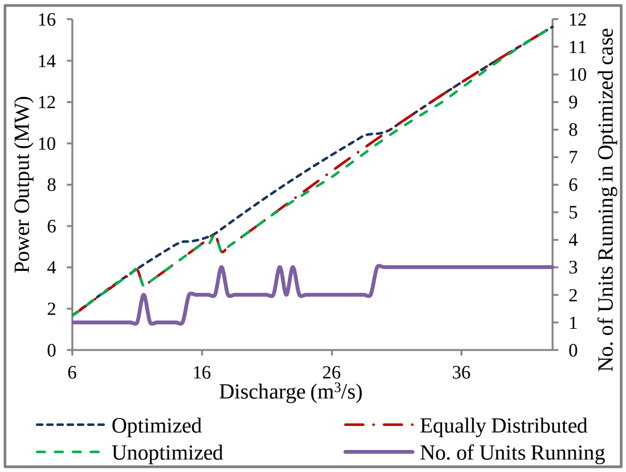

Figure 4: Comparison between different discharge distributions

Figure 20 compares power output from different modes of discharge distribution for different units in DHPP. For high value of discharge, variation in power output from all three modes of discharge distribution is quite low. But for medium and low discharge, power output from optimized distribution is significantly high. Moreover, equal distribution and un-optimized distribution (worst case distribution) result in similar power output. This indicates that for medium and low flow condition, conventional practice of equal distribution is not an effective way of power generation. After discharge of 29.5m^3/s, all three units are operating, so unit commitment is best applicable below this range of discharge.

4. Conclusion

The output from hydro power plant is function of net head, available discharge and unit's efficiency factor. For a pre-installed plant designed head and designed discharge can't be changed. Thus maximized output from pre-installed plant can be obtained by methods that enhance efficiency of units thus enhancing overall efficiency of hydro power plant.

Type I optimization helps to increase unit's efficiency by the process of overhauling or rehabilitation. Type II optimization enhances output by efficient unit commitment and loading.

Both Type I and Type II optimization help to enhance performance of units in a power plant resulting in better generation with better performance indices. By implementation of Type I optimization, output i.e. generation is increased due to enhancement of unit's efficiencies also Type I optimization helps to enhance performance indices of hydro power plant by increasing availability, reliability, capacity factor, load factor, plant utilization factor, MTBF and by decreasing forced outage rate, MTTR.

Implementation of Type II optimization output generation of hydro power plant helps to maximize output i.e. generation by optimal allocation of discharge between units.

Large amount of investment is required for Type I optimization with certain period of no power output. Hence, prior economic and financial analysis should be performed before committing for Type I optimization. Nevertheless, Type I optimization is capable of enhancing generation by reducing failures and improving performance characteristic of units.

Type II optimization is lucrative in a sense that it doesn't require plant shut down and requires only a small amount of investment and effort to create opportunity for enhanced generation from existing units. Type II optimization is best suited for dry season (low discharge periods) when there is an acute deficit in energy supply in the system. For DHPP, Type II optimization can result in 2.62% (2619.33MWh) enhancement in generation which is equivalent to addition of 0.4MW plant in the system without any additional investment and environmental cost.

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Identifying Key Features of Nepali Language for Automated News Classification

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***Abstract*: With an increasing trend of publishing news online on website, automatic text processing becomes more and more important. Automatic text classification has been a focus of many researchers in different languages for decades. The wide recognition of such text analytics is due to its application in search engine, text clustering and various recommendation systems. There is huge amount of research repository on features of English language and their various uses on automated text processing. This research identifies Nepali language key features for such applications. In particular, the study on impact of Nepali language based features, which are extremely different than English language, is a more challenging because of the higher level of complexity to be resolved. The research experiment using vector space model with very large number of dimensions for number of Nepali news dataset provides the promising results with identified key feature based processing specific to Nepali language for the task of automated Nepali news classification.**

Keywords: Document similarity, Nepali text classification, morphological analysis, Vector Space Model

1. INTRODUCTION

The availability of news in electronic form is ever increasing mainly because of the rapid growth of the World Wide Web. The task of automatic classification of such colossal news is emerging as the key challenge for organizing that huge information and also for any processing with an aim of knowledge discovery in this information. Proper classification of online news needs text level analysis using various natural language processing and machine learning techniques to get meaningful knowledge. Text classification is becoming interesting to many researchers, which consists of several challenges like appropriate document representation, dimensionality reduction to handle algorithmic issues and an appropriate classifier function to obtain good generalization. The language level specifics, which might be entirely different from one language to another language both at syntax and semantics adds other challenging issues on text classification problem.

Vector Space Model (VSM) represents each document as a feature vector of the terms in the document. Each feature vector contains term weights of the terms in the document. First step in classification system based on Vector Space Model (VSM) is the generation of words. Words are generated using analyzer. Different analyzers available for English text cannot be used for Nepali text due to the differences in the language. Preprocessing is done by analyzer before generating final set of words for VSM.

An analyzer tokenizes text by performing number of operations on it, which include extracting words, discarding punctuation, removing accents from characters (for certain languages), lowercasing, removing common-words which is also termed as stopwords, reducing words to a root form, etc. These operations are language dependent and exact implementations vary from language to language.

For an example, in English, words such as the, an, a, etc., are very common and are used as stopwords. In Nepali text, these stopwords do not exist and new stopwords are needed to be identified. It is also common to process verbs to reduce them to their roots for English text. In Nepali language, root verbs are combined in different ways to form new verbs. Similarly, different suffices are added to nouns and pronouns to form different words. There are various forms of word reduction based on suffices as per the nouns and pronouns used in a particular sentence and context. Such feature is not seen in English text. Lowercasing is common in English but is not applicable in Nepali text. Similarly, accent is used in Nepali text. Another feature common in Nepali language is different forms of words with same meaning. These words are not the synonym words, rather similar words but written in different forms with minor variations on characters being used in writing. Examples are अवरुद्ध - अबरुद्ध, उपलव्धि - उपलब्धि, कमिटि - कमिटी, इकाइ - इकाई, आइतवार - आईतवार, अवकास - अवकाश, etc. It is required to substitute such different forms with single form.

In addition to these all syntax level processing, this paper also investigates the effects of combining semantics based processing methods and preprocessing based on Nepali language features. However the principle focus of this research work is in news classification, this research contribution is equally applicable in building news clustering models for news search engine optimization similar as Zhang and Dimitroff models [13] and Krestel and Mehta [8] for the purpose of designing efficient news recommendation systems.

The rest of this paper is organized as follows. Section II discusses previous works related to this paper. Section III introduces baseline approach and some other methods. It then discusses the proposed approach using preprocessing based on Nepali language features. Section IV then discusses the experimental setup for the methods. Based on the experiments, section V shows the evaluation of these methods and discusses the performances of the classifier. Finally, section V summarizes and concludes the paper.

2. Related Works

VSM represents each document as a feature vector of the terms including both words and phrases [12]. Each feature vector contains term weights of the terms in the document. In the simplest form, it does not consider the dependency between the terms and ignores the sequence and structure of the term in the document. A document is represented by n-dimensional term vectors in VSM. A term vector is a collection of term-weight pairs. The weight of a term depends on the frequency of occurrence of the term called Term Frequency (TF). Term Frequency - Inverse Document Frequency (TF-IDF) weight outperforms TF and is commonly used weights [5,6]. A wide variety of distance functions and similarity measures have been used, such as squared Euclidean distance, cosine similarity, and relative entropy. Cosine similarity is a commonly used similarity measure [3,4].

Khan et al. proposed the semantics based feature vector using Parts-of-Speech (POS) model for text classification [5]. The feature space was reduced remarkably considering parts of speech. Masuyama and Nakagawa presented the roles of the different POS in feature selection and showed that nouns best describe a category's contents [10]. Krestel and Mehta used Latent Dirichlet Allocation (LDA) to find the hidden factors of important news stories [8]. Authors focused on verb, adjective and noun for part-of-speech (POS) information. For Named-Entity information, the most common named-entities like person, locations, organization and job-titles were used for efficient results. Lo, He and Ounis generated stopwords automatically using frequency of occurence of words for information retrieval system [9]. Basnet and Pandey have shown different aspects of morphological analysis of verbs in Nepali [1]. The study focused on inflection aspect of verb morphology and the use of compounding of verbs for Nepali language.

Latent Semantic Indexing (LSI) remained one of the predominantly used techniques in information retrieval systems because of the method featuring in dimensionality reduction and overall quality improvement in results [2,3]. LSI uses Singular Value Decomposition (SVD) to find low rank approximation of the original term space. Users in different contexts, or with different needs, knowledge, or linguistic habits will describe the same information using different terms. In contrary, same word may have more than one distinct meaning. LSI captures the essential meaningful semantic associations while reducing redundant and noisy semantic information [2]. Paulsen and Ramampiaro combined LSI with a new clustering algorithm to retrieve and cluster biomedical information using Lucene and JAMA API in Java [11]. They obtained best result when rank was reduced to few hundreds. Gleich and Zhukov used SVD to recommend related terms at varying levels of generality by varying the rank of SVD space [3].

3. Methodology

The proposed method uses various Nepali languages features to reduce the dimension of feature space. These feature based improvements are cascaded in similar style as Masuyama and Nakagawa [10] nevertheless the authors used different method than the proposed method. Finally the results are verified using cross-fold validation techniques detailed out as in [7].

A. Algorithm of Baseline Method

1. Split the whole documents into training and testing datasets. The splitting ratio will be different in each iterations of validation cycle following k-fold cross-validation.
2. Analyze the news document using StandardAnalyzer in Lucene[1].
3. Calculate the term weight using the standard TF-IDF calculation scheme.
4. Using the training documents compute the term-weight vectors, which is also known as document vectors.
5. Use term-weight vectors associated with training documents of each class to compute corresponding centroid vector.
6. Compute term-weight vector of test documents, exactly repeating similar steps of training documents.
7. Compute similarity measure between the test document and news classes. Similarity measure between a document and a class is calculated by computing the cosine similarity between the test vector of the former and centroid vector of the latter.

[1] Lucene 3.6.1 and JDK 1.7.0 were used for processing and baseline evaluation purpose. Lucene can be downloaded from http://lucene.apache.org/

8. Classify the test document to a class which gives minimum similarity measure.
9. Repeat whole processes to evaluate using k-fold cross-validation.

B. *Algorithm of Proposed Method*

1. Generate stopwords using frequency thresholding where frequency is the total number of documents in which a term appears. Remove stopwords from the complete set consisting total terms.
2. Replace ब with व, इ with ई, ु with ू, ि with ी, ढ with ध, ड with द, ठ with थ, ट with त and श with स.
3. Remove word suffices such as बाट, द्वारा, मार्फत, देखि, सँग, तर्फ and सम्म.
4. Calculate weights of the reduced term space.
5. Calculate term-document matrix from the reduced term space.
6. Generate term-weight vector from the new term-document matrix.
7. Evaluate the classifier using k-fold cross-validation.

4. EXPERIMENT AND EVALUATION

The data required for this work was prepared from the raw dataset used for morphological analysis of Nepali text by Basnet and Pandey [1]. The original dataset consists of 71981 news documents, occupying 453 MB disk space, collected from various sources of Nepali daily newspapers such as Gorkhapatra, Kantipur, Samacharpatra, Mahanagar, Nagariknews and Annapurna Post published during January 2009 to November 2009. The dataset was used for morphological analysis of Nepali text by Basnet and Pandey [1]. Data cleaning was required before the dataset could be used. Duplicate news documents were replaced with unique news documents. The dataset containing non-Nepali encodings were also removed. Many news documents contained more than one news items in the same document, which was useless for classification, as each news document must belong to a single category.

To test the performance of the classifier, actual category of news document must be compared with the category predicted by the classifier. A web-based application was developed for this purpose. A web-interface displays news from the dataset and human user can select respective category. After selection, the provided category was stored in a database. The web-interface was developed using HTML, PHP and mysql. The database consists of two tables: "**ncategory**" and "**news**". The table "**ncategory**" stores the news categories which are loaded as options for classification. A user is provided the content of the news to be categorized and available options. The information submitted by the user is stored in the table "**news**". The information includes the news, category selected and user's name. Figure 1 shows the screenshot of the web-interface developed for manual categorization of news documents.

After going through such rigorous process of cleaning and manual categorization, dataset of 700 news documents is prepared. Initially, 50% were used for training and 50% were used for testing. Later the document set splitting was done following k-fold cross-validation. Different categories chosen for the model experimentation are shown in Table I.

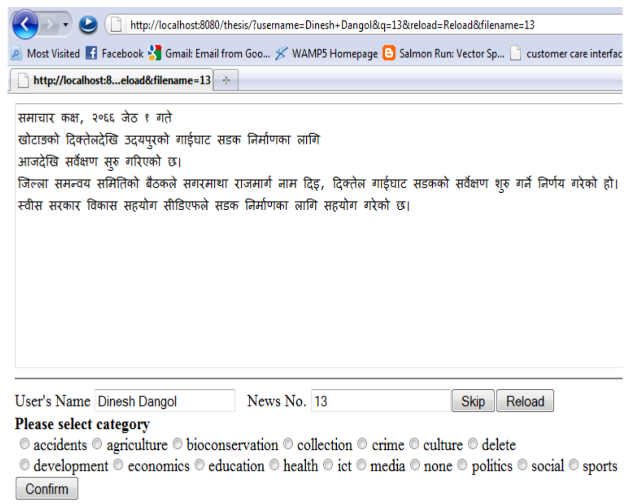

Figure 1: Screenshot of web interface used for manual classification

Table 1: Categories of the news documents

No.	Category	No. of documents
1	Accidents (A)	100
2	Politics (P)	100
3	Sports (S)	100
4	Development (D)	100
5	Health (H)	100
6	Education (E)	100
7	Crime (C)	100
	Total	**700**

Confusion matrix was created from the result of classification. Precision, recall and accuracy were used for evaluation of the classifier. Precision of a class measures the ratio of correctly classified documents to the total documents classified in the class. Recall of a class measures the ratio of correctly classified documents to the total documents in a class. Table 2 shows the confusion matrix of one of the experiments using baseline method. Table III shows the calculation of precision, recall and accuracy using True Positives (TP), False Negatives (FN), False Positives (FP) and True Negatives (TN) derived from confusion matrix of Table 2.

Table 2: Confusion matrix of an experiment on baseline method

		Predicted class						
		P	**A**	**D**	**C**	**S**	**H**	**E**
Actual class	**P**	93	2	2	0	0	2	1
	A	0	83	5	4	0	0	8
	D	0	1	70	16	8	1	4
	C	0	0	13	70	4	1	12
	S	0	0	9	10	71	6	4
	H	0	0	8	2	3	83	4
	E	0	2	6	22	3	0	67

Table 3: Performance measures of an experiment on baseline method

Class	TP	FN	FP	TN	Pr	Re	Acc
P	93	7	0	600	1	0.93	0.99
A	83	17	5	595	0.94	0.83	0.96
D	70	30	43	557	0.61	0.7	0.89
C	70	30	54	546	0.56	0.7	0.88
S	71	29	18	582	0.79	0.71	0.93
H	83	17	10	590	0.89	0.83	0.96
E	67	33	33	567	0.67	0.67	0.90
Avg.	**76.71**	**23.28**	**23.28**	**576.71**	**0.78**	**0.76**	**0.93**

Average precision for 7 classes were calculated for each experiment using 2-fold cross-validation. Experiments were repeated 20 times and average values were recorded. Baseline method uses standard analyzer to generate terms. First step was to filter commonly occurring words. Stopwords were generated using frequency thresholding. Top two most frequent terms छ and र were selected as stopwords. Second step was to replace various word forms. Different forms of replacements and corresponding number of terms reduced are shown in Table IV. After this, suffices that occur in nouns and pronouns were removed to reduce the dimension further. Suffices that gave best results are बाट, द्‌वारा, मार्फत, देखि, सँग, तर्फ and सम्म.

Table V shows the effect of addition of new methods applied to the baseline method. These three methods remarkably reduced the dimension of the feature to be used for classification and also increased average precision and recall compared to the baseline method as shown in Figure 2.

Figure 3 shows the comparison of average accuracy percentage among different methods.

Table 4: Effect of word replacements on dimension reduction

Word replacement forms	No. of terms reduced
ब व	233
इ ई	51
ु ू	228
ि ी	134
ढ ध	3
ड द	7
ठ थ	4
ट त	11
श स	82
All combined	**746**

Table 5: Effect of preprocessing on classifier performance

Code	Methods	Average precision	Average recall	No. of terms
B	Baseline	0.7863	0. 7699	28903
BS	Baseline with stopword filtering	0.7878	0.7773	28901
BSR	Baseline with stopword filtering and word replacement	0.7905	0.7800	28157
BSRS	Baseline with stopwords filtering, word replacement and suffices removal	0.7902	0.7803	27292

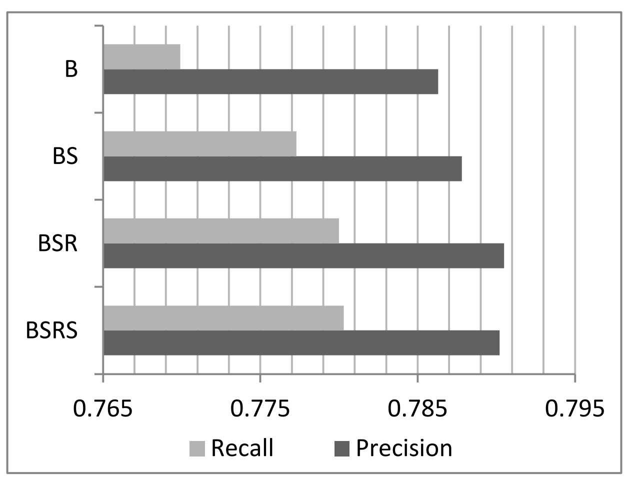

Figure 2: Comparison of new methods on classifier performance

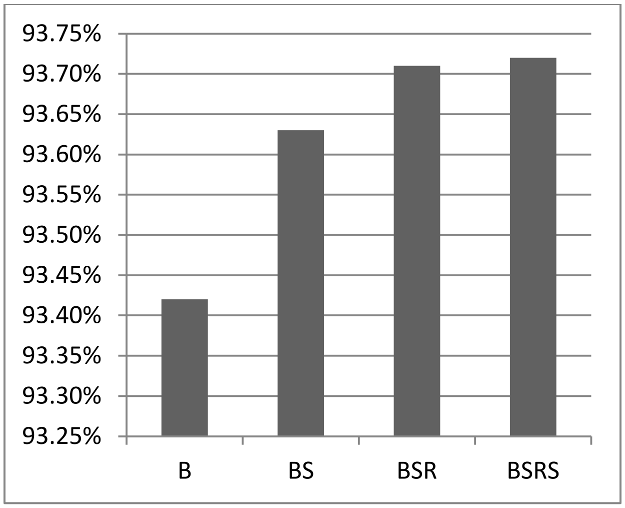

Figure 3: Average accuracy percentage comparison among different methods

5. Conclusion and Future Works

The language features are always important to be considered in text analytics. This paper presented the Nepali language specific features which are different than English language features. The results with feature based processing are quite promising in comparison to baseline methods. Both stopword filtering and word replacement are key processing to be included for the increment in precision and recall. The reduction in number of terms was also observed. Morphological analyzer that removed specific suffices increased both the average precision and average recall compared to the baseline method.

Suffices that occur in nouns and pronouns were only considered in this paper. Stemming algorithms in Nepali may be used to reduce different forms of verbs. Only common forms of word replacements were considered in this paper. Other forms of replacements are still possible. Examples of replaceable word pairs are ओखलढुंगा – ओखलढुङ्गा, एवं – एवम्, काठमाडौँ – काठमाडौं, इन्ष्टिच्युट – इन्स्टिच्युट, etc. More replacements may improve dimension reduction and classifier performance further.

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Modeling Pedestrian's Behavior at Road Crossings: A Case Study in Kathmandu

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***Abstract*: The pedestrian facilities provide segregation of pedestrian traffic from the vehicular flow, thereby increasing perceived safety. The behavior of pedestrian is essential before providing such facilities. It is, as a study in Kathmandu, problems regarding behavioral aspects of pedestrians are formulated using a mathematical model.**

Data are collected adopting observational and interview method at mid-block un-controlled crossings from eight locations in Kathmandu. Randomly selected 400 pedestrians were observed for their waiting time and he/she was asked with a set of questions including their age, gender, marital status, have children at home, crossing frequency, in group or individual during cross, access to private vehicle, destination, involve or witness to pedestrian accidents, education level.

Likelihood ratios were used to signify the variables to calibrate 'Cox Proportional Hazards Model'. The research was concluded with two set of predictors. One suggests pedestrians are likely to accept higher risk and cease their waiting time (male pedestrians, pedestrians crossing in group, pedestrians going to work and well educated pedestrians) and another suggests lowering the risk and extending their waiting (older pedestrians, past involvement or witness in pedestrian accidents, access to vehicles) at pedestrian crossings. Pedestrian oriented training classes along with enforcement by traffic law to the drivers on public vehicles and educational programs for pedestrians through mass media are recommended as policy implications.

Keywords: Pedestrians; Road Crossings; Safety; Cox Proportional Hazard Model; Policy Implications

1. INTRODUCTION

A. Background

Journey itself is not a primary need of society. In order to fulfill the need of society, travel demand is generated and people start journey to get their destination. They can use public vehicles or private vehicles to make their journeys. Walking is such a simple and essential mode, which basically involved for journeys with public vehicles and may be involved for journey with private vehicles. In Kathmandu valley, about 40% journeys are made on foot (JICA Report 2012). However, the trend of planning and designing the road system are based on automobile oriented one, resulting the large number of accidents.

WHO predicts that the road traffic injuries will rise to become the fifth leading cause of death by 2030, while it was under 9th position in 2004. Over 1.2 million people die each year in the world's roads and between 20 and 50 million people suffer non-fatal injuries (Global Status Report on Road Safety – 2009 by WHO). In 068/069 among 5096 road accidents in Kathmandu Valley, 148 were fatalities, 396 serious injuries and 3317 were minor injuries (Metropolitan Traffic Police Division, Kathmandu). In most regions of the world, this epidemic of road traffic injuries is still increasing. The data shows that over 90% of the world's fatalities on the roads occur in low income and middle income countries, which have only 48% of the world's vehicle. In the same report, Nepal is one of the low-income countries. Almost half of those who die in road traffic crashes are pedestrians, cyclists or users of motorized two-wheelers – collectively known as "vulnerable road users" and this proportion is higher in low economic countries of the world. The report suggests that not enough is being done to meet the needs of these vulnerable groups.

First of all, pedestrians' personal features play an important role in pedestrian safety crossing (McMahon et al., 1999). Some studies point to a link between age-related declines in driving and road-crossing skill and increased crash risk (Carthy et al., 1995; Helmers et al., 2004; Mathey, 1983; Oxley et al., 1997; Oxley 2000). Male pedestrians tend to violate traffic rules more frequently than females and are more likely to cross in risk situation (Rosenbloom et al., 2004; Diaz, 2002).

Besides the personal features, the external environmental factors also affect the street-crossing behavior. Sisiopiku and Alking, (2003) presented findings from an observational study of pedestrian behavior at various tyes of urban crosswalks and questionnaire survey which sought pedestrian perceptions towards various crossing facilities near university campus. For example, pedestrian waiting countdown timer can influence pedestrian behavior at signalized pedestrian crossing (Keegan and Mahony, O., 2003).

Tanaboriboon and Jing (1994) found that pedestrian in Beijing, preferred signalized crossings to other types, such as under or over pass crossing. However, crashes involving pedestrians often occur in signalized intersections (Tiwari et al., 1998). The road crossing behavior of pedestrians is also influenced by the social factor. The road waiting time at pedestrian crossings decreases as pedestrian flow increases, (Hamed, M. M., 2001), suggesting that pedestrians are more inclined to cross the road along with others.

B. Research Objectives

The main objective of this research is to trace out the pedestrian safety condition in Kathmandu and thus recommend appropriate measures to be implemented in order to enhance the pedestrian safety. Specifically this research has the following objectives:

i. To determine whether the following parameters plays significance role during modeling pedestrian behavior in road crossings

ii. Road surface and geometrical parameters

iii. Traffic parameters

iv. Time of day

v. To quantify the significance level of pedestrians' individual behavior that would influence the pedestrian delay and safety conditions.

vi. To determine the education level and social parameters (crossing in group rather than in individual) of pedestrian as a significant variable

vii. To develop a best-fit model for pedestrian behavior in road crossing

2. METHODOLOGY

A. Pedestrian's waiting time at the curbside

The hazard function is a popular theoretical construct that provides an index of the relative levels of pedestrians' risk taking. As such, the hazard function λ(t) is defined, in this research, as the instantaneous failure rate (stop to wait at curbside) assuming that the pedestrian has not crossed successfully (i.e. rejected available gaps) the street to time 't'. The random variable for hazard function is the distribution of Pedestrian's waiting time (t) at pedestrian's crossing. The pedestrian's waiting time at the curbside is assumed to depend on exogenous variable. As such, the hazard function can be stated as:

$$\lambda(t|X) = \lim_{\Delta t \downarrow 0} \Pr\left[\frac{[t \le T < t+\Delta t|T \ge t, X}{\Delta t}\right] \qquad (1)$$

Where, X is a column vector of exogenous variables. Since all pedestrians were observed to complete the duration of crossing, observations are said to be non-censored. The probability density function 'ϕ(t)' can be given as (Andersen, 1991):

$$\phi(t|X) = \lambda(t|X)\exp\left[-\int_0^t \lambda(s)ds\right] \qquad (2)$$

B. Cox Proportional Hazard Model

One of the popular mathematical models used or analyzing waiting time data is the Cox proportional hazards model (Cox, 1972; Andersen, 1991). In the context of this model, the risk function at time 't' for pedestrian 'i' can be written as:

$$\lambda(t, X_i) = \bar{\lambda}(t)f(X_i, B) \qquad (3)$$

Where $\bar{\lambda}(t)$ is referred to as the underlying risk or hazard function, B is as a row vector of unknown parameter and Xi is time-independent. The value of $\bar{\lambda}(t)$ function is non-negative. The time independent variable is defined as the variable whose values for a pedestrian do not change during the spell (time under study). For example, the sex for an individual does not change during the spell of employment. In duration model, the prediction with independent variable is more popular. However, the role of time-dependent variable in this research might not be so critical, as the research is concerning with waiting time (i.e. a few seconds) of the pedestrian at curbside. Therefore, the prediction of estimable parameters for time independent variable is the major concern.

The Cox proportional hazards model modified to associate the vector predictors 'X' and waiting time 't' can be written as:

$$\lambda(t|X_i) = \bar{\lambda}(t)e^{\sum_{i=1}^{K} B_i X_i} \text{ with } 0 \le \lambda(t|X) < \infty \qquad (4)$$

Where X= {X_1, X_2, X_3 ……..X_K) and B is a vector of estimable parameters. Clearly, the above model gives an expression for the risk at time 't' for a pedestrian with a given specification of a set of predictors X.

An important feature of this model is that the baseline risk is a function of time, but does not involve the X's. In contrast, the exponential expression involves the X's valued but does not involve t. If all X's value are zero, the model reduces to the baseline hazard function. Another important property of the proportional hazard model is that allowing $\bar{\lambda}(t)$ to be quite general has the advantage of providing reasonable good relative efficiency for estimation of X without having to make assumptions about $\bar{\lambda}(t)$, thus making this model a semi-parametric duration model. In general, it is preferred to use a parametric model if we are sure of the correct model. Thus, when in doubt, the proportional hazard model is likely to give reliable results so that it is a safe choice of model (Cox, 1972; Andersen, 1991; Chap, 1997).

C. Maximum Likelihood Estimates

The likelihood shall be defined as the probability of the observed data being explained by particular model. Maximum likelihood estimates of the models' parameters are determined by maximizing the likelihood function. The partial derivative of the log-likelihood function with respect to each parameter in the model is used for maximization process. The system of the equation thus obtained are solved for estimable parameters. As the waiting time of all pedestrians are taken into account; censoring is absent in this research. Censoring is the selection or omission of random variable(s). For the absence of censoring, partial likelihood is precisely the likelihood based on marginal of ranks of the failure times (Cox, 1972). The partial log-likelihood (lnL) is defined as the sum of the pedestrian' likelihood's. If we represent the number of pedestrians ending their waiting time at the same time t_i by C_i. The partial log-likelihood function shall be stated as:

$$\ln L = \sum_{i=1}^{N}\{B' \sum_{j\in T_i} X_j - C_i \ln \sum_{j\in E_j} e^{B'X_j}\} \quad (5)$$

Where E_j represents the index set of pedestrians with waiting time greater than or equal to ti. As such, for every pedestrian j in the set kj, $t_j \geq T_t$, where the T's are the pedestrian waiting times at curbside. The log-likelihood is maximized using SPSS. The coefficient thus determined from the SPSS has presented as the result of the research.

D. Goodness of Fit

The likelihood ratio (LR) test is used to determine the overall goodness-of-fit of the developed pedestrian waiting time model. The fit of the estimated model can be tested using LR test. If LLZ is the log-likelihood at zero with all regression coefficients are set to zero and LLC is the log-likelihood at convergence with K regression coefficients, this test shall be stated as:

$$LR = -2(LLZ - LLC\ (K)) \quad (6)$$

The LR has as Chi-Square distribution with K degrees of freedom.

3. DATA COLLECTION

A. Introduction

For the development of the proposed model, pedestrians attempting to cross the street were observed at eight midblock pedestrians crossing located in Kathmandu valley. These locations have similar road geometry and traffic characteristics. The one set of pedestrian's crossings consists of five crossing located on undivided streets and another set have three locations with a divided street.

The data was collected in August, 2012 (Shrawan-Bhadra, 2069). I have made successful observation and questionnaire survey for total 400 pedestrians including all eight locations. The information was gathered at different time of the day including both am and pm with peak hour and off hour. The data was tried to make as randomness and possible.

The data collection part includes two phases: firstly the pedestrians were observed for waiting time and secondly they were interviewed for some questions. Each pedestrian was monitored from the time he/she came to curbside with the intension of crossing the road until he/she starts to walk for successful crossings. The time lapsed for crossing the road by pedestrians was also noted. For the divided lane, the second waiting time and second walking time are also recorded separately. The number of attempts made by the pedestrians is also noted. Once the pedestrians have successfully crossed from opposite location of observers, they were asked a set of questions related with this research.

B. Survey Parameters:

Data includes the following parameters and are collected manually.

- Survey location
- Sample size
- Time of the day
- Behavioral and Societal parameters
- Road geometrical parameters

Survey Locations

The first work for this research work is to specify the locations, which are under high-risk zone for pedestrian, during crossing of the road. In order to specify these spots, I have taken the data from Metropolitan Traffic Police Office, Ramshahapath, Kathmandu, regarding road accidents. The data are available since 2067/68. I have chosen the spots based on these two-year accident data that includes the number of accidents occurring base on locations. Among all accident spots, eight most vulnerable locations were selected for taking survey work.

Sample Size Determination

There is no data in the selected locations regarding the exact number of pedestrians crossing the road per day. The collection of data is another huge work besides the thesis. Therefore, I have taken the survey in the field for every 15th pedestrian as sample pedestrian. Taking observation and questionnaire is continued until the required number of sample is surveyed.

The size of sample is determined based on 95% confidence level of the population 60 thousands with 45% marginal errors. It is seen that for such type of survey; the maximum size of sample will be 384 whatever the size of sample upto 3 millions.

$$n = \frac{\chi^2 * N * P * (1-P)}{\{ME^2 * (N-1)\} + \{\chi^2 * P * (1-P)\}} \quad (7)$$

Where,

n= sample size

χ^2= Chi-square for the specified confidence level at 1-degree of freedom

N= Population size

P= Population proportion (50 in this table)

ME= desired Margin of Error (expressed as a proportion)

This formula is one used by Krejcie and Morgan in their 1970 article "Determining Sample Size for Research Activities" (Educational and Psychological Measurement, #30, pp. 607-610).

Time of Taking Survey

- Peak hour (9:00 to 11:00 am and 4:30 to 6:30 pm) and off-peak hours
- Both am and pm

Individual and Societal Parameters of Pedestrians

- Age
- Gender (Male/Female)
- Marital status? (Married/Unmarried)
- Have children in the house? (Yes/No)
- Have private vehicle?(Yes/No)
- Have involved or witness of any road accidents? (Yes/No)
- Is the destination to work? (Yes/No)
- Pedestrian's flow in group? (Yes/No)
- Number of road cross per day
- Education level of pedestrian
- Waiting time
- Number of attempts before successful crossing
- Crossing Time

Road Geometrical Parameters

- Width of road
- Number of lane
- Type of lane (Divided/Undivided)

Summary of Data

The summaries of data are presented herewith.

Part-I: Categorical Variable

Table 1: Categorical Variable Coding [c d e f g h i j] :

Variables	Categories	Frequency	Coding
gendera	0=Female	133	0
	1=Male	236	1
maritala	0=Un-Married	146	0
	1=Married	223	1
childrena	0=No, donot have	167	0
	1=yes, have children	202	1
Priveha	0=No, do not have	280	0
	1=yes, have private vehicle	89	1
involvea	0=No, not involved/witness	234	0
	1=Yes, involved/witness	135	1
desta	0=No, other than work	310	0
	1=Yes, destination to work	59	1
carrya	0=Nothing	202	0
	1=Something	167	1
flowa	0=Not in group	216	0
	1=In group	153	1
Divideda	1=Divided	155	1
	0=Undivided	245	0

Part-II: Continuous Variables

Table 2: Continuous Variables [k l m n o] :

Variables	Explanation of Variable	Frequency
agea	Age of the sample pedestrian	398
ncrosspda	Number of road cross per day by the sample pedestrian	393
edua	Education level of the sample pedestrian	394
locn	Location of survey	400
ncattempta	Number of crossing attempts before the successful crossing	340
Surfacea	Surface Condition of the road	400

4. MODEL FORMULATION AND DISCUSSIONS

A. Introduction

Likelihood Ratio is the main process for selecting or rejecting the variable from the model. Taking age and gender as most important variables I have entered these variables into the model without checking the likelihood ratios. All other variables were checked for their goodness of fit over the model. The results for divided and un-divided street are presented separately as the distributions of pedestrians were found different in divided and undivided street. Similarly the hazard ratio for continuous variables has presented in separate charts.

B. Categorical Variables in Undivided Street:

Table 3 shows maximum likelihood estimation results of the pedestrian's risk of ceasing their waiting time during road crossings. The statistical significance of each individual variable is given by the p-value. To assess the effect of included variables on the waiting time at pedestrian crossings, the hazard ratios for both indicator and continuous variable are computed. The same table shows the estimation of hazard rations and their corresponding confidence interval for 95% confidence level.

The estimated results show that the pedestrians, who were involved or witnessed pedestrians' accident, have lower risk of ceasing their waiting time at pedestrian crossings. In other words, these pedestrians have higher waiting time as compared with other pedestrians. Pedestrians who have children and/or access to private vehicle in their house also have lower risk of ceasing their waiting time. Here is one interesting result; the married pedestrians who do not have their children have higher risk of ceasing their waiting time. During convergences of the model, it is seen that, marital and children category comes simultaneously to significance level. If one variable is removed other does not converge to significant level. Further research shall be recommended to conclude about this interesting result. Pedestrians who crosses road frequently have higher risk of ceasing their waiting time; i.e. they have lesser waiting time. The interesting result is that the well educated pedestrians bear more risk during crossing the road, i.e. they have lesser waiting time. As the density of vehicle in peak time increases, the pedestrians do not have acceptable clearance to cross the road. So the waiting time at peak hour is more than that for off-hour. The research has shown the similar result.

Recalling back to the equation of Cox Proportional Hazard Model; the value of Exp(B) is the hazard ratio. Table 3, shows that the pedestrians who were never been involved or did not witness of pedestrians accidents bear risk 1.536 times than the pedestrians who have been involved or witness of pedestrians accidents during crossing the road. Similarly pedestrians who do not have children at their home take risk 1.876 times than that of pedestrians with children at home.

Table 3: Pedestrian Risk of Ceasing Waiting Time at Undivided Street

Variable	**Coefficient (B)**	**Significance (P)**	**Exp (B)**	**95% Confidence for Exp(B)**	
				Lower	Upper
age	-.006	.265	.994	.982	1.005
gender	.123	.294	1.131	.899	1.423
marital *	.560	.006	1.750	1.176	2.606
children	-.377	.096	.686	.440	1.069
priveh	-.234	.074	.792	.613	1.023
involve √	-.375	.001	.687	.554	.852
edu √	.102	.044	1.107	1.003	1.223
time	-.202	.064	.817	.660	1.012
Number of Observations			369		
-2Log-likelihood at convergence model			3147.768		
Chi-square model			29.943		
Degree of freedom			8		
Significance level of the model			0.0000		
√ = Variables under significant level					

C. Categorical Variables in Divided Street at Curbside

Table 4 shows the maximum likelihood estimation results foe pedestrian's waiting time to cross the road from one side of the street to central refuge. Overall, some parameter estimates are significant and of plausible sign. In addition to the set of explanatory variables included in undivided street model (Table 3) some new variables has seen to be significant. Result shows that the road surface condition plays significant role to effect the waiting time of the pedestrian at curbside for divided street.

Male pedestrians take more risk to cease their waiting time before crossing the road as compared to female pedestrians. i.e. the male pedestrians have lesser waiting time than female pedestrians. The hazard ratio between male and female is 1.176. Younger pedestrians have higher risk of ceasing their waiting time than older. i.e. adult pedestrians have longer waiting time than young pedestrians.

Those pedestrians who cross the road with group rather than in individual have higher risk of ceasing their waiting time. i.e., they have lesser waiting time. Similar to undivided street; the pedestrians who involved or witness of pedestrians accidents have lesser risk of ceasing their waiting time. i.e., they have longer waiting time as compared to others who neither involved nor witness of pedestrian accidents.

Table 4: Pedestrian Risk of Ceasing Waiting Time at Curbside of a Divided Street

Variable	**Coefficient (B)**	**Significance (P)**	**Exp(B)**	**95% Confidence for Exp(B)**	
				Lower	**Upper**
age	-.005	.450	.995	.981	1.009
gender	.162	.405	1.176	.803	1.720
priveh *	.235	.230	1.264	.862	1.855
involve √	-.367	.046	.693	.483	.994
dest *	-.373	.166	.688	.406	1.168
Edu √	.221	.008	1.247	1.061	1.466
flow √	.370	.034	1.447	1.027	2.038
Surface √	.421	.003	1.524	1.160	2.003
Number of Observations			369		
-2Log-likelihood at convergence model			1322.953		
Chi-square model			37.870		
Degree of freedom			8		
Significance level of the model			0.000		
√ = Variables under significant level					

D. Categorical Variables in Divided Street at Central Refuge

Table 5, shows the maximum likelihood estimation results for risk of ceasing pedestrian's waiting time to cross the road from central refuge to destination curbside. Overall, some parameter estimates are significant and of plausible sign. In addition to the set of explanatory variables included in undivided street model (Table 3) and in divided street from beginning curbside to central refuge (Table 4); some new variables has seen to be significant. Result shows that two explanatory variables age and gender lies in significant region however the outcome is similar to the Table 4.

Table 5: Pedestrian Risk of Ceasing Waiting Time at Central Refuge on Divided Street

Variable	Coeffi-cient (B)	Signifi-cance (P)	Exp (B)	95% Confidence for Exp(B)	
				Lower	Upper
age √	-.019	.046	.981	.963	1.000
gender √	.407	.049	1.503	1.001	2.255
Children *	.366	.171	1.442	.854	2.433
dest	.344	.204	1.411	.830	2.398
edu	.097	.231	1.102	.940	1.292
flow	.270	.133	1.309	.921	1.861
Surface	.215	.106	1.240	.955	1.610
Number of Observations			369		
-2Log-likelihood at convergence model			1194.897		
Chi-square model			11.641		
Degree of freedom			7		
Significance level of the model			0.133		
√ = Variables under significant level					

E. Continuous Variables

Figure 1, 2, and 3 are plotted for the hazard ratios for continuous variables age, surface condition and education level respectively. The hazard ratios of these variables are expressed as the difference from mean of these variables.

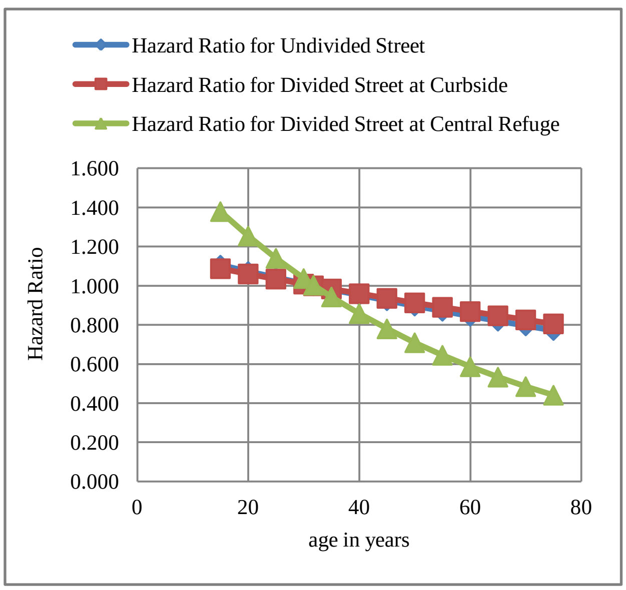

Figure 1: Hazard Ratios for Different Age of Pedestrians

Figure 1 shows that the average age of pedestrian has a hazard ratio of one. The figure shows that, pedestrian below mean age have increased (more than unity) hazard. The pedestrian with the age greater than average age; the hazard is decreased (less than unity). The above statement shall be expressed in terms of risk. Pedestrian below average age has greater risk of ceasing their waiting time whereas the pedestrian above the mean age have lesser risk of ceasing their waiting time. i.e. the pedestrian below mean age have lesser waiting time as compared with the pedestrian having age more than the mean age. Similar result was found by Griffiths (1984) and M. M. Hamed (2001). In Griffiths' findings, it was conformed that the walking speed on pedestrian crossing is different for age. As such, age of pedestrians is likely to have varied perception of dangers when crossing. This perception is base on the pedestrian's expected walking time.

One interesting findings from Figure 1 is that there is no significant difference between the risk taken by pedestrians at curbside in undivided and divided street. However in the case of divided street the line for risk plotted for central refuge is steeper than the risk line plotted at curbside. This indicates that the pedestrians seem more hurry when he/she reaches to the central refuge.

Figure 2 show that the hazard ratio for mean surface condition is unity; this is the condition which is developed in order to analyze the data. The figure shows that the pedestrian in poor road surface takes more risk of ceasing their waiting time as compared with the good surface roads. The speed of vehicle in roads with poor surface condition is generally less as compared roads with good surface. The pedestrians shall be taking the advantage of this in order to make his/her successful crossings.

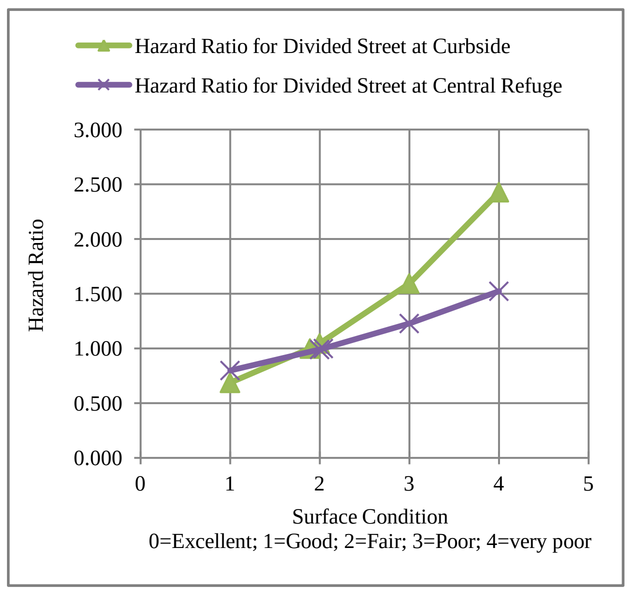

Figure 2: Hazard Ratios for Different Road Surface Conditions

In Figure 3, the hazard ratios for mean education level of pedestrians has expressed to unity. The result is interesting, the well educated pedestrians takes more risk of ceasing their waiting time as compared with the pedestrians having education level less than mean education level.

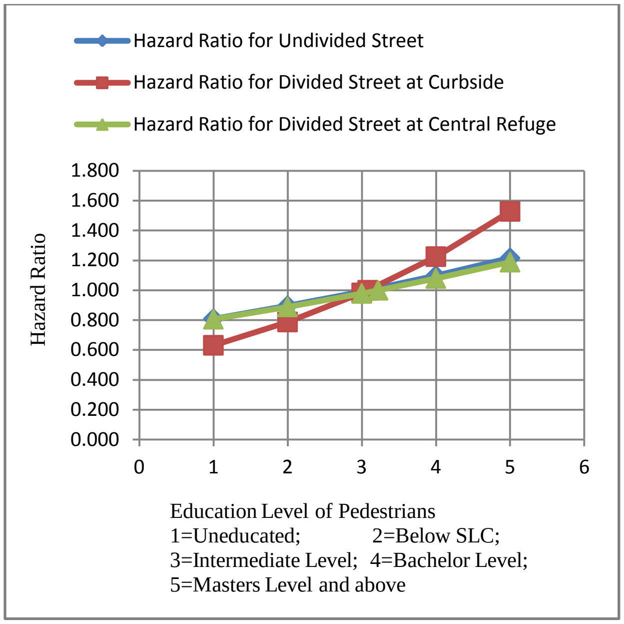

Figure 3: Hazard Ratios for Different Education Levels of Pedestrians

5. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

In this research, the proportional hazard models are specified and estimated to identify the determinants of pedestrians waiting time (delay) on pedestrian crossings. The pedestrian's risk of ceasing their waiting time is modeled separately for divided and undivided streets. In the case of divided street; separate determinants were determined from beginning curbside to central refuge and central refuge to the ending curbside.

Estimated results for divided and undivided streets, one suggested set of predictors that are likely to make pedestrians accept higher risk and cease their waiting time and another suggested set of predictors that are likely to lower the risk and extend their waiting at pedestrian crossings. For example male pedestrians, pedestrians with group, pedestrians going to work and well educated pedestrians are likely to accept higher risk and cease their waiting time at pedestrian crossings. On the other hand, the pedestrians' past involvement or witness in pedestrian accidents seem to inhibit pedestrians from accepting higher risk to cease their waiting time. i.e. they have longer waiting time before his/her successful crossings. As driver's willingness to give the way to the pedestrian crossing the road in group is more than individual; pedestrians in group are more likely have lesser waiting time. Furthermore, pedestrians who have access to private vehicles seem to be more aware of risk involved. Therefore, they are more cautious of time needed before crossing.

Firstly, Pedestrians who spent more time waiting to cross from one side of the street to central refuge are likely to have a higher risk of ending their waiting time as the cross from the central refuge to the other side of the street (i.e. the waiting time from central refuge to the other side of the street decreases. Secondly, the estimates of hazard ratios suggest that pedestrians seem to behave differently as they cross from one side of the street to central refuge and from central refuge to the other side of the street. This is manifested by waiting time that the pedestrian is able to tolerate. For example male pedestrians are1.176 time more likely to have shorter waiting time to cross from one side to refuge than female pedestrians. However, males are 1.503 times more likely to have shorter waiting time to cross from refuge to the other side of the street.

B. Recommendations

There are two phases of policy implications that follow these findings.

1. Modeling the behavior of vehicular speed and traffic volume shall be a new research, however, in this research these parameters are instrumental for determining the pedestrian waiting time (delay). Thus, from field inspection and pedestrians invoice, reinforcement programs directed towards drivers by traffic law and regulations are recommended in suppressing undesired risky behavior. In addition, drivers of public vehicles (especially microbus drivers) should attend specially designed pedestrian oriented compulsory training courses.

2. In Kathmandu Pedestrians should be targeted through educational and public information awareness campaigns to deter pedestrians from engaging in risky behavior. Such programs are recommended to apply through mass media and should be directed toward young pedestrians, male pedestrians, educated pedestrians who take more risk to cease their waiting time.

Along with these policy implications, I recommend following measures to be taken in Kathmandu:

- It is found that the pedestrians seem in hurry when they reach the central refuge. For minimizing the risk at central refuge, a small refuge area at the central part of two-way traffic road is recommended to construct. Recently central refuge at various locations in Kathmandu are just installed.

- As results shows, the risk of ceasing the waiting time of pedestrians are not evenly distributed, and this leads to fluctuating headway, thereby lowering efficiency and LoS of the road. The Installations of PHB at various mid-block pedestrian crossings shall reduce the extra delay for crossing thereby enhancing the efficiency of road to better perceived safety. DoR has recently installed PHB at various locations and operated in few of them.

- Most of the pedestrians were found crossing the road from the site where they are. The installations of curbside railings shall induce pedestrians not to cross the road other than zebra crossings.
- Road surface should be maintained, as pedestrians were taking more risk for crossing the road in poor surface.

It is hoped that this piece of research work will increase the sophistication of measurement in this area to better understand pedestrians' behavior at pedestrian crossings.

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Spectrum Sensing using Cooperative Energy Detection Method for Cognitive Radio

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Abstract: **In order to utilize the spectrum efficiently, the role of spectrum sensing is essential in cognitive radio networks. The transmitter detection based techniques, energy detection, cyclostationary feature detection, and matched filter detections are most commonly used for the spectrum sensing. However, detection performance in practice is often compromised with multipath fading, shadowing and receiver uncertainty issues. To mitigate the impact of these issues, cooperative spectrum sensing has been shown to be an effective method to improve the detection performance by exploiting spatial diversity. The main idea of cooperative sensing is to enhance the sensing performance by exploiting the spatial diversity in the observations of spatially located CR users. By cooperation, CR users could share their sensing information for making a combined decision more accurate than the individual decisions. Thus the Cooperative sensing can formulate excellent use of network assets and make the network smooth.**

Keywords: Cognitive radio, radio spectrum, spectrum sensing, cooperative sensing, detection probability.

1. INTRODUCTION

In CR network, each CR user in the primitive sense is to detect licensed (primary) users if they are present and also identify if they are absent. This is achieved by a process called spectrum sensing. The objective of spectrum sensing are twofold i.e., CR users should not cause interference to PUs and CR users should efficiently identify and exploit spectrum holes for required throughputs and quality of services. Thus the detection performance can be primarily determined on the basis of two metrics i.e., probability of false alarm, which denotes the probability of a CR user declaring that a PU is present when the spectrum is actually free, and probability of detection, which denotes the probability of a CR user declaring that a PU is present when the spectrum is indeed occupied by the PU. Since a miss in the detection will cause the interference with the PU and a false alarm will reduce the spectral efficiency, it is usually required for optimal detection performance that the probability of detection is maximized subject to the constraint of the probability of false alarm. In practice, several factors such as multipath fading, shadowing and, consequently, the hidden terminal problem may affect the detector's performance. These factors could be, however, mitigated if the CR users shared their sensing results with the other CRs. This mechanism is called cooperative spectrum sensing [1]. This scenario can be illustrated as below figure.

Due to this multipath fading and shadowing the signal to noise ratio (SNR) of the received primary signal can be quite small and detection task may very difficult. Since the receiver sensitivity indicates that the capability of detecting weak signal.

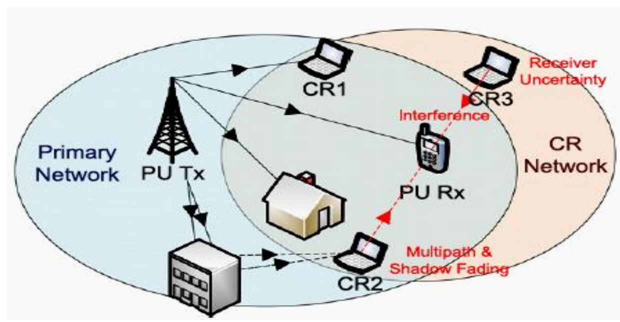

Figure 1: Receiver uncertainty and multipath fading

2. SPECTRUM SENSING CHALLENGES

Before the detail discussion of the spectrum sensing techniques, some of the challenges associated with spectrum sensing are mentioned.

Hardware requirements

In cognitive radio networks [2] analogue to digital converter with high speed processors, high resolution and with dynamic range are required for spectrum sensing. Therefore, terminals are essential for processing transmission for any opportunity over a much wide band. Hence in order to identify and spectrum opportunity the CR should be in a position to capture and analysed a larger band. Radio frequency (RF) components are imposed on additional requirements by larger operating bandwidth such as antennas and power amplifiers.

Hidden primary user problem

This hidden primary user problem is like the hidden node dilemma in Carrier Sense Multiple Accessing (CSMA) [3]. Many factors like shadowing or severe multipath fading which is observed by secondary user during the transmission scanning for the primary user, create this hidden primary user problem.

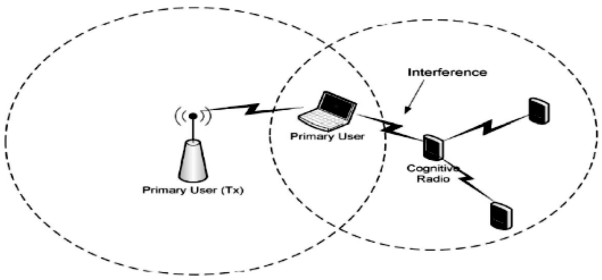

Figure 2: Hidden primary user problem in CR System [3].

Figure above illustrates the hidden node problem while the operating ranges for the primary user (PU) and for the cognitive radio device are shown by dashed lines.

Detecting spread spectrum primary users

A DSSS device resembles the FHSS devices but they utilize a single band in order to spread their energy. Primary users (PUs) which use spread spectrum signalling are hard to identify as the power of the PUs is dispersed over a broad frequency range, while the real information bandwidth is much narrower [4]. A partial solution of this problem is that if I know the hopping pattern and method of perfect synchronization, but it is possible but not easy to develop such an algorithm through which estimation in code dimension is possible.

Sensing duration and frequency

As the CR operates in the bands of primary users, these bands can be claimed by primary users at any time so in order to avoid interference to and for PU, the CR should be so sensible that it could identify the presence of the PU and leave the band immediately. Hence within certain duration, the CR should identify the presence of the PU. Although these conditions put some complexity and challenge for the design of CR, the sensing frequency is a key parameter which should be chosen carefully. Sensing frequency requirements can be relaxed if the status of the PU is going to change slowly. For example in the case of TV channel detection, in a geographical area presence of a TV channel does not change frequency unless an existing channel goes off or a new channel starts broadcasting. Sensing period for IEEE 802.22 draft standard is 30 seconds. Except sensing frequency, other timing related parameters like channel move time and channel detection time etc, are also defined in the standard [5].

Decision fusion in cooperative sensing

For the case of cooperative sensing all results due to various measurements and sharing information among CR was a difficult task. There are two types of decisions i.e.; soft and hard decisions, based on shared information made by each cognitive device [6]. The results existing in [6], illustrates that soft information made by each outperforms hard information combining techniques in term of the possibility of missed opportunity. While on the other hand when cooperative users are high, hard decisions perform as good as soft decisions. A variety of simpler schemes for combining results are exploited in [7].

Security

The cognitive radio air interface can be modified by a malicious user to mimic a primary user. Hence primary users can be misleading during the spectrum sensing process. Such a behaviour or attack is called primary user emulation (PUE) attack. The transmitter position is used to identify an attacker in [8]. A challenging problem is to develop valuable countermeasure when an attack is identified. In order to prevent secondary users masked as primary users, public key encryption based primary user recognition is proposed in [9]. An encrypted value which is generated using a private key is required to transmit with the transmission of legitimate primary users.

3. ELEMENTS OF COOPERATIVE SPECTRUM SENSING

The conventional cooperative sensing is generally considered as a three-step process i.e., local sensing, reporting, and data fusion. The overall elements used for cooperative sensing as follows.

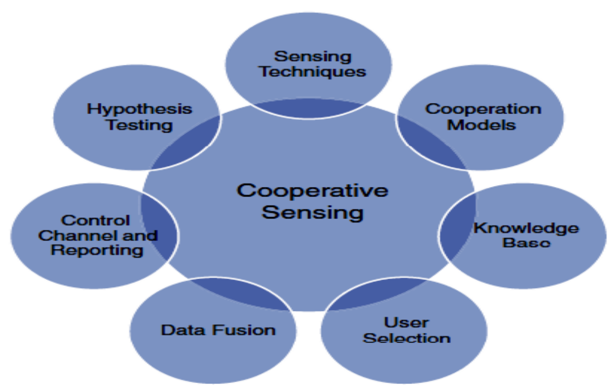

Fig3: Element of cooperative sensing [1]

Cooperation models

I considered the most popular parallel fusion network models and recently developed game theoretical models. For this paper preferred primarily fusion model only.

Sensing techniques

It used to sense the RF environment, taking observation samples, and employing signal processing techniques for detecting the PU signal or the available spectrum. The choice of the sensing technique has the effect on how CR users cooperate with each other.

Hypothesis testing

It is a statistical test to determine the presence or absence of a PU. This test can be performed individually by each cooperating user for local decisions or performed by the fusion centre for cooperative decision.

Control channel and reporting

It concerns about how the sensing results obtained by cooperating CR users can be efficiently and reliably reported to the fusion centre.

Data fusion

It is the process of combining the reported or shared sensing results for making the cooperative decision.

User selection

It deals with how to optimally select the cooperating CR users and determine the proper cooperation footprint/range to maximize the cooperative gain and minimize the cooperation overhead.

Knowledge base

It stores the information and facilitates the cooperative sensing process to improve the detection performance.

4. CLASSIFICATION OF SPECTRUM SENSING

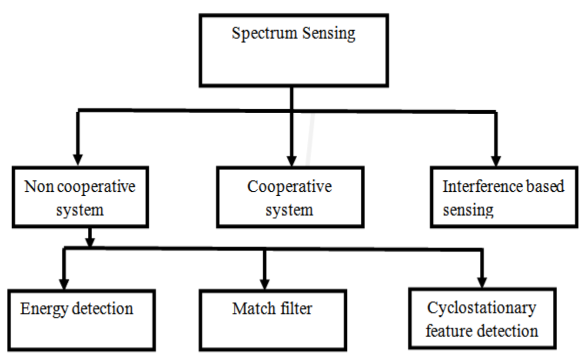

Figure 4: Classification of spectrum sensing

Figure above shows the detailed classification of spectrum sensing techniques. They are broadly classified into three main types, transmitter detection or non cooperative sensing, cooperative sensing and interference based sensing. Transmitter detection is further classified into energy detection, matched filter detection and cyclostationary feature detection.

Spectrum Sensing using Energy Detection

It is not coherent detection method that detects the primary signal base on sensed energy. Due to the simplicity in the circuit and needlessness of prior knowledge of primary user signal .Energy detection (ED) is the most popular sensing technique in cooperative sensing [11].

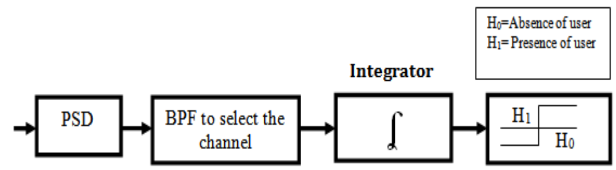

Figure 5 : Energy detection block diagram.

The block diagram for the energy detection technique as shown in the above figure 3.4.1.In this method signal is passed through the band pass filter of a band with 'W' and is integrate over a time interval. The output from the integrator is then compared to an already predefined threshold. This comparison is used to discover the existence or absence of primary user. The threshold value can set to be fixed or variable based on channel condition. The ED is said to be a blind signal detector because it is unaware of the structure of the signal. It estimates the presence of the signal by comparing the energy received with a known threshold derived from the statistics of the noise. Analytically signal detection can be reduced to be a simple identification problem and formalizer as a hypothesis test.

$$y(k) = n(K) \qquad \dots\dots\dots\ H_o \qquad (1)$$

$$y(k) = h * s(K) + n(K) \qquad \dots\dots\dots\ H_1 \qquad (2)$$

Where $y(k)$ is the sample to be analysed at each instant k and $n(K)$ is the noise of variance σ^2. Let $y(k)$ be a sequence of received samples k= {1, 2... N} at the signal detector then a decision rule can be sated as

$$H_o \text{.....if } \varepsilon > \gamma$$

$$H_1 \text{.....if } \varepsilon < \gamma$$

Where $\varepsilon = E|(y)^2|$ the estimated energy of the received signal and is chosen to be the noise variance σ^2.

However ED has the following disadvantages as follows

i. The sensing time taken to achieve a given probability of detection may be high.

ii. Detection performance is subjected to the uncertainty of noise power.

iii. ED cannot be used to distinguish primary signals from the CR user signals. Thus, CR users need to be tightly synchronized and refrained from the transmissions during an interval called quite period in cooperative sensing.

iv. ED cannot be used to detect spread spectrum signals.

Match filter method

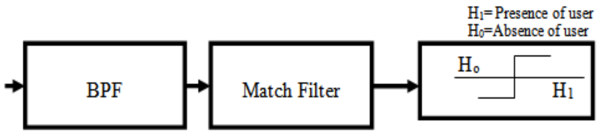

Figure 6: Block diagram of match filter method

A match filter (MF) is the linear filter design to maximize the output signal to noise ratio for a given input signal. When secondary user knows about the primary user signal, a method called match filter detection, which is equivalent to correlation, in which the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of a reference signal. The operation of match filter detection is expressed as,

$$Y[n] = \sum_{k=-\infty}^{\infty} h[n-k]x[k] \quad (3)$$

Where X is the unknown signal and is convolved with 'h' the impulse response of matched filter, which is matched to the reference signal for maximizing the SNR. Detection using matched filter is useful only in the cases where the information from the primary users is already known to the cognitive users [12].

Advantages: Matched filter detection needs less detection time because it requires only (1/SNR) samples to meet a given probability of detection constraint. When the information of the primary user signal is known to the cognitive user, matched filter detection is optimal detection in stationary Gaussian noise.

Disadvantages: Matched filter detection requires a prior knowledge of every primary signal. If the information is not accurate, MF performs poorly. Also, the major disadvantage of MF is that a CR would need a dedicated receiver for every type of primary user.

Cyclostationary feature detection

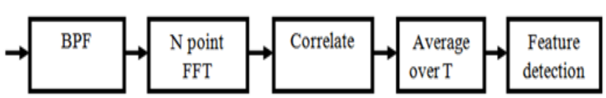

Figure 7: Cyclostationary feature detection method.

It exploits the periodicity in the received primary signal to identify the presence of primary users (PU). The periodicity is commonly embedded in sinusoidal carriers, pulse trains, spreading code, hoping sequences or cyclic prefixes of the primary signals. Due to the periodicity, these cyclostationary signals exhibit the features of periodic statistics and spectral correlation, which is not found in stationary noise and interference. Thus cyclostationary feature detection is robust to noise uncertainties and performs better then energy detection in low SNR levels. Although it requires a prior knowledge of the signal characteristics, cyclostationary feature detection is capable of distinguishing the CR transmissions from various types of PU signals. This eliminates the synchronization requirements of energy detection is cooperative sensing. Moreover, CR users may not be required to keep silent during cooperative sensing and thus improving the overall CR throughput. This method is not encouraged to apply as it has its own drawbacks owing to its high computational complexity and long sensing time. Considering these issues, this detection method is less common compared to energy detection in cooperative sensing.

Interference based Detection

In this section I present interference based detection so that the CR users would operate in spectrum underlay (UWB like) approach.

Primary Receiver Detection

In general primary receiver emits the local oscillator (LO) leakage power from its RF front end while receiving the data from primary transmitter. This method is useful to detect primary user by mounting a low cost sensor node close to a primary user's receiver in order to detect the local oscillator (LO) leakage power emitted by the RF front end of the primary user's receiver which are within the range of communication from CR system users. After that the local sensor reports the sensed information to the CR users so that they can identify the spectrum occupancy status. This method can also be used to identify the spectrum opportunities to operate CR users in spectrum overlay.

Interference Temperature Management

Unlike the primary receiver detection, the basic idea behind the interference temperature management is to setup an upper interference limit for given frequency band in specific geographic location such that the CR users are not allowed to cause harmful interference while using the specific band in specific area. Typically CR user transmitters control their interference by regulating based on where they are located with respect to the primary users. This method basically concentrates on measuring interference at the receiver. The operating principle of this method is like an UWB technology, where the CR users are allowed to coexist and transmit simultaneously with primary users using low transmitting power that is restricted by the interference temperature level so as not to cause harmful interference to primary users.

Here, CR users do not perform spectrum sensing for spectrum opportunities and can transmit right way with specified preset power mask. However the CR users cannot transmit their data with higher power even if the licensed system is completely idle since they are not allowed to transmit with higher than the preset power to limit the interference at primary users. This is noted that the CR users in this method should know the location and corresponding upper level of allowed transmitted power levels. Otherwise they will interfere with the primary user transmissions.

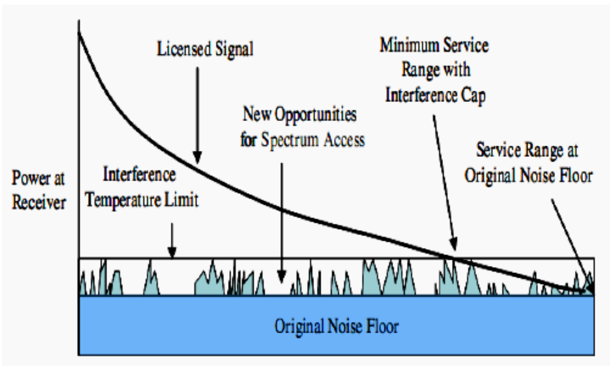

Figure 8: Interference temperature model [10].

5. Classification of Cooperative Sensing

There are three different cooperative sensing categories based on how CRs share data in the network i.e., centralized, distributed and relay-assisted. In the centralized category, an entity called fusion centre (FC) controls all the cooperative sensing process.

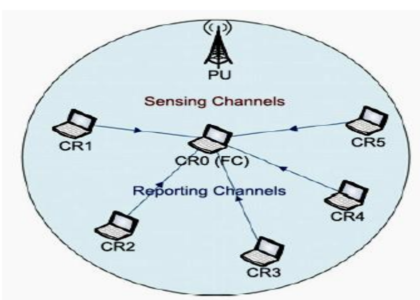

Fig 9: Centralized cooperative sensing [1]

Figure illustrated these functions as CR0 is the FC and CR1–CR5 are cooperating CR users performing local sensing and reporting the results back to CR0. For local sensing, all CR users are tuned to the selected licensed channel or frequency band where a physical point-to-point link between the PU transmitter and each cooperating CR user for observing the primary signal is called a sensing channel. For data reporting, all CR users are tuned to a control channel where a physical point-to-point link between each cooperating CR user and the FC for sending the sensing results is called a reporting channel. Note that centralized cooperative sensing can occur in either centralized or distributed CR networks. In centralized CR networks, a CR base station (BS) is naturally the FC. Alternatively, in CR ad hoc networks (CRAHNs) where a CR BS is not present, any CR user can act as a FC to coordinate cooperative sensing and combine the sensing information from the cooperating neighbours [4].

In distributed cooperative sensing does not rely on a FC for making the cooperative decision. In this case, CR users communicate among themselves and converge to a unified decision on the presence or absence of PUs by iterations. Figure below illustrates the cooperation in the distributed manner.

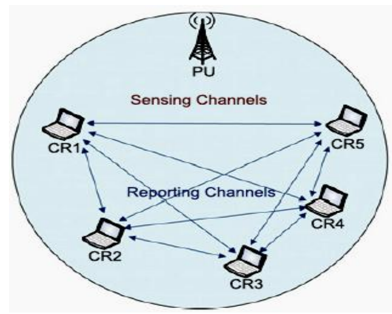

Figure 10: Distributed cooperative sensing [1].

After local sensing, CR1–CR5 shares the local sensing results with other users within their transmission range. Based on a distributed algorithm, each CR user sends its own sensing data to other users, combines its data with the received sensing data, and decides whether or not the PU is present by using a local criterion. If the criterion is not satisfied, CR users send their combined results to other users again and repeat this process until the algorithm is converged and a decision is reached. In this manner, this distributed scheme may take several iterations to reach the unanimous cooperative decision [4].

The third scheme is relay-assisted cooperative sensing. In this scheme both sensing channel and report channel are not perfect, a CR user observing a weak sensing channel and a strong report channel and a CR user with a strong sensing channel and a weak report channel, for example, can complement and cooperate with each other to improve the performance of cooperative sensing. Figure illustrates the functioning of relay assisted cooperative sensing.

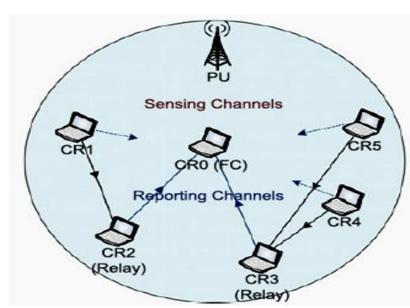

Figure 11: Relay Assisted cooperative sensing [1].

From figure, CR1, CR4, and CR5, who observe strong PU signals, may suffer from a weak report channel. CR2 and CR3, who have a strong report channel, can serve as relays to assist in forwarding the sensing results from CR1, CR4, and CR5 to the FC. In this case, the report channels from CR2 and CR3 to the FC can also be called relay channels.

6. Benefits of Cooperation

Cognitive users who have a major role in a big deal to sense the channels that have large benefits among which the plummeting sensitivity requirements: channel impairments like multipath fading, shadowing and building penetration losses, impose high sensitivity requirements inherently limited by cost and power requirements. Employing cooperation between nodes can drastically reduce the sensitivity requirements up to -25dBm, and thus, reduction in sensitivity threshold can be obtained by using this scheme agility improvement: all topologies of cooperative network reduce detection time compared to uncoordinated networks.

7. Disadvantages of Cooperation

Sensing should be done from time to time at periodic intervals by CR users as the sensed information is passed at fast rate due to factors like mobility, channel impairments etc., which increases the chances of data overhead; large sensory data, since the spectrum, which results to large amounts of data to be processed, being inefficient in terms of cooperatively sensing data poses lot of challenges, it could be carried out without incurring much overhead because only approximate sensing information is required eliminating the need for complex signal processing schemes at the receiver side and reducing the data load. Also even though a wide channel has to be scanned, only a portion of it changes at a time requiring update only the changed information and not all the details of the entire scanned spectrum.

8. ED with Cooperative Method

Step 1: Numbers of signal are received from two or more users. Each received signal is sampled with certain sampling frequency.

$y_i(k)$ = h *s(K)+ $n(K)$ where "i" is the number of users,

i=0, 1, 2, 3….

Step 2: Estimated energy of each received signal is calculated with noise varianceσ^2 .

$\varepsilon_i = E|(y_i)^2|$

Step 3: Integrated output signal of each user is compared with already defined threshold value.

$\gamma = gammaincinv(pf(i), u, 'upper')$

Step 4: Each user sends estimated energy to fusion centre and compared with threshold value

H_o…..if $\varepsilon_i > \gamma$

H_1…..if $\varepsilon_i < \gamma$

Step5: Final decision at FC related to given band is based on data fusion rule.

ε_i, ε {0, 1},

Where "0" ("1") indicates the absence (presence) of primary user,

ε_i = decision of i-th CR user upon a given sub-band.

ε = final decision made at FC for the sub-band.

9. Simulation Results

Cooperation communication has obtained much attention because of its capability to obtain high diversity gain, decreased transmitted power, increased system throughput and combat fading. Diversity gain is achieved by allowing the users to cooperate in cooperative networks and even better performance can be achieved by combing the cooperation with other techniques.

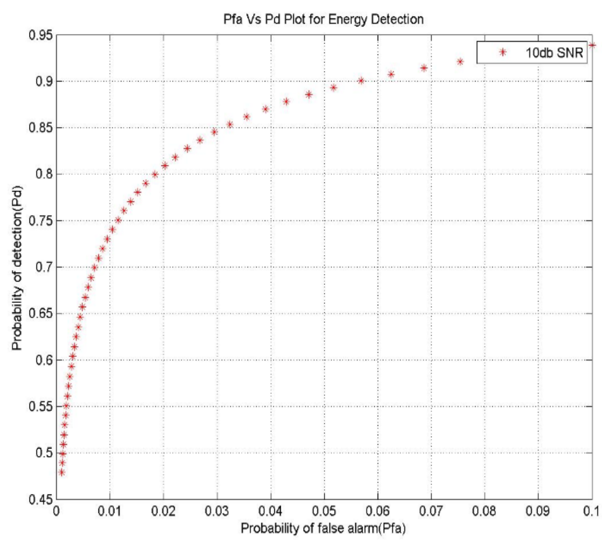

Figure 12: Energy detection simulation result

For simulation purpose, the graph is plotted in terms of probability of false alarm (P_{fa}) and probability of detection (P_d). The detection performance can be mainly determined on the basis of these two things, i.e.; the probability of false alarm which denotes the probability of CR users declaring that a PU is present when the spectrum is actually free. And another one is probability of detection, which denotes the probability of CR users declaring that a primary user is present when the spectrum is indeed occupied by primary user. Since a miss in the detection will cause the interference with the primary user and the false alarm will reduce the spectral efficiency. Thus it is usually required for optimal detection performance that the probability of detection is maximized subject to the constraint of the probability of false alarm.

In above figure 12, P_{fa} versus P_d simulation result at -10dB SNR level was shown. From this simulation, different value of probability of false alarm (P_{fa}) having with different value of probability of detection (P_d) are shown. However ED is always accompanied by various disadvantages like noise uncertainty problem, sensing time take to achieve a given probability of detection may be high, ED method cannot be used to distinguish primary and secondary signal. Therefore ED method is not useful in low SNR level applications.

Practically, Energy Detection method is best among, different transmitter based detection method. Thus to mitigate the issues arises in non cooperative techniques like multipath fading, shadowing and hidden terminal problem, cooperative ED is used.

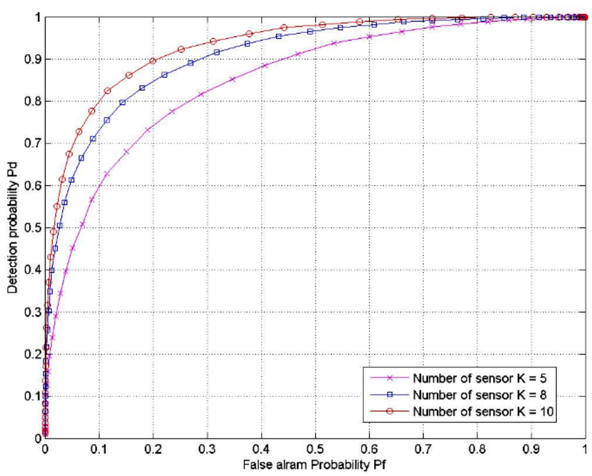

Figure 13: Receicer Operating Characteristics for ED with cooperative method

The ROC curve (figure 13) shows the simulation result in terms of probability of false alarm versus probability of detection. The simulation was done at -10db SNR level and considering Gaussian channel. The simulation uses the different number of users showing with different Receiver Operating Characteristic (ROC) in above figure 13. The number of user (sensors) was considered 5, 8 and 10. If the number of users were higher the chance of detection is maximized. The different numbers of cognitive users are cooperates to each other and make a centralized decision from fusion centre. This decision may increase the chance of detection; from this simulation result if the number of user is 10 the probability of detection is maximum at a constant probability of false alarm. Similarly in another side in figure 14, if the numbers of users are minimums the chance of misdetection is high. From another perspective if the numbers of users are higher the chance of probability of misdetection is also minimized using cooperation. Hence the higher numbers of users the chance of misdetection is minimized using cooperation, which optimizes the spectrum utilization.

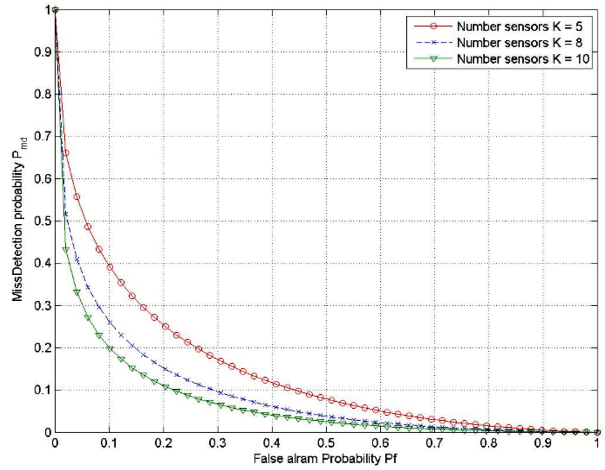

Figure 14: Complementry Receicer Operating Characteristics for ED with cooperative method

To overcome the shortcomings of energy detection, the other methods based on the eigenvalue of the covariance matrix of the received signal is useful. But this method may give the ratio of the maximum eigenvalue to the minimum eigenvalue can be used to detect the presence of the signal. Based on some latest random matrix theories (RMT) [13], here quantify the distributions of these ratios and find the detection thresholds for the detection algorithms. The probability of false alarm and probability of detection are also derived by using the RMT. The methods overcome the noise uncertainty problem and can even perform better than energy detection when the signals to be detected are highly correlated. The methods can be used for various signal detection applications without knowledge of the signal, the channel and noise power. Furthermore, different from matched filtering, the methods do not require accurate synchronization.

10. CONCLUSION

Cognitive radio is the promising technique for utilizing the available spectrum optimally. The important aspect of cognitive radio is spectrum sensing and from that identifying the opportunistic spectrum for secondary user communication. In this paper, different existing spectrum sensing techniques were studied. Among them, the performance of energy detection was simulated in non cooperative and cooperative environment. The performance of the ED method is presented in term of Receiver Operating Characteristic (curves). Hence the probability of presence or absent of the primary user is decided using the ROC curves. The probability of false alarm versus probability of detection or misdetection is plotted. The ED method having uncertainty noise variance at low SNR level is the major demerit. Besides this, it increases the probability of detection and minimized the probability of miss detection by using cooperation. Thus the higher number of cooperative users gives the higher probability of detection even low SNR level.

Hence the cooperative spectrum sensing technique is a best technique for sensing spectrum which optimizes the use of spectrum dynamically by using cooperation among number of available cognitive users.

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A Research on Torrefaction and Briquetting of Biomass in Nepal

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Abstract: **Biomass is a major source of energy in developing countries like Nepal. Traditionally, biomass in its raw form has been used for cooking and heating purposes, industrial purpose has however been limited due to lower heating value of loose biomass. Various attempts have been made in energy sector to improve energy density of raw biomass. Consequently processes such as pyrolysis have been invented which aims at increasing efficiency and heating value (per unit mass) of loose biomass by removing moisture and volatiles from it. Another process known as briquetting compacts loose biomass resulting in increased energy density.**

Torrefaction is a type of biomass upgrading process in which raw biomass is heated to 200°C –300°C removing moisture and volatiles from the biomass and making it dense in energy. Torrefaction is an emerging subject in which various researches have been carried out especially to study effect of temperature and residence time on torrefaction process. Our study was aimed at studying effect of temperature and residence time. Torrefaction conditions of 270°C temperature with 15 minutes residence time was found most suitable. Biomass used for torrefaction was saw-dust. Further, torrefied biomass was briquetted to increase energy density. Economic analysis was carried out for the process.

Keywords: Biomass, torrefaction, residence time

1. INTRODUCTION

Energy is very important in every phase of human life. From the very beginning of civilization man has been using energy. From sustaining life to generating income, human beings required energy in every aspect of their life. This is why study of energy, its generation and distribution has always been given great importance all over the world from the very beginning of scientific development. There are numerous classifications of energy but the most popular one is on the basis of availability: renewable and non-renewable. Energy sources such as biomass, wind and solar which can be replenished by nature with time are called renewable energy source. This sources never extinct and can be used again and again. On the contrary non-renewable resources are those sources of energy which can be used only once. Examples are fossil fuel which cannot be replenished once used. Biomass can be considered as a renewable energy source if the rate of depletion does not exceed rate of consumption otherwise biomass becomes non-renewable.

Over the centuries man has been using fossil fuel, a non-renewable source of energy for satisfying energy demand. Even nowadays almost 80 % of world's energy demand is fulfilled through use of fossil fuel. Since fossil fuels are going to be scarcer in days to come we have to move to another energy source. Biomass can be one of them.

Biomass has been used all over the world for energy generation. In rural villages biomass is a major source of cooking. Biomass such as leaves and tree branches are used for cooking as well as heating purpose. Biomass is an easily available source of energy in rural areas hence used very often. The disadvantage of using biomass is that in its raw form it is a low form of energy and during its burning lot of energy is wasted in burning volatile organic compounds and removing moisture.

Torrefaction of biomass can be described as a mild form of pyrolysis at temperatures typically ranging between 200-300°C. During torrefaction the biomass properties are changed to obtain a much better fuel quality for combustion and gasification applications. Torrefaction combined with densification leads to a very energy dense fuel carrier of 20-25 GJ/ton.

Annually, photosynthesis is said to store 5-8 times more energy in biomass than humanity currently consumes from all sources. Biomass is currently the fourth largest energy source in the world – primarily used in less developed countries and could in principle become one of the main energy sources in the developed world. Biomass can be an important energy source to create a more sustainable society. However, nature has created a large diversity of biomass with varying specifications. In order to create highly efficient biomass-to-energy chains, torrefaction of biomass in combination with densification (pelletisation/briquetting), is a promising step to overcome logistic economics in large scale green energy solutions.

Torrefaction, a process traditionally used to roast coffee beans, could give biomass a power boost, increasing the energy content of some leading energy crops and agricultural residues by up to 20 per cent, a study by engineers from the University of Leeds shows. Meanwhile, researchers in the Netherlands have produced an interesting case-study showing that, because of its significantly higher energy content, torrefied biomass can be imported from much further away, making long-distance trade feasible. The process makes the logistics of transporting and storing bulky biomass more efficient. Most interestingly, torrefaction also makes biomass more friable, making it far easier to grind. This opens the prospects of using existing coal pulverizes and of considerably lowering costs of co-firing biomass to generate electricity. With coal prices at all time highs, torrefaction technology might arrive just in time to make biomass even more attractive to energy companies looking into co-firing.

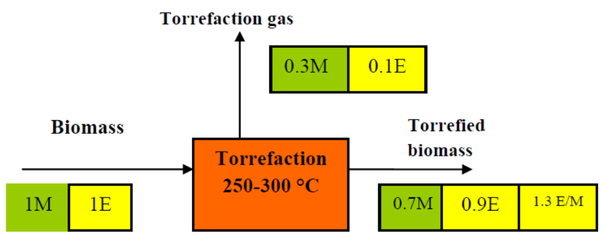

Figure1 Typical mass and energy balance of the torrefaction process.
Symbol E = Energy unit, M = mass unit (Bergman 2005)

A. Principle characteristics of torrfied product

The principal characteristics of torrefied product are as follows:

1) Torrefied biomass contains 70-80% of the original weight while retaining 80-90% of original energy of the biomass.
2) The equilibrium moisture content of torrefied biomass is very low (from 1 to 3%) [Lipinsky et al., 2002]
3) It has high hydrophobicity, as it does not absorb water.
4) Besides its higher heating value, torrefied biomass also produces less smoke when it burns.
5) Its grindability and mechanical strength are superior to those at the initial biomass.
6) Torrefaction makes a biomass better suited for gasification and combustion processes.

B. Definition of important terminologies in Torrefaction

Bergman (2005) had defined some important terminologies of torrefaction.

1) Residence time: Bergman has considered residence time as time elapsed after temperature reaches 200°C. Definition of residence time has however differed according to researchers.

2) Initial heating: In torrefaction initial heating is heating process until the evaporation of moisture starts. Temperature of biomass continuously increases during this process.

3) Pre-Drying: In this stage free water is evaporated from the biomass at constant rate and its temperature remains practically constant, until the critical moisture constant is reached and the rate of evaporation starts to decrease. This stage is characterized by sharp increasing in heating demand shown in Figure 2.3.

4) Post drying and intermediate heating: In this stage, temperature of biomass increases to 200°C. The biomass is practically free of moisture after this stage. Some mass loss also can be expected, as light organic compounds can evaporate.

5) Torrefaction: This process begins as soon as temperature reaches 200°C and ends when temperature falls below 200°C. In this stage biomass gets torrefied. This stage consists of heating, cooling and constant temperature process. The constant temperature is called torrefaction temperature. Heating is done before the torrefaction temperature is reached and cooling after the torrefaction temperature is reached. Devolatilisation or mass loss occurs during heating period and continues during the constant temperature process. It stops when cooling starts.

6) Solid cooling: During this process solid product is cooled down below 200°C to desired final temperature. At this stage no mass loss occurs but some evaporation of adsorbed reaction products may occur.

7) Mass yield: Mass yield is defined as ratio of mass of char to mass of feed on dry and ash free basis.

8) Energy yield: Energy yield is defined as ratio of energy given by char to energy given by feed multiplied by mass yield on dry and ash free basis.

2. OBSERVATION AND FINDINGS

The result and various findings is summarized below:

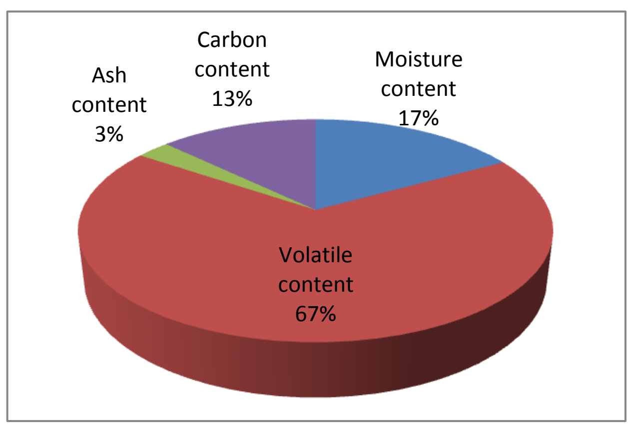

Figure 2: Pie-chart shows constituent of biomass among which carbon content is important in torrefied biomass.

A. Mass loss Analysis of torrefied sawdust

Table I: Sawdust torrefaction temperature 210°c

Residence time	15 minutes	30 minutes	45 minutes
Initial weight	4 g	4 g	4 g
Final weight	3.27g	3.23 g	3.08 g
% mass loss	18.25	19.25	23

Table II: Sawdust torrefaction temperture 240°C

Residence time	15 minutes	30 minutes	45 minutes
Initial weight	6g	6g	6g
Final weight	3.18 g	3.04g	2.43 g
%mass loss	47	49.33	59.5

Table III: Sawdust torrefaction temperature 270°C

Residence time	15 minutes	30 minutes	45 minutes
Initial weight	6g	6g	6g
Final weight	2.69 g	2.44 g	2.29g
% mass loss	55.16	59.33	61.83

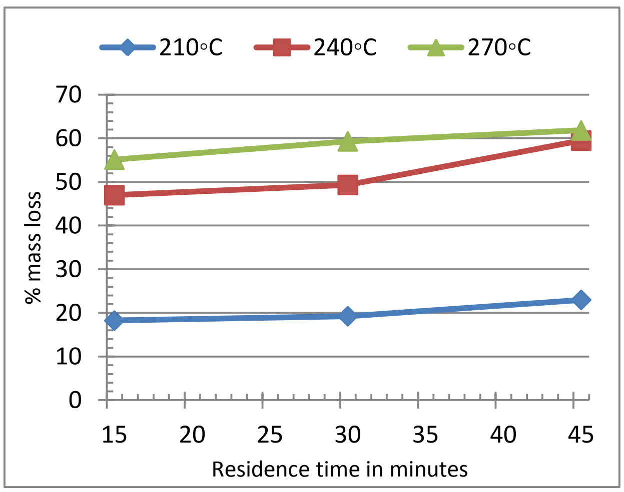

Figure 3: Graph of mass loss vs residence time at constant temperatures

The graph above shows that percentage mass loss increases with increase in torrefaction temperature. This is because according to science of torrefaction after temperature exceeds 200°C volatile materials start to be released from the biomass. Higher release of volatiles occurs at higher temperature. We can also see that mass loss increases slightly with increase in residence time but effect of temperature is prominent than that of residence time. Rate of mass loss is relatively low for higher residence time at temperature 270°C. That occurs because almost all volatiles are removed at higher temperature (270°C) at 15 minutes residence time resulting in no further significant mass loss for higher residence times.

B. Calculation of calorific value using bomb calorimeter

Table IV: Calorific value of torrefied biomass at 270°c and 15 minutes residence time

Time (min)	Temperature (°C)
1	29.06
2	29.05
3	29.04
4	29.04
5	29.04
6	29.04
7	29.32
8	29.88
9	30.1
10	30.18
11	30.21
12	30.22
13	30.22

Table V: Calculated calorific value with their average values for different temperature and residence time

Calorific value 1 (cal/g)	Calorific value2 (cal/g)	Calorific value 3 (cal/g)	Average(cal/g)	Temperature (°C)	Residence Time(min)
4262.86	4309.08	4280.75	4284.23	210	15
4125.75	4424.23	4280.8	4276.93	210	30
4445.73	4138.425	4302.12	4295.43	210	45
4893.62	4937.54	4911.48	4914.21	240	15
4992.04	4859.07	4921.53	4924.21	240	30
4700.46	4719.5	4711.2	4710.39	240	45
5549.352	5364.39	5449.27	5454.34	270	15
4685.11	4580.29	4782.92	4682.77	270	30
4156.16	4879.19	4598.36	4544.57	270	45

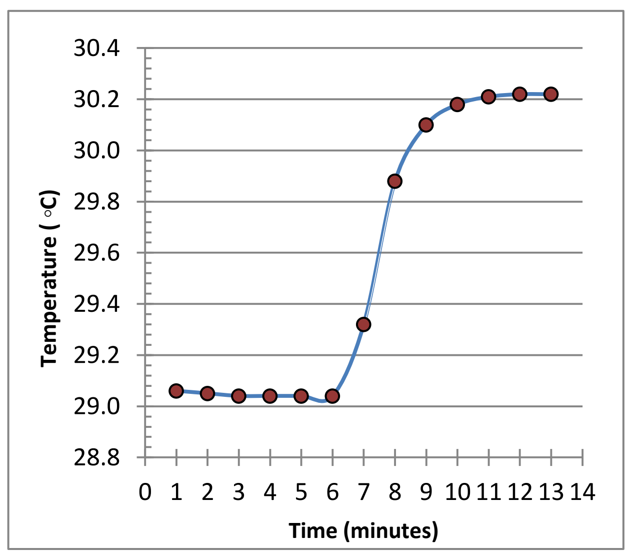

Figure 4: Temperature vs. time graph for values obtained during calorific value calculation of torrefied biomass (270°C, 15 minutes residence time)

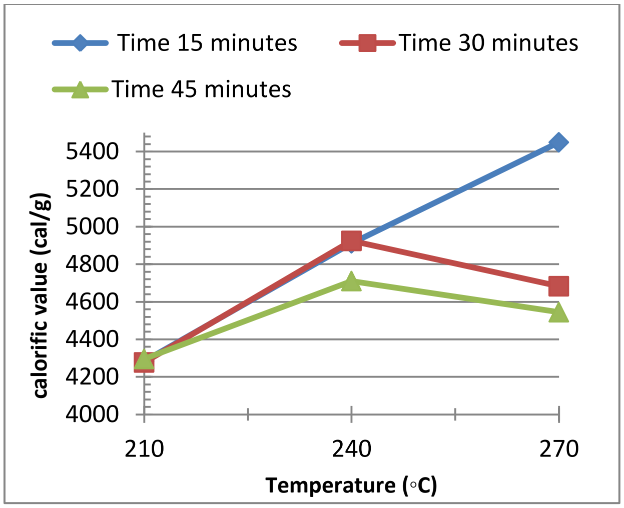

Figure 5: Graph of calorific value vs. temperature at constant residence time

Graph above shows that calorific value increases with increasing temperature for 15 minutes residence time. Calorific value decrease for 30 to 45 minutes residence time at temperatures 240°C and 270°C.This is because volatiles combustible materials get more time to fire which cause unwanted combustion of carbon content of biomass. Hence this graph shows that highest calorific value is obtained at 270°C torrefaction temperature and 15 minutes residence time.

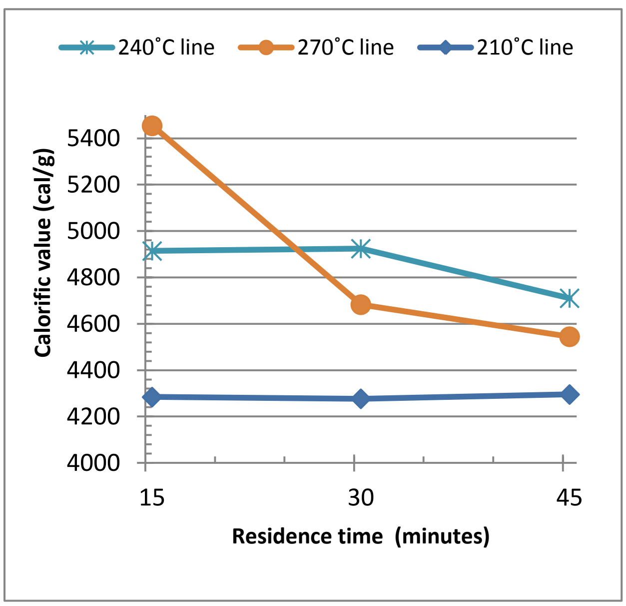

Figure 6: Graph of calorific value vs. residence time at constant temperature

We can see from the graph that at 210°C calorific value increases slightly with increasing residence time. At temperatures 240°C and 270°C calorific value decreases after residence time 30 minutes. This fall in magnitude of calorific value is sharp for 270°C. This graph asserts the fact that effect of torrefaction temperature is more prominent than residence time for increasing calorific value. Again optimum condition for torrefaction is found to be 270°C torrefaction temperature at 15 minutes residence time.

3. Conclusion

12.86 % of biomass consists of combustible solid (carbon content) which was observed in approximate analysis. Extracting this combustible solid from biomass is challenge of our project. Several pyrolysis and carbonization processes have been designed for this purpose. Among all these processes torrefaction is one of the efficient processes. Though torrefaction is in its emerging state, few researches on it have shown that it excels many other pyrolysis processes. It is a low temperature process requiring less residence time. Though some energy input is required for heating, calorific value of biomass is increased significantly.

Torrefaction of sawdust was carried out in our project. After the completion, it can be concluded that torrefaction process increases calorific value of raw biomass. Further, it has other properties like burning efficiency, easy grindability and compacting along with being hydrophobic. Different conditions of temperature and residence time were set and calorific values for individual conditions were calculated. Torrefaction at temperature 270°C and 15 minutes residence time was found to be most suitable condition on the basis of calorific value.

Financial analysis of the process was carried out. According to this analysis, breakeven cost for a briquette was found to be Rs 8.93.Seventy briquettes was assumed to be produced per day which when sold at Rs. 20 per each would give the total revenue of Rs. 4, 20,000 per annum. We calculated net present value and internal rate of return which showed process financially viable.

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Developing a Pro Poor Public Private Partnership Business Model for Enhancing Sustainability of Rural Energy Projects in Nepal

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***Abstract*: The Government of Nepal recognizes that access to clean and reliable energy (renewable energy) contributes to rural poverty reduction and environmental conservation. Nepalese renewable energy sector so far has been heavily dependent on subsidy. Private sectors are contracted only for providing services and are not considered as project owners. As private sectors do not own the projects, the projects become a social or grant/charity projects and sustainable operation of such systems are always at risk. The aim of this paper is to design a project where private sector's participation is ensured not only as a contractor but also as an equity investor. Pro poor public private partnership business model for rural energy projects have been designed in order to ensure participation of private sector as equity investor in order to enhance sustainability.**

INTRODUCTION

Nepal is considered to be one of the richest countries in terms of per capita hydro potential but it has not been able to exploit its hydro resources. Nepal's energy situation has been heavily dependent on traditional and imported fuels. About 87 percent of the total energy requirement (401 million GJ in 2008) was met from traditional fuels i.e. fuel wood, agro-residues and the animal waste. The commercial energy forms such as fossil fuels and electricity meet the energy demand of around 12.1 percent, whereas the renewable energy forms just a less than one percent. According to the national census report of 2011-2012, 31 percent of the total populations mostly from rural areas are still deprived of electricity in Nepal. Due to difficult terrain and sporadic distribution of rural households, the extension of grid electricity in a number of villages in the high mountains and hilly areas is unfeasible due to long transmission and distribution line network and low rate of return. Ninety percent of the rural customers connected to the grid consume less than 20 kWh per month making on grid electrification financially unattractive in rural Nepal (Mainali & Silveira, Financing off grid electrification.Country case Nepal, 2011). The contribution of renewable energy in total energy mix is about 1 percent only however it electrifies 12% of the total population mostly in rural areas (AEPC A. E., 2012). In this context, renewable energy has/will become the viable means of rural electrification in Nepal.

Realizing the importance of renewable energy in rural areas, the Government of Nepal recognizes that access to clean and reliable energy contributes to rural poverty reduction and environmental conservation (Rural Energy Policy, 2006) and has set its target to electrify additional 7% rural households through renewable energy technologies in the current three year period (2010-2013). This includes generation of 15 MW power from micro hydro projects, 225,000 solar home systems including solar Tuki and installation of 90000 biogas plants in rural areas of Nepal.

Brief Overview of Existing Implementation Model

Nepalese renewable energy sector so far has been heavily dependent on subsidy. Subsidy has been the main motivating factor for private companies to participate in the program as users receive subsidy through private companies. This service contract type of approach is one of the models of public private partnership (PPPs). In this service contract model, the public sector prepares policy, manuals, guidelines, regulation and selects private sector based on their capacity on human resources, financial resources, physical resources and business plan. Once they are contracted, they are asked to (i) install the feasible renewable energy system, (ii) perform the power output test (iii) ensure that installed systems meet performance standard and related policies and (iii) submit the documents to central renewable fund through Alternative Energy Promotion Center (AEPC) technical component for 90 percent of the subsidy amount. The remaining 10 percent of the subsidy amount is retained as after-sales service guarantee money, which will be released with evaluation of the promised after-sales service after a year. After one year, users need to take responsibility for operation and maintenance of their system. They also need to pay for maintenance and replacement of the parts when required. Under the service contract model, some 1000 micro hydro and 1500 pico hydro projects generating 24 MW electricity, 400,000 solar home systems, 300,000 biogas plants and 600,000 improved cooking stoves have been installed in different parts of the country (AEPC A. E., 2012).

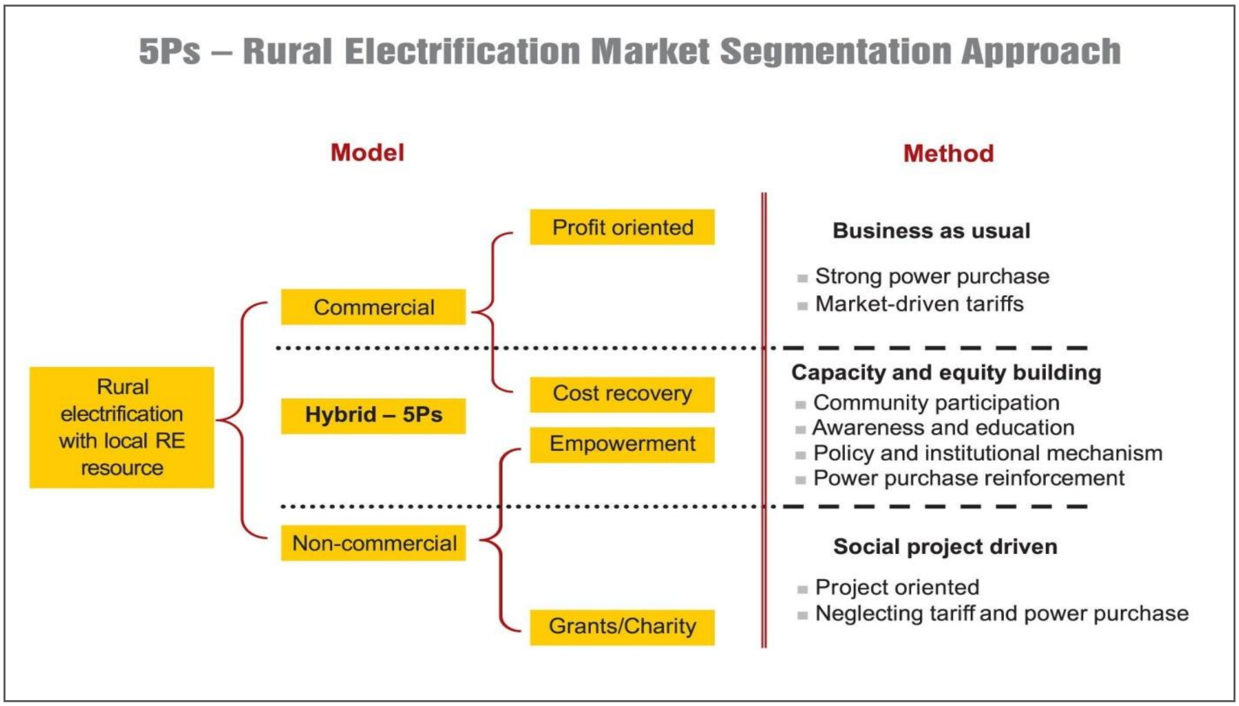
This approach of promoting renewable energy technologies requires strong quality assurance and monitoring mechanism. Moreover private sectors are contracted only for providing services and are not considered as project owners. As private sectors do not own the projects, the projects become a social or grant/charity projects and sustainable operation of such systems are always at risk. The aim of this paper is to design a project based on field survey of two potential sites where private sector's participation is ensured not only as a contractor but also as an equity investor.

Pro Poor Public Private Partnership (5 Ps) for Rural Electrification

The traditional service contract based subsidy model for small scale renewable energy projects is purely grant based approach. For large hydro power projects, public sector allows independent power producers to operate the project in the commercial segment of the market. The pro poor public private partnership (5 P) approach follows a hybrid model which targets the mid segment of the market. The key features that make 5 Ps unique from traditional service contract based and profit oriented PPPs are:

- They are participatory, involving a broad number of public, private and community organizations including local government;
- 5 Ps focus not only on profits but overall social and economic development, contrary to how most corporations operate;
- They are inherently cooperative rather than competitive, attempting to get partners to work together rather than at the advantage or at the expense of others

This 5 P model has been successfully practiced in Cinta Mekar, Indonesia with support from United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). The community hydro power plant built using this model is operational since 2004 and has proven its sustainability. The 5 P model segments the market towards fulfillment of both - economic and social goals as shown in the following figure.



Source: Pro Poor Public Private Partnership, Regional training handbook by UNESCAP. Unpublished

In the 5 P design, a special purpose vehicle represented by private sector and community is established. They both share the capital investment, asset ownership and, commercial risk. In the model, private sectors and community are treated as partners not as suppliers and beneficiaries. The ultimate aim of this model is to transform rural areas from a cost-center, one relying on grants, to a resource-center by recognizing the existence of: 1) entrepreneurship skills in communities and, 2) locally available resources that cater basic infrastructure services.

Project Site Selection Criteria

The potential stakeholders for 5 P projects were listed out at first. Community Business Organizations (CBOs), private sector, financial institutions, local government bodies such as District Development Committee (DDC) and Village Development Committee (VDC) and Non-Government Organizations (NGOs) were identified as potential stakeholders. Consultations with potential stakeholders were carried out to enhance sustainability of 5 P rural energy projects.

Two potential sites where 5 P projects can be implemented have been identified based on site selection criteria presented below. The pilot projects shall be developed in these sites with support from AEPC and UNESCAP. These projects are intended to serve as sustainable business model for rural energy projects.

The following criteria have been used for site selection:

S.N.	Criteria	Weighting (Percentage)
1	Remoteness	20
2	Number of beneficiaries	15
3	Productive use	10
4	Community willingness	10
5	GESI Consideration	20
6	Entrepreneurship Potentiality	10
7	Environmental and Financial issues	5

The selection criteria have been designed from the perspective of Nepal but can serve as guideline for other developing countries.

Implementation Modality for the Selected Sites

Two sites have been selected for implementation of 5 P pilot projects and both of them are rural electrification projects. The sites are Raksirang village of Makawanpur district and Baidi Village of Tanahun district. The salient features of sites are as below:

<u>Raksirang VDC, Makawanpur</u>

Project Location: Raksirang VDC, Makawanpur

Targeted Households for electrification: 100

Ethnicity: Mostly Chepang community

Site Accessibility: 2-3 hours of uphill walk from Manahari Baazar

<u>Baidi VDC, Tanahun</u>

Project Location: Baidi VDC, Tanahun

Targeted Households for electrification: 100

Ethnicity: *Magar* (major population*), Gurung, Chetrei, Newar, Kumal, Rai, Dharai, Thakali, Limbu, Sanyashi,Bharmin, Bhujel, Dhakuri*

Site Accessibility: 4 hours of 4 Wheel drive from Damauli

These two sites have been selected such that they represent different contexts and scenarios of rural villages in Nepal within the framework of site selection criteria mentioned above. Raksirang is resided by people of marginalized and backward ethnicity called *Chepang* that are poor whereas the village Baidi is resided by people who are comparatively well-off than that of Raksirang. In addition, the electrification technologies are also different for these two villages. Biomass Gasifier plant shall electrify Raksirang village and solar photovoltaics based mini-grid shall electrify Baidi. Another contrast between the two villages is site accessibility. Vehicles can reach up to the Baidi village although the road is earthen in a rugged mountain landscape but the vehicles cannot reach Raksirang village.

Productive end uses of electricity have been conceived for both these projects because productive end uses that can create businesses will lead to social and economic development of villages and ultimately enhance sustainability. In Raksirang, the electricity shall be used to operate agro-machineries such as rice huller and grain mill apart from lighting. This will enhance productivity and lead to social and economic welfare in village. The installed capacity of gasifier plant shall be 12kW in Raksirang. In Baidi, the installed capacity of solar mini-grid will be 22kW. This electricity will be used to power a telecom tower apart from lighting households. On the one hand, the revenue collected from the electricity tariff from telecom will be used for the development of Baidi village, and on the other hand, Baidi village will get better access to communication. Thus, socio-economic development, along with involvement of private sector as equity investor, have been planned to enhance sustainability in 5P projects.

The implementation modality includes formation of Special Purpose Vehicle (SPV) Company. SPV Company shall be formed to own the project with the joined ownership of private company and local community. The government grant shall be provided to the SPV. The bank shall finance small feasible portion of the project installation cost as loan. The bank loan shall be secured against the projected cash flow of the project and project assets. Roles and responsibilities have been defined for major stakeholders in the implementation model to ensure effective implementation of projects. The local governments (DDCs & VDCs) shall provide monitoring and supervisory roles. They shall also provide necessary statutory approvals for project construction. Furthermore, they shall mediate and resolve disputes in case any disputes arise during project implementation. The community shall participate as equity shareholder of the project. They shall also actively participate in power plant installation by providing local resources, labor force and other logistical support. Furthermore, they shall coordinate with private company for smooth and effective project implementation. In addition, the community shall manage and operate the power plant after commissioning. The private company shall participate as equity shareholder of the project just like the community. The private company shall install power plant in collaboration with local community. They shall also train representatives of local community for the successful operation and management of power plant after commissioning. In addition, private company shall provide technical and managerial support to local community for operation and maintenance of power plant throughout the project life span.

NGO shall be involved in social mobilization of the project. They shall raise awareness of the local community about the importance of electrification project. The NGO shall facilitate communication between local community and private company. The tariff rate shall be fixed based upon a consensual agreement between private company and the local villagers and the NGO shall act as facilitator to reach the consensus. The focal point of the 5 P project shall be AEPC. AEPC is a Government institution under Ministry of Science, Technology and Environment with the objective of developing and promoting renewable/alternative energy technologies in Nepal. The mission of AEPC is to make renewable energy mainstream resource through increased access, knowledge and adaptability contributing for the improved living conditions of people in Nepal (official website, AEPC). AEPC shall be responsible for overall project supervision and management. Besides, AEPC shall also be responsible for quality control of the 5 P projects.

Capitalization and Ownership

The ownership and capitalization structure have been envisioned in such a way that the project is participatory in nature where different stakeholders like community and private company feel the ownership of the project. Therefore, equity investment from both private sector and community is anticipated in 5 P projects. The participation and involvement of different stakeholders have been given special attention in capitalization and ownership design in order to enhance the sustainability of projects. Although exact capitalization and ownership structure is project specific and cannot be generalized, one example of the structure is as below:

Capitalization	Share	Ownership	Share
Bank	15%	Private sector	50%
Private Sector	20%	Community	40%
Community	15%	NGO	10%
Grant	50%		

As it is seen from the table above, both private sector and community are equity investors of project. The long term objective is to remove the grant component from capitalization by gradually reducing the grant amount because reliance on grant for project development is not sustainable in long term.

CONCLUSIONS AND RECOMMENDATIONS

Pro poor public private partnership business model can be a sustainable model for rural energy projects in Nepal and this business model has already been proven successful in Indonesia. 5 P projects enhance sustainability by ensuring participation of all stakeholders for the success of project and by improving socio-economic status of villages through productive end uses of electricity. Two pilot projects have been identified under a 5 P business model that can serve as demonstration of sustainable rural energy projects in Nepal.

The two identified pilot projects are recommended for implementation under 5 P business model. The policies favorable for sustainable development of rural energy projects have to be identified and implemented. Extensive research and development of 5 P business model has potential to make rural energy projects sustainable in Nepal.

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Demand Side Management in Industrial Sector of Nepal

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***Abstract*: This paper analyzes current as well as forecasted energy consumption scenario and effective Demand Side Management (DSM) options with potential GHG emission reduction in industrial sector of Nepal under different income growths scenario. In the beginning, the author reviewed the related literatures on energy consumption pattern in Nepal, application and usefulness of demand side management around the world and review of available energy models. Based on an end use approach of energy management, a survey with a list of questionnaires which included questions about type and amount of fuel used in different end-uses was carried out among 93 out of 3446 manufacturing industries for current energy consumption. The collected data was compiled, analyzed and compared with the help of energy planning tool LEAP (Long Range Energy Alternative Planning). The energy demand and global warming potential was forecasted at different scenarios for the planning horizon up to 2032. The scenario includes different growth rates, efficiency for demand side management and sustainability. The paper concludes with recommendation for different DSM strategies to reduce the energy demand and GHG emission from manufacturing industries in Nepal.**

Keywords: Demand Side Management, Energy Management, GHG Reduction.

1. INTRODUCTION

Energy is a crucial resource for nurturing economic and social development. Economic growth requires increasing amount of energy. Its rate of utilization is observed as a measure of the level of development achieved by a country. The production and consumption of energy affect the environment through emission of greenhouse gases (GHG) and other wastes which are responsible for climate change and other environmental issues.

The energy resources are scarce while the demand is increasing. The supply of petroleum products is interrupted time and often. For sustainability there is the need for Sustainable Energy Planning and Management along with reduction of GHG emission. This planning should include the process of developing long-range policies to help guide the future of a local, national, regional or even the global energy system for sustainable development. The objective of sustainable development is not only

economic growth but also social development which means improvement of health, eradication of poverty, environmental protection, conservation of natural resources, and a better quality of life. Development in order to sustain over a long period of time must not destroy the resources on which it depends.

Energy use in developing countries is increasing rapidly and affecting global climate change with the world's energy resource stocks. GHG emission from

developing countries is projected to contribute to 61% of the global GHG emission by 2030 (Koh, 2011). With less economic resources, the developing countries face the unique challenge of balancing their economic growth and GHG emission reduction. For developing countries, it is important to ensure sufficient energy supply in order to keep the momentum of growth. The already existing infrastructure is usually insufficient to meet the increased demand, which frustrates further economic and social development or even stop development all together.

Nepal's energy resources are broadly divided into three categories: Traditional, Commercial and Alternative. Traditional energy resources include all types of biomass resources used for energy production conventionally. All the energy resources with well-established market prices are grouped under commercial energy category whereas indigenous renewable energy resources are grouped as alternative category (WECS, 2010).

It is crucial to have an idea of fuel consumption by various sectors so that potential energy saving sectors can be identified. Residential sector consumes about 89% of the total energy whereas transport sector consumes about 5% and the industrial sector consumes about 3%. Commercial and agriculture sectors together consume approximately 2% (WECS, 2010). It is clear that energy saving and substitution, and less energy consumption practices in residential sectors is very important to transform our society into a low carbon society.

Moreover, transport and industrial sectors are also potential sectors in which energy saving measures can be implemented. Coal, electricity and agricultural residue have larger shares in industrial energy. From this data it can be said that within the industrial sector the energy saving potential is high. Many industrial processes and energy conversion technologies are conventional where immense potential can be tapped by implementing energy efficiency measures. Improving energy efficiency in industrial sectors (basically on boilers, furnaces, lighting and electric motors etc.) can reduce a huge amount of carbon emission. However, detail investigation of associated economic cost per unit of emission reduction should be identified in order to formulate an action plan of carbon mitigation strategy.

2. Objectives of the Study

The main objective of the paper is to assess demand side management potential and estimate GHG mitigation potential in industrial sector of Nepal with following specific objectives:

1. Find out energy consumption pattern in industries in Nepal.
2. Forecast the energy demands and global warming potentials for future for different scenarios.
3. Determine the energy savings and GHG reduction potential within the industry.
4. Formulate energy plan with scenarios as a basis for sustainable development of energy sources.

3. Assumptions and Limitations

1. The study is limited to the manufacturing industries with NSIC code of Nepal.
2. The number of manufacturing establishments remains constant throughout planning horizon.

4. Methodology

Research methodology is a way to systematically solve the research problem (Kothari, 2005). It depicts the systematic steps of confronting a problem. Methodology includes

4.1 Problem formulation and literature review

The need of demand side management in industrial sector was formulated as a problem and extensive literature review was conducted with the help of internet, books, and journals available.

4.2 Questionnaire design

Questionnaires are typically used for feedback research to determine the current status or "situation," or to estimate the distribution of characteristics in a population. For the data collection from different manufacturing establishments, a list of questionnaires was prepared and collected data was used as input in the LEAP.

4.3 Sample size and field determination

As per the Manufacturing Establishments-2006 (Bureau of Central Statistics), there are about 3446 manufacturing industries in Nepal. It was impossible to collect energy consumption data from all the industries. So, suitable sample size was taken to project total energy consumption for the analysis. The sample size was calculated. After sample size determination, industries were selected for data collection such that they fell into all categories of manufacturing industries.

4.4 Field survey

After listing of manufacturing establishments, the prepared list of questionnaires was taken to listed industries and collection of energy consumption data was done.

4.5 Data compilation

The collected data was recorded in the questionnaire sheet, which was time consuming to read. So, this collected data was then compiled in Microsoft Excel for easier handling and easier input of data in the LEAP for data analysis.

4.6 Analysis, conclusion and recommendation

This compiled data was then analyzed with the help of LEAP by developing different scenarios. Results were found, necessary conclusions were drawn and recommendations were given.

5. Data Collection

The purpose of data collection is to obtain information to keep on record, to make decisions about important issues, or to pass information on to others. To draw conclusions from data, the methods of data collection need to be known. In this research, sample survey has been adopted to collect primary data as the method for data collection. The steps followed for the data collection were:

5.1 Questionnaire development

To find out necessary information and data, first of all questionnaire was prepared. This questionnaire included queries about the introduction, location, energy consumption by fuel type and end-use, technology efficiency, load curve, number of employees, annual purchase of the fuel etc. of the respective manufacturing establishments.

5.2 Sample size calculation & field determination

Based on the literature used by Krejcie & Morgan in their 1970 article “Determining Sample Size for Research Activities” (Educational and Psychological Measurement, #30, pp. 607-610)., the Sample Size Calculator sheet was prepared in Microsoft Excel and the calculations for 3446 manufacturing establishments were shown in a table as below. According to Census of Manufacturing

Establishments Nepal 2006-2007, there were about 3446 manufacturing establishments and no current number of manufacturing establishments was available. Since then many manufacturing establishments had been closed and many have been established. So, 3446 manufacturing establishments were assumed to be the current number for the calculations.

Table 1: Required sample size

Required Sample Size									
Population size	Prob. of Success	Confidence = 95.0%				Confidence = 99.0%			
		Degree of Accuracy/ Margin of Error				Degree of Accuracy/ Margin of Error			
3,446	0.5	0.1	.035	.025	.01	.1	.035	.025	.01
		93	641	1068	2565	158	977	1510	2890

In the above calculation, the required sample size for the population size of 3446 with different confidence limits and respective margin of error can be seen. Due to a short period of time for research, it was impossible to take a large sample size. So, 93 was taken as an appropriate sample size which is within 95% confidence limit and with 10% margin of error. After calculation of sample size, the 93 manufacturing establishments were selected as per NSIC code so that the sample size contained all categories of manufacturing establishments according to their weighted proportion. Special care was given while selecting the samples so that the samples would give overall energy consumption pattern and behavior of industries.

5.3 Field survey

After sample size calculation and field determination, the field survey was carried out in the manufacturing establishments. This was done with the help of well-trained mechanical engineering students of IOE. This was the most time consuming part of this research as it lasted for two months.

The questionnaire developed earlier was used for data collection. The collected data includes the energy consumption of industries by their fuel type such as firewood, coal, diesel, LPG, petrol, kerosene, agricultural residues and electricity etc. and energy consumption by end use i.e. process heating, motive power, boilers, lighting and operating other equipment. Besides this, the time period of energy use, the efficiency of technology and equipment being used, number of employees working and the total annual cost of purchase of fuel were also collected. The primary data was collected in the hardcopy of questionnaire.

The primary data collected from the different manufacturing establishments was not enough for analysis in LEAP. The secondary data included Gross Value Added by Manufacturing Establishments, Share of Gross Value Added by different manufacturing categories in percentage which was collected from National Account Statistics for fiscal year 2068/69, CBS and Census of Manufacturing Establishments 2006/07, CBS respectively.

6. RESULTS AND DISCUSSIONS

6.1 Data compilation

The collected data was then compiled in Microsoft Excel Sheet so that it would be easier to read and handle. The data collected was compiled under different headings such as Energy Consumption of Manufacturing Establishments by Fuel Type, Energy Consumption of Manufacturing Establishments by End-use, Efficiency of Technology being used and Annual purchase of Fuel etc. The sample total value was projected for population total. Some of the important observations are summarized below.

The total current (year 2012) energy consumption of industrial sector was about 13.03 million GJ. Regarding the end-use energy consumption, it is dominated by process heat (39%) that is why coal is heavily consumed in this sector. Other main end-uses of the sector are motive power (31%), boilers (27%) and lighting and other equipment operation contribute about 3%.

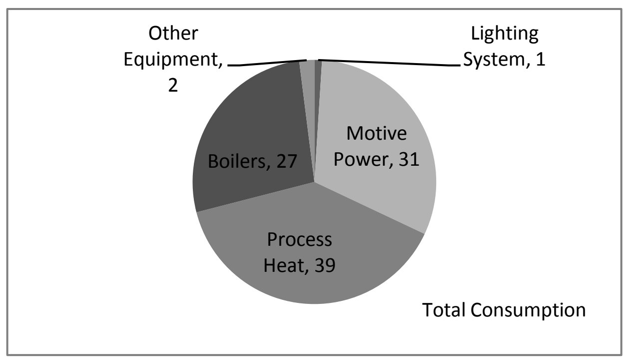

Figure 1: Share of end-use in energy consumption of industrial sector of Nepal, 2012

Many traditional and small scale industries are being closed due to their inability to compete with the international goods. This trend seems likely to continue in the future. Insufficient and unreliable supply of energy, particularly electricity, is the main cause of shutting down of different industries. Electricity provides 32% of the total energy which is the second largest energy source after Coal (39%). Coal is mostly used in boilers and process heating and electricity is mostly used in motive power, lighting and operating other equipment. Biomass resources, particularly fuel-wood and agricultural residue, are still being used in the industrial sector for ignition of fire as well as for heating purpose, sometime together with coal. Biomass still supplies about 14% of the industrial energy requirement. Nowadays, coal is being replaced by diesel in boilers contributing 11% of the energy requirement.

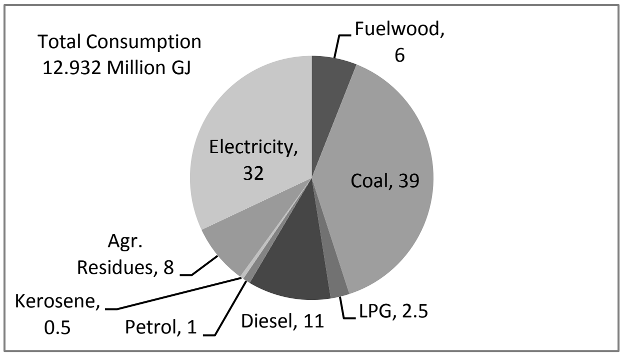

Figure 2: Share of fuel in energy consumption in industrial sector of Nepal, 2012

Based on seven categories of manufacturing establishments, there are about 891 Food, Beverage and Tobacco industries and consumes about 48% of total industrial energy consumption. About 1042 Chemical, Rubber and Plastics industries are responsible for about 40% of energy consumption and the rest energy is consumed in five different categories as shown in Figure 3. Table 1 shows the average efficiency of the technologies and equipment being used.

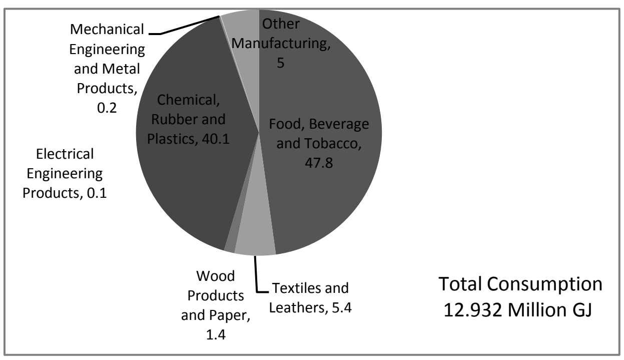

Figure 3: Share of energy consumption of different manufacturing categories, 2012

Table 1: Average efficiency of different technologies

S.N	Type of Equipment	Average Efficiency
1	Florescent	75
2	CFL	80
3	Incandescent	15
4	IC Engines (Diesel)	30
5	IC Engines (Gasoline)	25
6	Electric Motors	87.5
7	Boilers	65
8	Fuel-fired Heating	35
9	Electrical Heating	75
10	Other Equipments	85

Table 2 shows the cost of different fuel types per energy content in GJ. Coal, fuel wood and agriculture residues are the cheaper fuel but they are the most polluting fuel with high GHG emission. The purchase rate below is according to the current market price. Other petroleum products and electricity have high purchase rate per energy content.

Table 2: Cost of fuel per energy content in GJ, 2012

SN	Description	**Purchase Rate** (Rs.per kg or lit. or kwhr)	**Energy content** (GJ per tonnes or kl or mWhr)	**Rate** (Rs. Per GJ)
1	Firewood (tonnes)	10	16.75	597
2	Coal (tonnes)	2	25.12	80
4	Petrol (KL)	120	36.421	3295
5	Kerosene (KL)	93	36.26	2565
6	LPG (tonnes)	105	49.24	2132
8	Electricity (MwHr)	7	3.6	1944
9	Agri. Residues (tonnes)	5	12.56	398
11	Diesel (KL)	93	37.93	2452

Figure 4 shows the annual purchase of fuel in Rs.'000 in manufacturing industries in Nepal. Although coal contributes about 39% of total energy requirement of manufacturing industries, it is cheaper so it is relatively a low investment. Electricity contributes about 32% of the total energy requirement but the investment on it is very high in comparison to other fuels. It is also due to its high purchase rate per energy content.

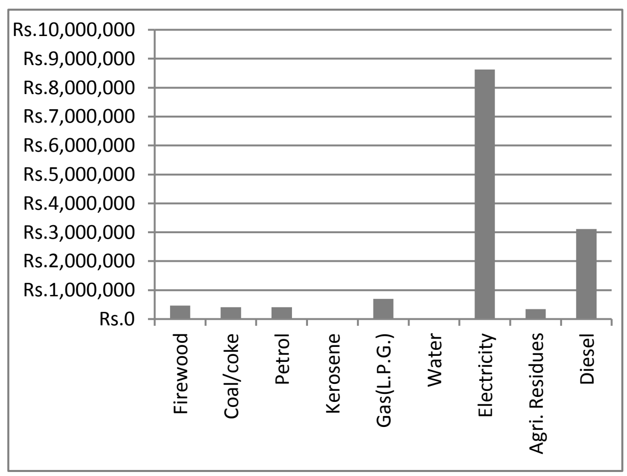

Figure 4: Annual purchase of fuel in Rs. '000 in manufacturing industries of Nepal, 2012

6.2 LEAP structure design

Before 2000, world real GDP (based on USDA Economic Research Institute data) was indeed growing faster than energy use, as measured by BP Statistical Data. Between 1980 and 2000, world real GDP growth averaged a little below 3% per year, and world energy growth averaged a little below 2% per year, so GDP growth increased about 1% more per year than energy use. Since 2000, energy use has grown approximately as fast as world real GDP increases for both have averaged about 2.5% per year growth (Gail Tverberg, 2011). Looking at the relationship between world GDP and world energy use it seems that decoupling is really possible as shown in figure 5. So, in this research it is assumed that the change in energy consumption in industries is solely dependent on the Gross value added by manufacturing establishments and is directly proportional.

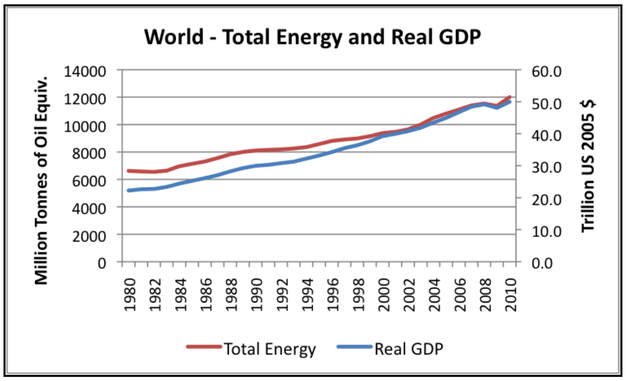

Figure 5: Relation between Total Energy and Real GDP (Source: Grail Tverberg, 2011)

6.2.1 Model development

The collected data regarding energy consumption in different end use energy demand of manufacturing establishments in Nepal was fed into the LEAP energy model to forecast the future energy demand and conduct the demand side management simulation analysis.

Energy Demand = Energy Intensity × Activity Level

Energy intensity is the amount of energy used per gross value added by the respective manufacturing category in national GDP.

Activity Level is the gross value added by the respective manufacturing category in Nation GDP.

Energy demand changes with the change in energy intensity or activity level or both.

6.2.2 Industrial demand side management LEAP model

The key assumptions and activity level are defined first for the analysis of Demand Side Management of Industrial Sector i.e. manufacturing establishments. The industrial sector is further divided into seven different manufacturing categories namely Food, Beverage and Tobacco; Textiles and Leathers; Wood Products and Paper; Chemical, Rubber and Plastics; Mechanical Engineering and Metal Products; Electrical Engineering Products; and Other Manufacturing. Under each manufacturing category, five different energy consuming end-uses are taken namely Lighting System, Motive Power, Process Heat, Boilers and Other equipment. Under each end-use, the fuel being used is placed and in each fuel being used, the Global Warming Potential is taken. But in this analysis, electricity is considered to have zero emission. The general schematic flowchart of Industrial Demand Side Management LEAP Model is shown in figure 6.

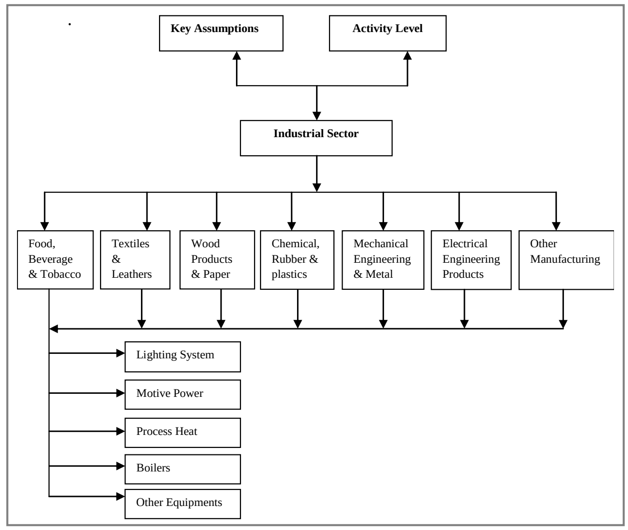

Figure 6: Industrial Demand Side Management Leap Structure

6.2.3 Key assumptions

They are used to indicate variables and data (e.g. GDP, industrial output, population, consumption, investment etc). These variables are not output as results from LEAP, but are used instead as intermediate variables that can be referenced in your Demand, Transformation and Resource models. (Source: User Guide for Leap, 2005)
The chief key assumption included in this model is Economic Industrial GDP.

6.2.4 Activity level analysis

Activity level analysis was pursued in the LEAP model to calculate and forecast the future energy need of the area. In this, the default methodology, energy consumption is calculated as the product of an activity level and annual energy intensity (energy use per unit of activity). Total energy consumption is thus calculated by the equation:

Energy consumption = activity level × energy intensity

In the industrial demand side management LEAP model,

Activity level = Gross value added by the respective manufacturing category in national GDP

Energy intensity = gross value added by the respective manufacturing category in national GDP

Total energy consumption = Activity level × Energy intensity

6.3 Scenario development, results and analysis

After feeding the collected primary and secondary data in Current Accounts of LEAP, the different planning scenarios were developed according to the objective of this research for forecasting the energy consumption and Global warming potential.

The assumptions made in forecasting all scenarios in this research are:

- The change in energy consumption in industries is solely dependent on the Gross value added by manufacturing establishments and is directly proportional.
- The base year for the model is 2012 and a horizon of 20 years is used, thus modeling until 2032.

6.3.1 Growth rate scenario

The Growth rate of Gross value added by manufacturing establishments was sometime positive and sometimes negative in the past. The growth rate in percentage for 2005 was 2.00 and 2.55, -0.87, -1.05, 2.96, 2.29, and 1.28 for consecutive years. So, the growth rate for the next 30 years was forecasted using CB predictor (Crystal Ball) with Single Exponential Smoothing. It was about 1.87 as shown in figure 7 and was used as normal growth rate. Under this growth rate scenario further two scenarios were developed, namely high growth rate scenario with 3. 00 as growth rate and low growth rate scenario with 0.5 as growth rate.

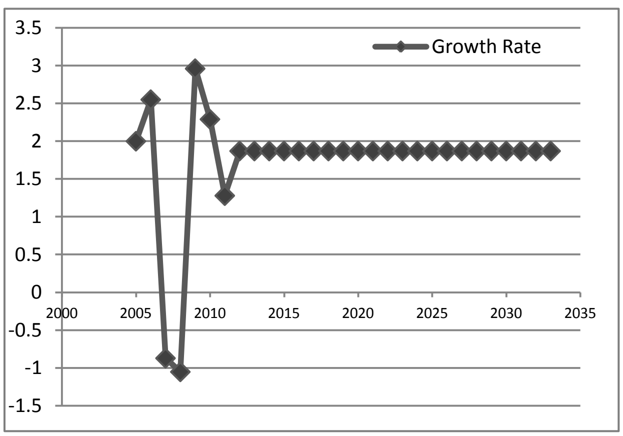

Figure 7: Forecasting of normal growth rate using single exponential smoothing

From figure 8, the energy demand is increased to 18.732 million GJ with normal growth rate, 23.356 million GJ with high growth rate and 14.288 million GJ with low growth rate scenario by the end of year 2032 from base year consumption of 12.932 million GJ. From figure 9, the global warming potential is increased to 872.298 thousand metric tons CO_2 equivalent with normal growth rate, 1087.635 thousand metric tons CO_2 equivalent with high growth rate and 665.365 thousand metric tons CO_2 equivalent with low growth rate scenario by the end of year 2032 from base year emission of 602.197 thousand metric tons CO_2 equivalent.

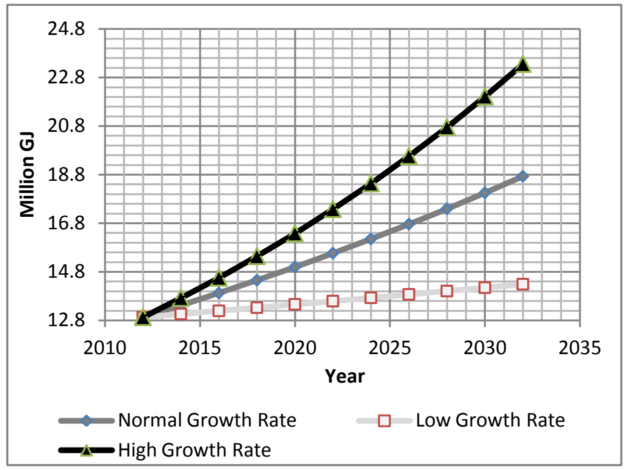

Figure 8: Comparison of Energy Demand of Different Growth Rate Scenario

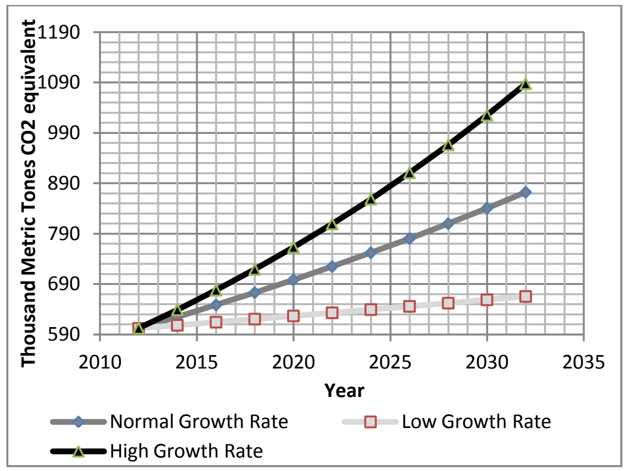

Figure 9: Comparison of Global Warming Potential of Different Growth Rate Scenario

6.3.2 Demand side management scenario

The assumptions made in forecasting this demand side management scenario are

- The Growth rate of Gross value added by manufacturing establishments is 1.87 throughout the planning horizon.

Under this demand side management scenario, five different energy efficient systems were developed.

In **Efficient lighting scenario**, the energy consumption pattern is assumed to remain the same i.e. no new technology is introduced except CFL replaces other lighting system by the end of year 2020 to fulfill 90% energy demand and modeling is totally based on base year energy consumption.

In **Efficient motive power scenario**, the energy consumption pattern is assumed to remain the same i.e.

no new technology is introduced except energy efficient motors replace all standard motors by the end of year 2020 and modeling is totally based on base year energy consumption.

In **Efficient process heat scenario**, the energy consumption pattern is assumed to remain the same i.e. no new technology is introduced except new energy efficient technology is introduced in all brick industries by the end of year 2020 and modeling is totally based on base year energy consumption.

In **Efficient boilers scenario**, the energy consumption pattern is assumed to remain the same i.e. no new technology is introduced except different above discussed techniques are adopted to increase the efficiency of boilers from 65% to 80% by the end of year 2025 and modeling is totally based on base year energy consumption.

In **Efficient scenario**, the energy consumption pattern is assumed to remain the same i.e. no new technology is introduced except CFL replaces other lighting system by the end of year 2020 to fulfill 90% energy demand, energy efficient motors replace all standard motors by the end of year 2020, new energy efficient technology is introduced in all brick industries by the end of year 2020, different above discussed techniques are adopted to increase the efficiency of boilers from 65% to 80% by the end of year 2025 and modeling is totally based on base year energy consumption.

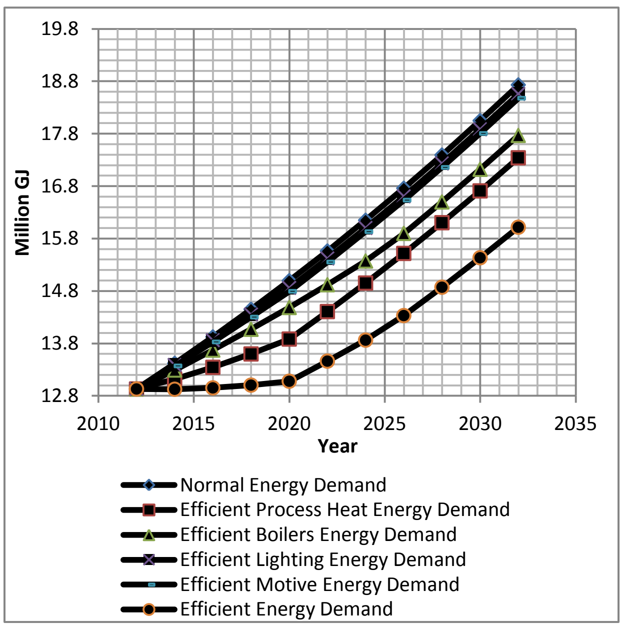

Figure 10: Comparison of energy demand of different DSM scenarios

In figure 10, the trend line representing Efficient Lighting scenario and Normal Growth Rate Scenario are different; about 0.17 million GJ can be saved only in the year 2032. The amount of energy that can be saved is increasing every year which suggests a significant amount of energy can be saved throughout the planning horizon when switched to CFL with little expense in replacement of existing lighting system. This is justifiable since the payback period is very short. Similarly, the trend lines representing Efficient Motive Power scenario and Normal Growth Rate Scenario are different; about 0.25 million GJ can be saved only in the year 2032. The amount of energy that can be saved is increasing every year which suggests a significant amount of energy can be saved throughout the planning horizon when switched to energy efficient motors with little expense in replacement of existing standard motors. This is justifiable since the payback period is short.

Also figure 10, shows that about 1.39 million GJ of energy consumption can be saved in the year 2032 and the amount that can be reduced is increasing every year and remains constant after 2020 which suggests a significant amount of energy can be saved and GHG can be reduced throughout the planning horizon when switched to new energy efficient technology with little expense in installation of induced fan. This is also justifiable since the payback period is short. Similarly, about 0.96 million GJ of energy consumption can be saved in the year 2032 and the amount that can be reduced is increasing every year which suggests a significant amount of energy can be saved and GHG can be reduced throughout the planning horizon when efficiency of boilers is increased with little investment in repairing which is justifiable since the payback period is short.

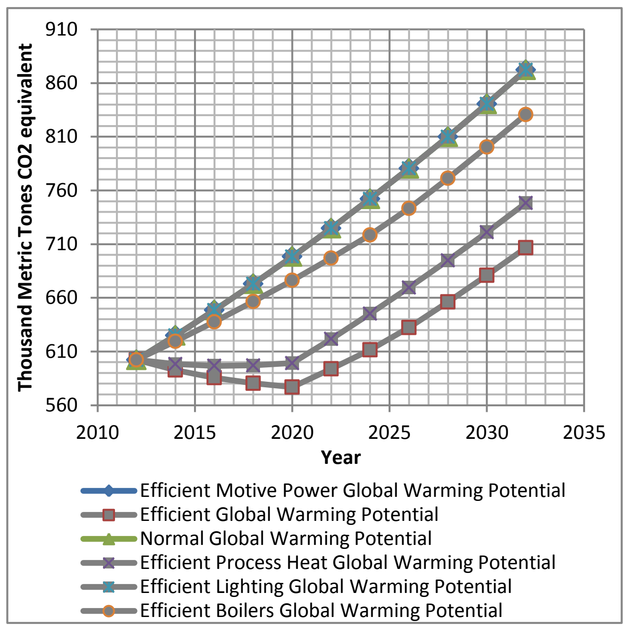

Figure 11: Comparison of global warming potential of different DSM scenarios

In figure 11, the trend lines for global warming potential for normal growth rate, efficient lighting and efficient process heat both are the same. This is because the fuel used in lighting system and motors is electricity and it has negligible amount of emission so switching to CFL and energy efficient motors has no significant contribution in GHG reduction. But, the trend lines for global warming potential for efficient process heat and efficient boilers when compared to normal scenario are different. This is because the fuel used in brick industries and boilers are coal and fuel-wood. After introducing new technology, the efficiency increases reducing energy consumption and GHG emission.

From both figure 10 and 11, the trend lines for both energy demand and global warming potential for efficient and normal scenario are different. This is because in this efficient condition less fuel is used resulting in reduction of GHG emission. About 2.71 million GJ energy consumption and 165.63 thousand metric tons CO2 equivalent GHG emission can be reduced only in the year 2032. The amount that can be reduced is increasing every year which suggests a significant amount of energy can be saved and GHG can be reduced throughout the planning horizon when all efficient conditions are applied all at a time with the investment which is justifiable since the payback period is short.

6.3.3 Sustainable scenario

The assumptions made in forecasting this scenario are

- All other fuels are replaced by electricity by the end of year 2025 and modeling is totally based on base year energy consumption and the growth rate is 1.87.

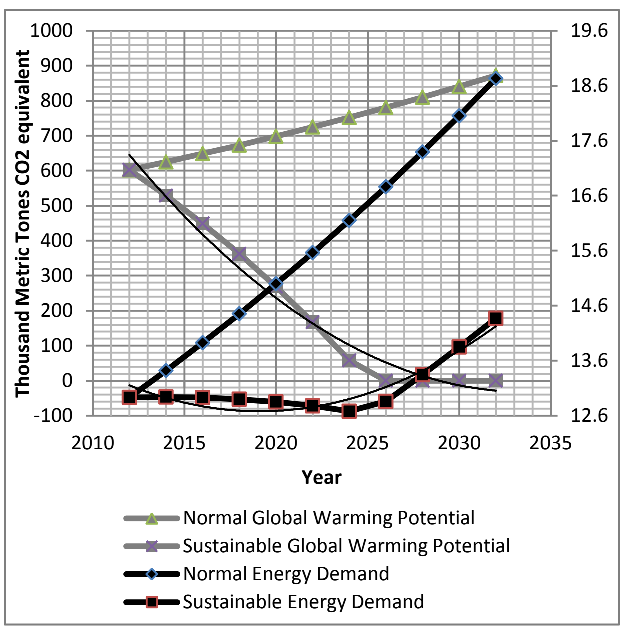

Figure 12: Energy demand and global warming potential of sustainable Vs normal growth rate scenario

This planning scenario is forecasted where all types of fuel are replaced by electricity. Electricity is considered as sustainable fuel since its environmental loading is negligible in comparison to other fossil fuels. From figure 12, the trend lines for both energy demand and global warming potential for both the scenario are different. This is because in this sustainable scenario the only fuel used is electricity which is efficient technology resulting in significant reduction of GHG emission. About 4.36 million GJ of energy consumption can be reduced only in the year 2032 and the amount that can be reduced is increasing every year which suggests a significant amount of energy can be saved throughout the planning horizon and GHG emission reduces to zero after 2025 when all types of fuel are replaced by the end of 2025 with the investment which is justifiable with short payback period.

7. SUMMARY

In this research, the total energy consumption and global warming potential has been projected and forecasted for the planning horizon up to 2032 in different scenarios. To address the increasing energy demand and GHG emission, different demand side management strategies have been found applicable with significant reduction in energy consumption and GHG emission for the upcoming years. This demand side management strategy includes replacing of others lighting system with CFLs, replacement of standard motors with energy efficient motors, using an Induced Draft Fan (ID Fan) in brick industries and increasing efficiency of boilers by adopting different measures. Also, replacing all existing technologies with technology using electricity would the best option for the sustainable development significantly reducing energy consumption and GHG emission but with little more capital investment and payback period.

8. CONCLUSION

Manufacturing industries being the most important sector contributing to the GDP, demand side management would be the best approach to be adopted for energy savings and emission reduction. Here are the some of the important conclusions of this research.

- The current energy consumption was found by taking suitable sample size of 93 out of 3446 manufacturing industries with the help of list of questionnaires which includes the questions about type and amount of fuel used in different end-uses. The collected data was compiled and the current total energy consumption was projected about 12.932 million GJ.
- The current total energy consumption was projected about 12.932 million GJ and for same consumption trend at normal growth rate of 1.87% which was forecasted by single exponential smoothing, the energy demand and global warming potential would

be 18.73 million GJ and 872.29 thousand metric tons CO_2 equivalent respectively by the end of year 2032. This would be 23.35 million GJ and 1087.63 thousand metric tons CO_2 equivalent for high growth rate of 3 % and 14.28 million GJ and 665.36 thousand metric tons CO_2 equivalent for low growth rate of 0.5%.

- In efficient scenario like Efficient Lighting, Efficient Motive Power, Efficient Process Heat and Efficient Boilers, results show that a huge amount of energy can be saved and GHG emission can be reduced.
- Likewise in sustainable scenario in which all types of fuel are replaced by electricity, the GHG emission can be reduced to zero along with significant decrease in energy demand.

So, the finding suggests that it's worth adopting demand side management in industries with justifiable investment in the technology within a short payback period.

9. Recommendations

Based on the findings of this research, recommendations for management of energy consumption in industrial sector are as follows.

- Demand side management would be the best approach to be adopted to meet the increasing energy demand and GHG emission reduction in industrial sector.
- DSM approaches suggest replacing lighting systems by CFL and standard motors by energy efficient motors, introducing Induced duct fan in brick industries, increasing efficiency of boilers to be applied in industries.
- Switching other types of fuel to electricity is highly recommended for sustainable development and significant energy savings and GHG emission reduction.

10. Further Research Areas

This research is intended to find the energy consumption pattern in industrial sector and its demand side management. Further research can be carried out to find the energy consumption pattern in other sectors such as residential areas, transport system, etc. This would be significant for getting latest energy consumption data. For this taking a large sample size would be better to minimize margin of error. Also, apart from these demand side management strategies included in this research there are many other DSM strategies which would be further areas of research in energy management in industrial sector.

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Effect of Conc. Sulphuric Acid on the Adsorption Capacity of Char Obtained from Lapsi (*Choerospondias axillaris*) Seed Stone

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Abstract*: An acid treated char was prepared by pylolysis of Lapsi seed stone at 300^o C for 3hrs followed by conc. H_2SO_4 treatment of the resulting char. The characteristics of the untreated char and acid treated char were determined by pH, Fourier transform infrared spectroscopy (FTIR), scanning electron Microscopy (SEM), and iodine number. The adsorption of methylene blue by acid treated char was analyzed by the Langmuir and Freundlich adsorption isotherms. It has shown that, adsorption capacity of acid treated char for Iodine and methylene blue (431 and 156 mg/gm) is higher compared to untreated char (186 and 59 mg/gm). The enhancement of porous structure of untreated char by acid treatment was also confirmed by SEM image. The FT-IR analysis depicts the presence of various acidic surface functional groups in acid treated char compared to that of untreated char. The methylene blue adsorption equilibrium data of acid treated char was best represented by the Langmuir adsorption isotherm. Based on the results of the characterization studies, it has shown that the adsorption capacity of char obtained from Lapsi seed stone is significantly increased by sulphuric acid treatment and can be used as *cost effective adsorbent.

***Keywords:* *Lapsi seed stone, acid treated char, sulphuric acid*.**

1. INTRODUCTION:

The char is a black solid carbonaceous residue with a high amount of fixed carbon (75%) that can be used directly as a precursor for activated carbon production, fuel or fertilizer [1]. One of the choices for char utilization is for adsorption purpose. This property makes these solids very interesting to be used in many industrial applications.

Char has a rudimentary porous structure and is not enough for practical application. So the pore structure and surface area of char has to be enhanced by activation process [3]. Activation of char is performed by treating it with physical and chemical agents. It improves the porosity and increases the acidic functional groups mainly on the aromatic surfaces of carbon. Similarly, Acid treatment is generally used to oxidize the porous carbon surface. It removed the mineral elements and enhanced the acidic characteristics and improved the hydrophilic of surface. Among which, nitric acid and sulphuric acid are the widely used. The acid used for this purpose should be oxidizing in nature used [4]. Acid treated char with increased acidic functional groups could be used for water and wastewater treatment. One of the challenges of both char production and subsequent activation is to keep production costs and at the same time produce value-added products that will encourages research in the production and use of char [5].

Char is produced as a charred material by thermal decomposition of biomass material under conditions of limited supply of oxygen and at relatively low temperatures (300-700°C) [6]. Thermal processes will develop pores on the biomass char surface, which make char capable of acting as an adsorbent [1]. Fast pyrolysis of biomass includes rapid thermal decomposition of organic compounds in an inert atmosphere to produce a mixture of liquid organic compounds, gases, and char [7]. The distribution of products depends on the heating rate, residence time, surrounding atmosphere and temperature. Pyrolysis conditions and feedstock characteristics largely control the physical and chemical properties (e.g. composition, particle and pore size distribution) of the resulting char, which in turn determine the suitability for a given application [8]. The pyrolysis conditions includes environment of charring (e.g. temperature and type of atmosphere), and additions during the charring process [9, 10]. The carbonaceous feedstock can be used advantageously to produce chars or activated carbons, due to their low cost and wide availability [11]. The feedstock include agricultural wastes such as nut shells, rice hulls, bagasse, wheat straw, and forest residue such as sawdust and bark [12].

In present study, Lapsi seed stone were selected as feedstock for char preparation because of their availability and economic feasibility. Lapsi seed stone is the waste product of Lapsi (Choerospondias axillaris) fruits commonly used as fuel in brick kilns in the factories [13]. Earlier studies have investigated Lapsi seed stone as a precursor for the preparation of high surface area activated carbon [14, 15]. The objectives of the current work aimed to study the influence of sulphuric acid on characteristics of Lapsi seed stone char as well as to introduce the Lapsi seed based char as a cost effective adsorbent.

2. EXPERIMENTAL

2.1. Materials

The Lapsi seed stone were purchased from food Industry, Kathmandu, Nepal. The chemicals used for this investigation and analysis were all analytical grade purchased from Qualigen, India were used.

Lapsi seed stones were washed with distilled water and oven dried at 110°C for 24 hrs. The seed stones were then washed dried and crushed into powder. The seed stone powder was then sieved to obtain the fraction of size 212 μm.

2.2. Preparation of Adsorbent:

An acid treated char was prepared according to the procedure [16]. 20 gm of the crushed Lapsi seed stone was kept for 3 hrs in a low temperature muffle furnace at 300°C to prepare char. One portion of char was then treated with 30 ml of concentrated sulphuric acid. Then the acidified char was then kept in an oven at 110°C for overnight. After that, both the char and the acid treated char were washed with distilled water to make it free of acid. The prepared char was finally dried in an oven at 110°C for 24 hours and sieved to obtain a particle size of 106 μm. Those chars were labelled as $\mathbf{C_1}$ (Untreated char) and $\mathbf{C_2}$ (acid treated char).

2. 3. Characterization of the Activated Carbon

The acidity or basicity of char was confirmed by determining pH. The specific surface of the $\mathbf{C_1}$ and $\mathbf{C_2}$ was determined by the adsorption on different adsorbates, such as methylene blue and iodine.

2.3.1. Determination of pH

In order to determine pH of both char, the standard test method ASTM-D3838-80 was used [17]. 1.0 gm of each sample $\mathbf{C_1}$ and $\mathbf{C_2}$ was separately transferred into 100 ml distilled water taken in a beaker and kept in a magnetic stirrer for one hour. pH of the solution was then measured by using pH meter.

2.3.2. Iodine number (IN)

The iodine number of the char was determined according to the ASTM D4607-94 method. The iodine number is defined as the milligrams of iodine adsorbed by 1.0 g of carbon [18]. It is a rough measure of capacity of small molecules and correlates with surface area and may be used as an approximation of surface area for activated carbons and char [19]. 0.1 gm of each $\mathbf{C_1}$ and $\mathbf{C_2}$ sample was separately treated with 10.0 mL of 5% HCl and gently swirled the mixture until the carbon was completely wetted. Then the mixture was boiled and cooled. Soon afterwards, 10.0 mL of 0.1 N iodine solutions is added to the mixture and shaken the contents vigorously for 4 min. The resulting solution was filtered and 10.0 mL of the filtrate was titrated with 0.1 N sodium thiosulphate, using starch as indicator.

2.3.2. Methylene blue number (MBN)

The methylene blue number is defined as the maximum amount of dye adsorbed on 1.0 gm of adsorbent. Methylene blue number was determined according to Method described in the literature [20]. In this assay, 0.1 gm of each sample $\mathbf{C_1}$ and $\mathbf{C_2}$ was separately placed in contact with 100 mL of a methylene blue solution at different concentrations (ranging from 10 to 100 ppm) for 24 hr at room temperature (approximately 25°C). After agitation, the suspensions were filtered and the remaining concentration of methylene blue was analyzed using a UV/Vis spectrophotometer (UV- CECIL- CE-100) at 645 nm.

2.3.4. Scanning electron microscopy (SEM)

Surface morphology of the prepared char was studied using scanning electron microscopy. SEM samples were prepared on a carbon tape and images were taken using U-8000, Hitachi Co. Ltd. Japan.

2.3.5. Fourier Transform Infrared Spectroscopy (FTIR) analysis

The FTIR of the char sample was analysed using Shimadzu 8300 spectrometer and the spectrum was recorded in a spectral range of 400-4000 cm^{-1}. The powder is mixed with KBr before being pressed into a disk.

3. RESULT AND DISCUSSION

3.1. pH, Iodine and methylene blue numbers of both char

pH, Iodine number and methylene blue numbers of $\mathbf{C_1}$ and $\mathbf{C_2}$ are given in Figure 1**.** The pH value of $\mathbf{C_1}$ and $\mathbf{C_2}$ indicates that, $\mathbf{C_1}$ is neutral while $\mathbf{C_2}$ is fairly acidic in nature.

Since Iodine is a small molecule, it provides an indication of the adsorption capacity of particular carbon for smaller molecules and correlates with the surface area in pores with diameters less than 1 nm [21, 22]. Iodine number of $\mathbf{C_2}$ is higher compared to $\mathbf{C_1}$ indicating that, $\mathbf{C_2}$ was efficient in adsorbing Iodine (**Figure: 1**).Therefore, knowing that Iodine is used to characterize microporous carbons, it can be inferred that of the $\mathbf{C_2}$ studied was microporous.

Similarly, $\mathbf{C_2}$ gave fairly high methylene blue value (q_m) of 156 mg/gm compared to that of $\mathbf{C_1}$ of 59 mg/gm. It suggests that, $\mathbf{C_2}$ have a comparatively higher mesoporosity which it gain during acid treatment and favourable to adsorb larger molecules. Due to the acidic treatment of charcoal, it becomes protonated, having a positive charge on its surface, which provides effective sites for the dye adsorption. Hence $\mathbf{C_2}$ becomes more effective in adsorption for the above reason.

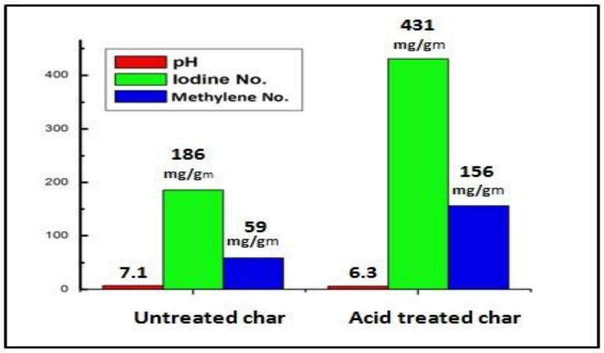


Figure 1: pH, Iodine No., Methylene blue No. of untreated char (C_1) and acid treated char (C_2)

3.2. Scanning electron microscopy (SEM)

SEM images are primarily used to determine the distribution of the pores that are present on the surface of the carbon. Scanning electron micrographs for external surface morphology of $\mathbf{C_1}$ and $\mathbf{C_2}$ are displayed (Figure 2). The SEM image of $\mathbf{C_1}$ has shown that, there is no pore formation seen on its external surface while the external surface of $\mathbf{C_2}$ seems to be porous, consisting of numerous tiny pores, resulted by oxidation with conc. sulphuric acid. It also confirmed that, the porosity of $\mathbf{C_1}$ has been increased by acid treatment.

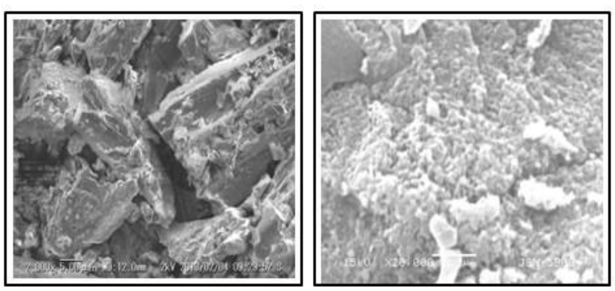


Figure 2: SEM Images of Untreated char (C_1) (left) and Acid treated char (C_2) (right)

3.4. Fourier Transform Infrared (FTIR) Analysis

The adsorption capacity of activated carbon depends upon porosity as well as the chemical reactivity of functional groups at the surface [23]. The presence of various functional groups on the carbon surface contributes to preferential uptake for different molecule species by carbon. FTIR spectra were collected for characterization of surface functional groups of prepared $\mathbf{C_1}$and $\mathbf{C_2}$ (Figure 3).

On comparing the FTIR spectra of $\mathbf{C_1}$ to that of $\mathbf{C_2}$, the increasing numbers of absorption bands were found in $\mathbf{C_2}$. These bands are located at around 3414 cm^{-1}, 3055 cm^{-1}, 1704 cm^{-1}, 1595 cm^{-1}, 1423 cm^{-1}, 876 cm^{-1},825 cm^{-1} and 761 cm^{-1} in acid treated char (Figure 3). A band at 3414cm^{-1} is assigned to O–H stretching vibration in hydroxyl groups [24]. However, weak peak appeared slightly above 3000 cm^{-1} in AC demonstrates unsaturation indicating alkenyl C= C stretch [15]. The band around 1704 cm^{-1} is related to the stretching of C=O in linear aliphatic aldehydes or ketones and carboxyls formed in an oxygen atmosphere [25]. The band in the region of ≈1600 cm^{-1} is due to C=C stretching vibrations in the aromatic ring for most carbonaceous materials [26].The band observed at 1423 cm^{-1} is ascribed to C–O–H stretching vibration in carboxylic group[27]. The bands at 876–761 cm^{-1} are assigned to C–H out–of–plane bending in the aromatic rings [28]. The adsorption bands for H–C=O (carboxylic group), O–H (hydroxyl group) and C=O (carbonyl group) in Thus FTIR spectra of $\mathbf{C_2}$ indicates the presence of oxygen containing functional groups which were generated during acid activation.

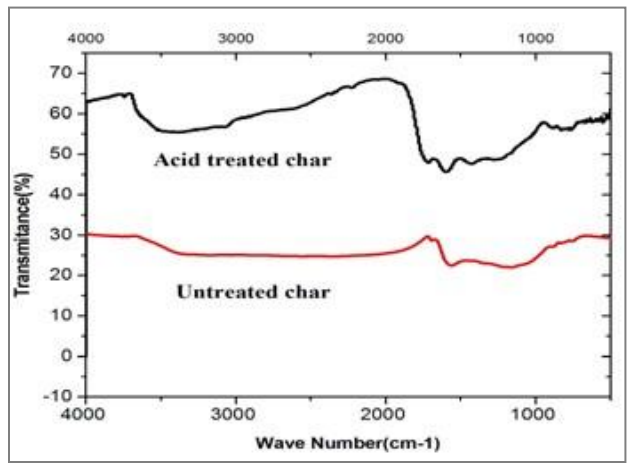


Figure 3: FTIR of untreated char and acid treated char

3.3. Adsorption isotherm of acid treated char for methylene blue

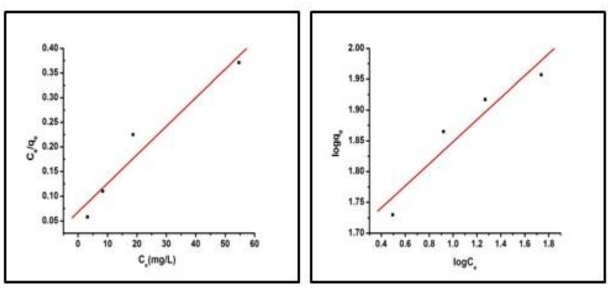
An adsorption isotherm represents the equilibrium relationship between the adsorbate concentration in the liquid phase and the adsorbate adsorbed on the surface of the adsorbent at constant temperature [29]. The Langmuir and Freundlich isotherms are the two well-known isotherms which have been used to describe the equilibrium of adsorption systems [30]. The Langmuir isotherm is based on an assumption that the adsorption occurs at specific homogeneous sites within the adsorbent and is often applied in solid/liquid system to describe the saturated monolayer adsorption [31]. The linearized form of the Langmuir equation can be represented as:

$$\frac{C_e}{q_e} = \frac{1}{bq_m} + \frac{C_e}{q_m}$$

where, Ce is the equilibrium concentration of methylene blue in solution (mg//L); qe is the amount of methylene blue adsorbed (mg/g); q_m is the maximum adsorption capacity corresponding to complete monolayer coverage. (mg/g); b is adsorption equilibrium constant (L/mg) which related to the affinity between adsorbent and adsorbate [30]. The two adjustable parameters q_m and b can be determined by the slope and intercept of the linear plot of $\frac{C_e}{q_e}$ versus $C_{e.}$ The Freundlich isotherm is an empirical equation employed to describe the heterogeneous system [31]. The linearized form of the Freundlich equation is shown as.

$$\log q_e = \log K + \frac{1}{n}\log C_e$$

Where q_e is the amount of ion adsorbed (mg/g); C_e is the equilibrium concentration (mg/L); K and 1/n are empirical constants, indicating the adsorption capacity and adsorption intensity, respectively. The plot of log q_e versus log C_e should result in a straight line. The constants n and K can be determined from the slope and the intercept. The applicability of the isotherm equations was compared by judging the coefficients of determination R^2 [32]. The methylene blue adsorption data of $\mathbf{C_2}$ was plotted for Langmuir and Freundlich isotherm (Figures: 4 a and 4 b).



a) Langmuir isotherm b) Freundlich isotherm

Figure 4: Adsorption Isotherm of methylene blue for acid treated char (C_2)

Table1: Correlation Coefficients in Langmuir and Freundlich isotherm

Acid treated char $(\mathbf{C_2})$	Langmuir constants		Freundlich constants	
	q_m (mg/gm)	R^2	Log K	R^2
	156	0.938	1.671	0.902

From the Table 1, It has shown that, for $\mathbf{C_2}$, the values of coefficient in Langmuir isotherm (R^2 =0.938) was found to be higher than that of Freundlich isotherm (R^2 =0.907) which shows that, the data both fitted Langmuir and Freundlich isotherms but fitted better in Langmuir isotherm equation. This implies that a monolayer adsorption proceeds over a surface of $\mathbf{C_2}$ containing a finite number of adsorption sites and uniform strategies of adsorption. Langmuir constant q_m and adsorption capacity log K were determined from the slope and intercept of the plot are presented (Table 1).

4. Conclusion

The influence of sulphuric acid on the char prepared from Lapsi seed stone was studied. Different parameter such as Iodine number, methylene blue number, SEM image and FTIR spectroscopy were used to characterize $\mathbf{C_1}$ and $\mathbf{C_2}$ performance. The experimental data of methylene blue adsorption for $\mathbf{C_2}$ fitted well to the Langmuir model showing monolayer adsorption. Adsorption capacity of $\mathbf{C_2}$ for Iodine and methylene blue (431 and 156 mg/gm) is higher compared to $\mathbf{C_1}$ (186 and 59 mg/gm). The increasing pores on the surface of $\mathbf{C_2}$ can also be seen in the SEM image. FTIR analysis has confirmed that, surface of the $\mathbf{C_2}$ contains more acidic surface functional groups compared to that of $\mathbf{C_1}$. It is concluded that adsorption capacity of char prepared from Lapsi seed stone is significantly influenced by sulphuric acid treatment and can also be applied as a possible low cost alternate adsorbent as well.

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Study on Diesel Fuel Consumption Reduction in Dairy Industries by Application of Solar Thermal Energy

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Abstract: This work analyses the fraction of total load that can be supplied by solar thermal technology using flat plate collectors. DDC, Lainchaur, which processes 60,000 litre of milk per day has been taken as the basis for this study, since most of the private dairy industries are smaller than this.

Technically, two isolated solar thermal storage tanks were used in conjunction with a collector array. The hot water collected from the first tank at the end of each day would be used in the boiler as feed water in the next morning. The second tank would then be used to store hot water for the next day. In this way each tank would supply and store energy on alternate days.

Initial screening was done by simulation using MATLAB from which the average temperatures that can be achieved per day for each month in a water storage tank of 2,500 litres were calculated and total energy gained annually on this temperature basis was calculated. Again, the total energy gained annually was calculated by total area of collector used. Energy gained by the area basis was found to be more by 7.17% only. This was due to the fact that losses in tank and connecting pipes were not accounted while calculating by area basis. The legitimacy of the above findings were checked by F-Chart [6] method and found that the fraction of total load supplied by area basis was only 1.17% more than that calculated value from F-chart method .Thus all further calculations were carried out using area basis.

It was determined that use of Solar Water Heating System with 55 square meter of collector area and two insulated hot water tank storage of 2,500 litres capacity each, can reduce the diesel fuel consumption by 5,843.27 litres annually for the size of the dairy considered i.e. a dairy of capacity of 60,000 litres milk processing per day. The CO2 emission reduced by15, 659.98 kg annually. The project is financial viable since its Net Present Value is positive.

Keywords: Solar radiation, Solar thermal system, Total fraction, F-chart

1. Introduction

Most industries in Nepal use diesel and kerosene boilers to meet their hot water requirements. Some of the industries that heavily depend on fossil fuel boilers for hot water are: hotels, dyeing factories, carpet washing factories, breweries, and dairies. Efficient solar water heaters can replace water boilers in hotels, dyeing and carpet washing industries almost completely and can be used to preheat water up to 60 degree centigrade in breweries and dairies. With these industries using diesel and kerosene for heating water, large amounts of GHGs are emitted every day. Under the recent energy scenario where fossil fuel prices are skyrocketing, using high efficiency solar water heaters can be a potential alternative. Meanwhile, the solar water heating technologies are getting more efficient and affordable. The upfront investments required installing a locally assembled high quality solar water-heating system can be paid back within 3 to 4 years from the savings made through avoided use of fossil fuels. Solar water heating systems are available with 20 plus years of "trouble free" guarantees. This proves solar water heating systems to be much more economical than diesel/kerosene boilers in terms of life-cycle cost. Apart from being economical, solar water heaters are environment friendly. They are zero-emission energy providers and contribute towards cleaning the local air as well as reducing GHG emissions.

2. Research Methodology

Every research needs systematic tools and methods in order to make remarkable achievements. Nowadays simulation of the model in computer is done at first in order to assess the feasibility of the actual model as well as to realize the performance of the system in advance. Then only the real model is built and experiment is conducted in it. In this research also, the basic steps followed during the study periods are:

a. Solar thermal System Design
b. Simulation of the Solar Thermal System
c. Financial Analysis

2.1. Design of Solar Thermal System

The solar thermal system design is done for the boiler used in the DDC, Lainchaur, Kathmandu, which processes 60,000 litres of milk per day. The designed solar thermal system would be used to heat the feed water of the boiler. The design is done under the consideration that certain amount of water is heated in a day by solar thermal system is stored in highly insulated tank which is used next day as feed water to the boiler. As rule of thumb 50 to 100 litres of water storage is required for per square meter of collector area [17]. From observation in DDC, Lainchaur, water consumed by boiler per shift per day is 1,820 litres and for design purpose 2,500 litres of water is taken. Here 55 m^2 of collector area would be used. Depending on different observations and readings that were taken in the boiler under running condition in DDC, Lainchaur the solar thermal system is designed.

2.2. Solar radiation Intensity

The solar radiation data taken from NASA and compared with data of SWERA [12] and noted that annual average difference between the data from the two sources is only 1.159 %, thus the data provided by NASA can be used with negligible error. Therefore the radiation data for tilted surface is directly used from the data provided by NASA.

2.3. Inlet Water Temperature for Load Analysis

Table: 2.3 below show the monthly average temperature of Kathmandu [9] which is used as the inlet water temperature to the solar thermal collector and used in load analysis.

Table 2.3: Average Temperature per Month (T, ˚C)

Month	Temp.		Month	Temp.
Jan	8		Jul	23
Feb	11		Aug	23
Mar	16		Sep	22
Apr	20		Oct	18
May	22		Nov	14
Jun	23		Dec	10

2.4. Simulation of the Solar Thermal System

The performance of the systems as shown in figure 2.4 was modeled by a simulation program written in MATLAB programming .The program calculates the solar gain for the specified system based on the insolation ,ambient temperature, the latitude ,the parameters specifying the solar collector system and the volume of storage tank. Since the daily hourly radiation data is not available, average monthly insolation and similarly average monthly ambient temperature is used for calculation .The simulation gives the maximum temperature that the storage tank water can attain at end of each day of each month in average. Finally the average monthly daily temperatures are used to calculate the maximum energy per month and then annually that can be obtained by using the thermal system under consideration and load fraction supplied by it.

Mathematical modeling of simple collector and storage tank:

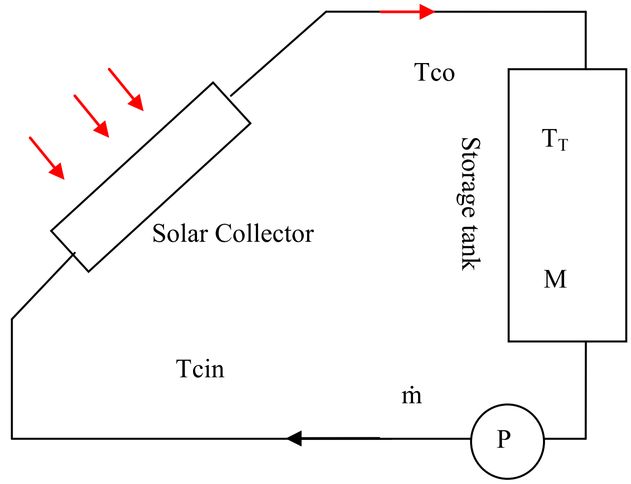

Figure: 2.4

During a particular instant energy balance equation of solar collector relating the temperature ‘ T_{co}’ of the circulated water at the solar collector exit and inlet temperature ‘T_{cin}’ can be given from equation:

$$(T_{co}-T_{cin})*\dot{m}*C_w = I*Area*\eta$$

Where,

η = Collector efficiency

Area = Area of collector

I = Irradiance

$\dot{m}$ = mass flow rate

C_w = Specific heat of water

From which we can calculate temperature ‘T_{co}’ of water exit form collector as given

$$T_{co} = T_{cin} + (I*Area*\eta)/(\dot{m}*C_w) \quad \ldots (1)$$

The collector efficiency can be calculated using the equation:

$$\eta = F_r(\tau\alpha)-(F_rU_c)*\{(T_i-T_a)/I\} \quad \ldots (2)$$

$T_i = T_{cin}$=Inlet water temperature to the collector

T_a = Ambient temperature around the collector

From selected collector type and its efficiency (η) plot against $((T_i-T_a)/I)$, we can get

$F_r(\tau\alpha)$ = Intercept of the plot

(F_rU_c) = Slope of the plot

Energy balance equation between collector and storage tank with water:

For initial second:

$$\dot{m}\,(T_{co}-T_{cin}) * C_w = M\,(T_T-T_{cin})$$

M = mass of water in storage tank

Solving we get:

$$T_T = T_{cin} + (\mathring{m}*(T_{co}-T_{cin}))/M \qquad \ldots (3)$$

Now this temperature 'T_T 'becomes inlet temperature' T_{cin}' to the collector for next second. In this way the temperature at the end of last second of average each day per month is calculated, where total number of second per average day is determined by multiplying peak sun hour of that day by 3,600 s per hour.

Output temperatures for 12 months individuals' average per day (final temperature in table: 2.5a) are used for calculating the energy supplied by the installed system.

2.5. Calculation of Energy Delivered by Temperature Basis

In the table: 2.5a the average energy per month that can be stored at the end of each day in the storage tank has calculated where initial temperature of the storage tank water is assumed to be equal to the average ambient temperature per day per month.

Table 2.5a: Energy Delivered by Temperature Basis

Mon	Av.Tem. / Month (T ˚C)	Vol. of Water Req. /day shift (kg)	Cp (J/kg ˚C)	Final Tem. (Th ˚C)	Monthly Av./day Energy (MJ)	Avg. Monthly Energy (MJ)
Jan	8	2500	4200	60.6983	553.33215	16599.9645
Feb	11	2500	4200	68.4495	603.21975	18096.5925
Mar	16	2500	4200	75.7075	626.92875	18807.8625
Apr	20	2500	4200	78.2736	611.8728	18356.184
May	22	2500	4200	76.7833	575.22465	17256.7395
Jun	23	2500	4200	71.1249	505.31145	15159.3435
Jul	23	2500	4200	65.4118	445.3239	13359.717
Aug	23	2500	4200	66.9549	461.52645	13845.7935
Sep	22	2500	4200	66.6399	468.71895	14061.5685
Oct	18	2500	4200	72.9819	577.30995	17319.2985
Nov	14	2500	4200	70.0967	589.01535	17670.4605
Dec	10	2500	4200	63.6475	563.29875	16898.9625
					Yearly En. (MJ)=197432.487	

A sample calculation for January:

Average ambient temperature = ˚C

Mass of water per shift per day = 2,500kg

Specific heat capacity of water = 4,200J/kg˚C

Final temperature that can be achieved at the

end of the each day = 60.69˚C

Energy Per day in January = 2500*4200*(60.69-8)

= 553.32MJ

Average Monthly Energy Collected = 30*553.32=16,599.6MJ

Similarly calculating energy collected in remaining months total energy delivered annually is obtained. Finally in the table: 2.5b energy delivered by the thermal system annually is converted into equivalent fuel saved and emission reduction is calculated.

2.6. Calculation of Energy delivered by area basis

Now in this section again maximum energy that can be provided by the system considered has been calculated but on the basis of area.

Table 2.5b: Fuel and Emission Reduction

	Diesel Quantity	Energy Equivalent
	1 Litre	36.4MJ[5]
Temperature Basis	Annually Energy Saved by Solar Thermal System =19,7432.487 MJ Which is Equivalent =197432.487/36.4 = 5,423.96 Litre of Diesel Saved Per year.	
Area basis	Annually Energy Saved by Solar Thermal System =19,7432.487 MJ Which is Equivalent =212695.3728/36.4 = 5,843.27 Litre of Diesel Saved Per year.	
	Diesel Quantity Burned	CO_2 Emitted
	1 Litre	2.68 kg[5]
Temperature Basis	Annually Diesel Saved=5423.96 Litre Which is Equivalent =5,423.96*2.68 =14,536.23 Kg of CO_2 Emission reduced.	
Area Basis	Annually Diesel Saved=5423.96 Litre Which is Equivalent =5843.27*2.68 =15,659.98 kg of CO_2 Emission reduced.	

Table: 2.5b shows the equivalent fuel saved and emission reduction on area basis.

2.7. Fractional Energy Supplied by Solar Thermal System

In this section the legitimacy of the data of diesel consumption provided by DDC Lainchaur has been verified so that the exact fraction of total energy consumed by boiler that is being provided by the solar thermal system could be calculated. Theoretically the energy generated by the boiler in the form of water steam is calculated and using the efficiency of boiler 0.6, the total amount of energy required to be given in boiler is calculated which is converted in terms of total diesel consumed. Now this calculated amount of diesel is compared with the data of diesel consumption annually provided by DDC, Lainchaur. Input energy to the boiler is calculated to be 22,99010MJ annually. Equivalent Diesel required is 63,159.61Litres annually. Comparing with the provided diesel consumption data of the DDC, it is only less by 3.39 % annually. This deviation is due to the fact that sometimes the industry runs two shifts per day. After this analysis we can rely on data of diesel consumed annually provided by DDD, Lainchaur. Now fraction (F) of this energy being supplied by solar thermal system can be calculated on area basis:

Total Fraction (f) =

$$\frac{\text{Total energy supplied by Solar Thermal System annually (in terms of diesel saving)}}{\text{Total enrgy required by Boiler alone as input annually(in terms diesel consumed)}}$$

= 5423.96/65377 = 0.0829 = 8.3%

2.8. Fractional Energy Supplied by Solar Thermal System using F-Chart method.

Sample calculation for January:

From specification of selected collector,

F_R (τα) = 0.706, $F_R U_L$= 4.19

Monthly average temperature, Ta = 8ºC

Standard reference Temperature, T_{ref} = 100ºC

Monthly average solar radiation, H_T =2 0.92 MJ/m^2

Collector Area, A_c = 55m^2

Monthly Average Load is taken from load analysis

Which is (using efficiency of boiler's = 0.6)

L = 116942.55/0.6 = 19, 4904.25 MJ

$X = F_R U_L *(Tref- \overline{T}a) * \Delta\tau * A_c/L$

= 4.19*(100-8)*31*86400*55/ (116942.55*103)

= 0.47

$Y = F_R\ (\tau\alpha)\ n*\overline{H}_T N*A_c/L$

= 0.706*20.92*106*31*55/ (116942.55*106)

= 0.21

$f = 1.029Y - 0.065X - 0.245Y^2 + 0.0018X^2 + 0.0215Y^3$

(For liquid system)

= 0.17

Similarly calculation for different months was done using Excel spreadsheet. Finally, annually fraction of the load supplied by solar energy is calculated as:

F = Σfl/ΣL = (12587.19)/(191584.17) = 0.0657 ≈ 6.6 %

2.9. Financial Analysis

The initial installation cost of the system would be NRs 2,594,112.5.Since there was only one running cost of centrifugal pump and negligible repair and maintenance cost for initial 15 year, 3% of initial cost was taken as annual running cost. From area basis analysis, it was found that annual amount of diesel fuel that could be saved is 5,423.96 litres. Now using the price of diesel per litre NRs.100 [10], annual cost of fuel saved was calculated to NRs. 5, 36,972.04 (5,423.96×100).This saving in fuel cost was taken as the annual income.

Initial Investment (P) = NRs.25, 94,112.5

Annual Cost(C) =3% of P = NRs.77, 823.375

Annual Income (E) = NRs. 5, 42,396

Useful Life of the System (N) = 15 Years

Discounted Payback period and Net Present Value were calculated using four different interest rates 8%, 10%, 12% and 14% respectively. From calculation, it was seen that in all cases net present value is positive so the project is financially feasible. Payback period increases from 8 to 12 years as interest rates increases from 8% to 14%.

3. RESULTS AND CONCLUSIONS

The solar water heating system with 55 square meters of collector area and two insulated hot water storage tanks of 2,500 litres capacity each was implemented in a dairy with a capacity of 60,000 litres milk processing per day. The results are listed below:

- Fractional contribution by temperature basis and area basis differs by 7.17% due to the fact that losses in pipes and storage tank were not accounted while calculating by area basis.
- Fractional contribution by area basis and F-chart method differed by only 1.7% which can be concluded that the approach was in right direction.
- It was found that 5,843.27 litres of diesel would be saved annually wherein present annual consumption is 65,377 litres of diesel.
- It was found that 15,659.98 kg of CO_2 emission would be reduced annually.
- In industrial sector an investment is taken as attractive if the payback period is 3 to 4 year. Thus the system considered is not attractive from investor's point of view as payback period is above 8 year. Though being renewable energy system, it is still beneficial from environmental point of view and Net Present Value is positive during the life span of the project.

Above findings led to the conclusion that solar thermal technology using flat plate and evacuated collector can be used to reduce the diesel fuel requirement for small to medium scale dairy industry processing less than 60,000 litres of milk per day. That is economical and environment friendly. It is to be noted that for large scale dairy industry and for large fractional contribution concentrated solar power should be used.

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Energy Efficient Planning in Towns of KMC

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***Abstract*: Increasing population pressure and urbanization constitute higher demand for energy. This has led a huge challenge to support energy demand of larger population while limiting their impact on energy. Increasing energy demand also results an increasing financial burden and a growing burden on the environment through the increased use of fossil resources. For these reasons, energy efficiency is an important aspect of sustainable urban development. Energy Efficiency increases energy security and reduces the level of per capita energy consumption.**

Keywords: Energy, Energy Efficiency, Land Use, Transportation and Water

1. INTRODUCTION

Energy is essential to maintain every form of life and every society. Adequate and consistent availability of usable energy sources is one of the prerequisites for social, economic, technological and environmental development of a country. It is related to sustainable development as a source of environmental stress, as a principal motor of macroeconomic growth, and as a prerequisite for meeting basic human needs [1]. In many developing countries and emerging economies increasing prosperity and growing population are causing the demand for energy to rise sharply. This results in bottlenecks in the energy supply, an increasing financial burden and a growing burden on the environment through the increased use of fossil resources. For these reasons, energy efficiency is an important aspect of sustainable urban development [2].

IEA estimates that in developing countries, about 70% of CO_2 reductions come exclusively from energy efficiency. Improvements in energy efficiency can reduce the need for investment in energy infrastructure, cut energy bills, improve health, increase competitiveness and improve consumer welfare. Powerful individuals can introduce new conceptions of energy and efficiency, but in order for these conceptions to 'stick' and become a part of everyday reality, they need to be adopted by socially interacting communities [3].

Today Nepal has a population living in urban areas 17% and it is projected to be about 50% by 2030. Population growth rate is 1.40 % per year whereas in urban, the growth rate is 3.38% per year [4]. This shows Nepal has to face immense pressure on energy in future. If urban planning continues to carry in the same conventional way then there is no longer to confront energy crisis in Nepal. Fuel imports absorb over one-fourth of Nepal's foreign exchange earnings [5]. Slow pace of hydropower development and the difficulty of replacing non renewable energy by alternative sources have raised the volume of import of petroleum products in the country, and import is expected to increase at a faster pace in the future.

The highest density of energy demands in urban areas is further endangering the overall economic development of productive sectors of country. Growth rate of non-agriculture sector in 2008/09 is less as compared to previous fiscal year [6]. Major reason for this decline is the shortage of energy supply. So this study is needed to identify potential of energy efficient planning in towns.

2. OBJECTIVE

The statement of purpose is made in the form of objectives. They are:

- To develop energy efficient planning approaches for town
- To seek integrated approach of land use and transportation for energy efficiency
- To identify energy efficient alternative solutions that will provide choices for energy decisions
- To give multiple solutions for awareness to society about energy efficiency and importance of energy in every aspect of life

3. RESEARCH QUESTION

To adequately achieve above objectives, the research questions are formulated. They are:

- How do people perceive energy efficiency?
- What is the energy scenario of domestic use and in community in Kathmandu?
- How does planning contribute in alleviating the problem of energy?
- How does transportation planning help in resolving the problem of energy?
- How have energy efficient approach been applied to planning of towns?

4. METHODOLOGY

The research is an explanatory research. The research has attempted to make an explanation on 'Why' energy efficient planning is important in cities and tries to explain approaches to energy efficient planning of towns from local and international experiences.

The research is based on Positivism/ Post Positivism paradigm and Constructivism paradigm. For the physical phenomenon positivism paradigm has been used based on objective reality whereas for the perception phenomenon constructivism paradigm has been used as it is based on subjective reality.

Case study is carried out as a research strategy as this research topic is oriented towards 'Why' and 'How' question. Since Nepal has not initiated any energy efficiency of planning, the international case studies have been reviewed. The selected case studies are: Freiburg: Eco-City of Germany, Urban Village Project: Eco-City of Oakland, Cape Town, Solar city movement in India and Chandigarh: Solar City.

For the positivism/ post positivism paradigm, quantitative data has collected whereas for constructivism paradigm qualitative data has collected. The qualitative-quantitative mixed-method study contributes to a bridging of the literature on influence of land use, transportation, drinking water, consumer behavior and lifestyle and many related aspects of energy efficiency.

The tools for data collection in the research are literature reviews, field observation and questionnaire. Literature review was carried out to understand various influencing aspects of energy efficiency of planning of towns. The questionnaire survey was conducted in 250 households in the twenty four toles/ lanes of Ward No. 13 of KMC. The questionnaire survey was carried out by the students of Paropakar Adarsha Higher Secondary School of class X and me.

The summary of data has been produced using Google Doc online program. Analysis of these data has been carried out using MS Excel. The findings from field observation and document reviews have been analyzed descriptively.

After analyzing the data, the findings have been drawn. Further the findings were discussed with the results of literature review. Conclusion has been drawn based on entire literature review, field data analysis, summary of findings and answers to the research questions. Few recommendations have been drawn in this research especially for management of Energy Efficient Operation in Town of KMC.

5. ENERGY EFFICIENCY

Energy efficiency, sometimes called efficient energy use, is using less energy to provide the same level of performance, comfort, and convenience. Energy efficiency has proved to be a cost-effective strategy for building economies without necessarily increasing energy consumption. Energy efficient solutions can reduce the energy bill for many homeowners and businesses by 20 to 30 percent [17]. In fact, energy efficiency offers a powerful and cost-effective tool for achieving a sustainable energy future. Energy efficiency is "Using less energy to provide the same service" [2].

6. STUDY AREA: WARD NO. 13 OF KMC

Ward No. 13 is located at the west sector of Kathmandu Metropolitan City .It is bounded by the Bishnumati River in the east, Syuchatar VDC in the west, Ward No. 15 in the north and Ward No. 14 in the south. This ward comprises 213.3 hectares of land.

7. RATIONALE OF SELECTION OF STUDY AREA

According to WECS (2010), the residential accounts for the major share of energy consumption (89.1%) followed by transport (5.2%) in Nepal. According to UN-HABITAT (2008), it is found that transport consumes more energy than building in Kathmandu. From this point of view, Ward No. 13 of Kathmandu Metropolitan City has been selected as study area since almost the entire ward is made up of residential areas. Also this ward is near to the city centre, the ward itself is facilitated with all basic facilities and public transport network. Despite this, majority of people are seemed to be using private vehicles to travel for the purposes which are available within the ward and at shorter distance to the neighboring wards. Inhabitants of Ward No. 13 are seemed to be pursuing energy inefficient way of life. Also Ward No. 13 contains mix type of income groups. So Ward No. 13 has been identified as suitable study area for research.

8. SUMMARY OF FINDINGS

Field observation

Ward No. 13 comprises characteristic of mixed land use as it offers the proximity of markets, study, basic facilities and other non residential land use to housing. But most of the ward's areas don't have pedestrian-friendly street and environment that convenient for people to travel by walking. Overall seven public transport networks have been found in and surrounding of Ward No. 13. Three principal roads that by-pass the ward no. 13 is the Ring road, Kalanki- Kalimati Road and Balkhu- Kalimati road. Also other roads dedicated to public transport are road linking to Sitapaila- Ratnapark, Swoyambu- Ratnapark, Paropakar- Lagankhel and Dallu – Lagankhel. Even though numerous public transports ply on roads of ward no. 13, these roads seems busy with private vehicles. All the transport modes are found fully depended on non- renewable source of energy.

Energy Scenario of Domestic Use

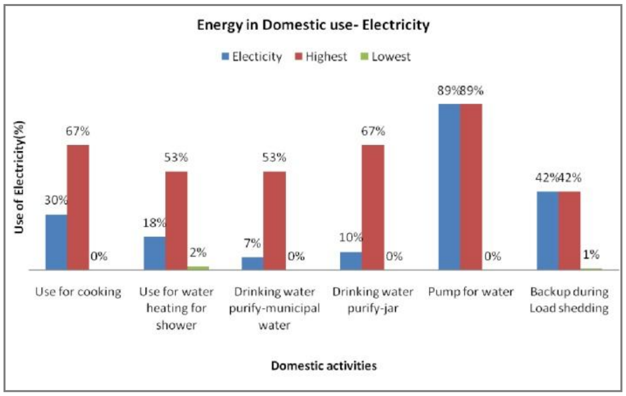

Figure 1: Correlation between Domestic Activities and use of Electricity

According to the survey results, electricity is found as the highest in demand to carry out domestic activities in ward no. 13. It takes the highest share for pump for water (89%) and backup during load shedding (42%). Majority of households are found using inverter as backup during load shedding. Electricity used for purification of jar water is higher (10%) as compare to purification of municipal water (7%). According to Practical Action Nepal (2009), minimum required energy to boil drinking water is 3.09 GJ/household/year in hill. 30% of households use electricity for cooking and 18% have used for water heating for shower.

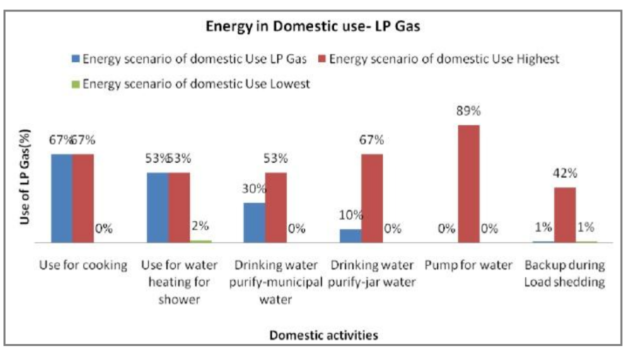

Figure 2: Energy Correlation between Domestic Activities and use of LP Gas

LP Gas is found the second largest mostly consumed energy in ward no. 13. It takes the highest share for cooking (67%) and water heating for shower (53%). LP Gas used for purification of municipal water is higher (30%) as compare to purification of jar water (10%).

Petroleum product is found mainly used for generateor as a backup during load shedding (12%); followed by use for water heating for shower (11%). Only 1% of household have found using petroleum products for cooking purpose.

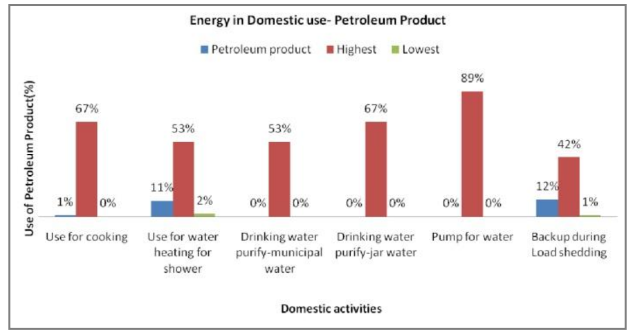

Figure 3: Correlation between domestic activities and use of Petroleum product

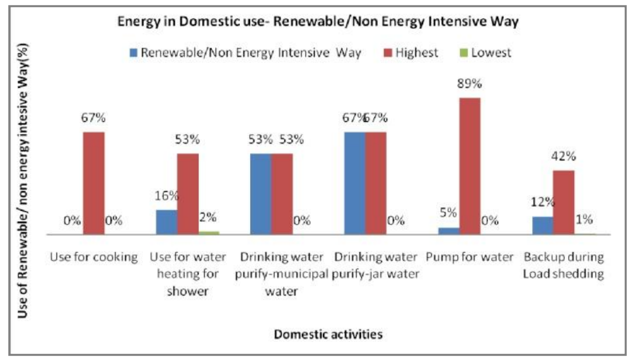

Figure 4: Correlation between domestic activities and use of Renewable/Non Energy Intensive Way

Use of solar water heater for water heating for shower (46%) is found higher than using PV system as a backup during load shedding (12%). Except for water heating and electricity, renewable energy has not been used for other purpose. The non energy intensive way accounts the highest percentage for purification of both municipal and jar water.

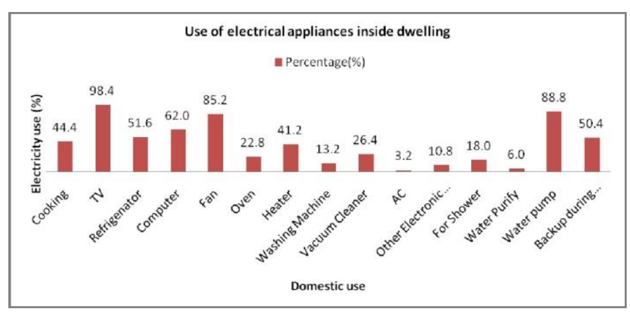

Figure 5: Use of electrical appliances inside dwelling

It is seen that households use electrical based home appliances extensively. Majority of households have TV (98.40%), followed by water pump (88.80%), fan (85.20%), computer (62%), refrigerator (51.60%) and then for backup during load shedding (50.40%). All of these devices consume electricity. Obviously, the more devices a household uses, the more electricity a household consumes. The literature study shows that by altering behaviour and substituting equipment, each family had a potential saving of 348 kWh/year per family; 10.4% of total electricity consumption [7].

Table 1: Correlation between Building use & Rain water harvesting

Building use	Yes	No	Total	Yes %	No%
Residential	50	104	154	47.16	72.22
Commercial	12	15	27	11.32	10.42
Mixed	44	25	69	41.5	17.36
Total	106	144			

From the correlation between building use and rainwater harvesting, it is found that more than half i.e. 72.22 % of residences are not involved in rainwater harvesting. According to source of ENPHO, 100 sq. m. plot area can yield 128,800 liters of water in case of Kathmandu. According to this if assuming average 100 sq. m. plot area of residences, then (6429* 128800) Million liters water can be collected through harvesting rainwater only. So rainwater harvesting can result on reducing the demand of municipal and commercial water and so on reducing the energy use for pumping and purification.

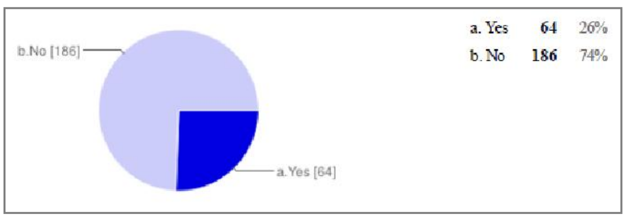

Figure 6: Use of renewable source of energy

Only 26% of household have installed renewable source of energy.

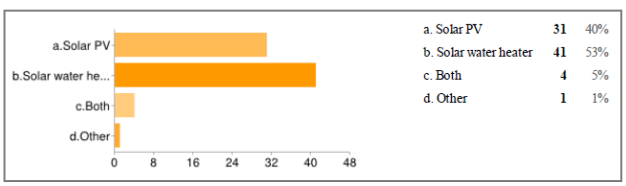

Figure 7: Installation of renewable source of energy

Among the 26% of household, only 5% have installed both solar PV and solar water heater. About 40% have installed solar PV only and 53% have solar water heater.

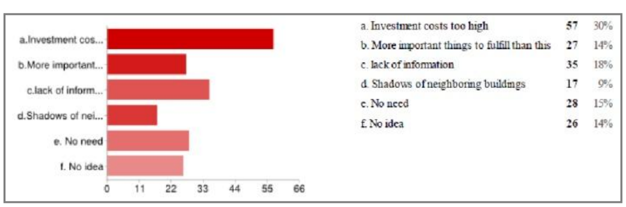

Figure 8: Barriers to install renewable source of energy

The major three barriers to install renewable source of energy are found: investment costs too high (30%), lack of information (18%) and no need(15%). Other barriers to install renewable source of energy aremore important things to worry about (14%) and shadows of neighboring buildings (9%). 14% respondents have no idea about renewable energy.

Energy Scenario of Community Use

Table 2: Travel distance for various purpose

Purpose for travel	<500M	500-1000M	1000-5000M	>5000M
Travel for work	27	18	42	12
Travel for Market	56	32	9	3
Travel for Study	17	34	41	7
Travel for Entertainment	4	13	58	24
Travel for Others	7	20	55	18
Total	**111**	**117**	**205**	**64**

It is found that market is quite accessible whereas work, study, entertainment and other purpose are inaccessible by walk. Majority of people are found to do travel a distance of 1000 -5000m which requires vehicle to travel.

Table 3: Travel Mode for Various Purpose

	Bus	Tempo	Micro Van	Walk	walk & ride	Institutional vehicle	Bicycle	Private car	Private Bike
Transport use for work	3	5	0	35	11	0	0	0	46
Transport use for Market	0	0	0	74	3	0	0	0	18
Transport use for Study	3	3	3	28	6	34	0	0	22
Transport use for Entertainment	8	6	11	6	37	0	0	2	30
Transport use for Others	17	9	9	4	34	0	0	1	26
Total	**31**	**23**	**23**	**147**	**91**	**34**	**0**	**3**	**142**

Use of private bike for work (46%), institutional vehicle (34%) for study and both walk & ride (37%) for entertainment are found dominant. Expect these travel modes, bus, tempos and micro van also used by people but found less used (table 18). All these travel modes rely on non-renewable source of energy. The literature review in this study shows that about 63% of the total petroleum consumption is occurred in the transport sector in Nepal.

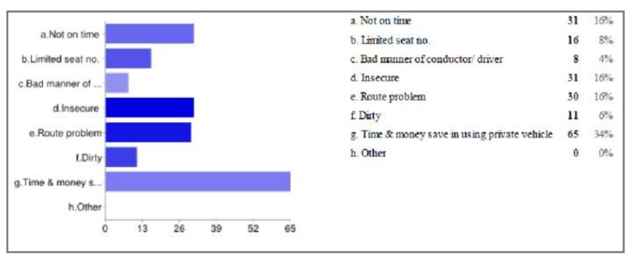

Figure 9: Reason for not using public vehicles

The top three reasons behind not using public vehicles by those private vehicle users are found: time saves in using private vehicle (34%), route problem (16%) and not on time (16%).

Street light is found major problem in community as per more than half (52%) of the respondents reported that there is a problem of street light. The problem of 'no light' is the major problem of street light then 'lack of management' and 'insufficient light.'

Table 4: Various problems of street light tole/ Lanewise

Tole/ Lane	No light	Insufficient light	Lack of management	Other	Total
Bafal	10	4	4	0	18
Balkumari	1	0	1	0	2
Chagal	7	3	0	0	10
Chuni Bhairab Marga	1	0	1	0	2
CWIN Nepal	0	0	1	0	1
Daha Marga	0	0	0	0	0
Ganeshsthan	0	0	1	0	1
Ganodaya	0	2	1	0	3
Kalanki	0	2	2	0	4
Kalimati	4	2	3	0	9
Kathmandu Campus	0	0	1	0	1
Khola Prabesh Marga	1	0	0	0	1
Kuleshwor	3	0	5	0	8
Lampati	0	1	0	0	1
Manamati Marga	0	1	2	1	4
Old Kalimati	3	0	2	0	5
Ravi Bhawan	0	0	1	0	1
Saraswoti Marga	1	0	2	0	3
Soltimode	0	0	1	0	1
Stone Spout	0	1	0	0	1
Tahachal	9	5	9	0	23
Tankeshwor	10	2	4	0	16
Byabasaya Marga	4	0	2	0	6
Chhauni	4	4	1	1	10
	58	27	44	2	131

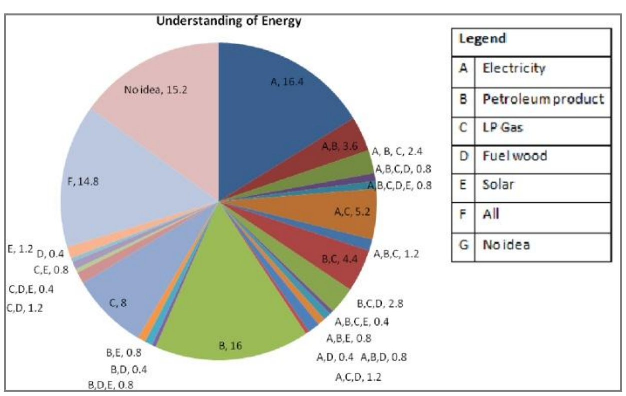

Figure 10: Understanding of energy

Only 14.8% people have right idea about energy.

Table 5: Understanding of energy occupationwise

Occupation	Electricity[16.4%]	All[14.8%]	No idea[15.2%]
Service	24.39	48.65	28.95
Business	34.15	16.22	23.68
Housewife	14.63	10.81	15.79
Student	19.51	16.22	18.42
Unemployed	0.00	5.41	5.26
Labor	0.00	0.00	2.63
Retired	4.88	0.00	0.00
Others	0.00	0.00	0.00
Agriculture	2.44	2.70	5.26

According to occupation, servicemen (48.65%), businessmen (16.22%) and student (16.22%) are found having good understanding about energy.

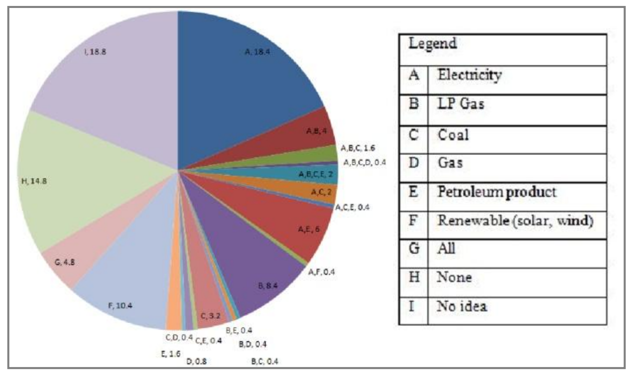

Figure 11: Understanding of energy produced in Nepal

Also it is found that majority of respondents don't have an idea of which energy is produced in Nepal.

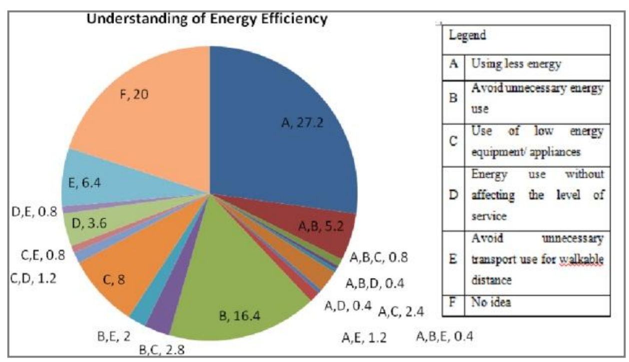

Figure 12: Understanding of energy efficiency

Only 3.6% of people have right idea about energy efficiency as they reported it is energy use without affecting the level of service.

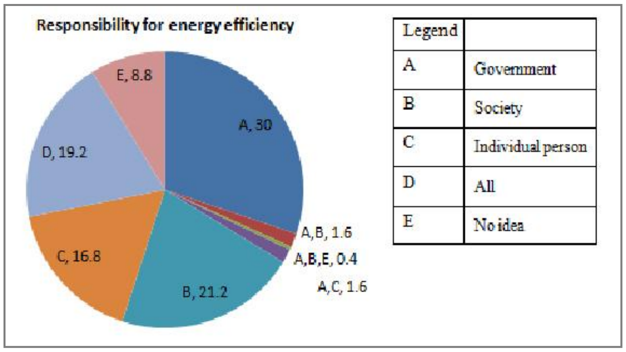

Figure 13: Understanding of responsibility for energy efficiency

Majority of people (32%) think that government should be responsible for energy efficiency.

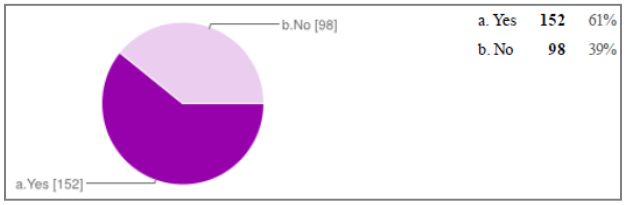

Figure 14: Willing to involve in energy efficiency

It is found that only 61% of people have willingness to involve in energy efficiency.

9. CONCLUSION

Energy efficiency is one of the world's largest energy resources. It increases the energy security and reduces the level of per capita energy consumption. But our country is not able to tap its potential. Despite the growing awareness about the merits of energy efficiency, Nepal is still far from realizing the significant energy efficiency potential because of a number of policy, institutional, informational, technical, financial, and market barriers. Rapid urbanization and population growth will exploit more energy and constitute a threat to the energy as well as environment. Energy efficiency if not taken into an action on time; the energy demand for next generation will be in danger.

10. RECOMMENDATION

Recommendations have been made at community level, domestic level, policy level and for awareness to the people about energy efficiency. All these recommendations need to be integrated for achieving Energy Efficient Town. The recommendations are:

Community Level

Bicycle Sharing System

Access to shared bicycles can reduce dependency on motorized transit, reduces traffic and congestion, reduces in fuel consumption and creates environmentally-friendly lifestyle. Bicycle sharing could be an integral part of transportation networks in town. The automated key stations and bicycles are proposed at places near mass transit locations and road junctions where users can access bicycles conveniently and consistently.

Smart Solar Street Lighting System

By planning of smart solar street lighting system it is possible to manage energy efficiency in town. This system will solve the problems of no light, insufficient light and lack of management in the town. The smart solar lighting stations are proposed to ring road, and inner wider connected roads,. By the central energy management system (CEMS), the backup of these stations will transfer to the street lights in the alleys or narrow areas where the solar gain is not possible due to tall buildings.

Solar City Programme

It is recommended to install grid interactive solar photovoltaic (PV) and wind turbines at the setback area of Bishnumati Link Road. Further grid connected PV installation is proposed in Government buildings and hotels as giving first prioritize to government buildings for PV development, followed by commercial and industrial buildings and finally residential buildings. Also traffic light should run on solar emery. All these grid connected system will offer to transfer excess power to the grid while power can be drawn from the grid in case of shortage. So the approach of solar city programme will reduce the electricity demand in town.

Improvement of Urban Planning

Improvement of urban planning include integrated transport-landuse, bicycle paths and bicycle parking spaces, connected pavements/ sidewalk, easy road crossings, safe and attractive pathways with street lighting, improved landscaping, availability of green spaces, parks etc. By improving urban planning, a compact, accessible and energy efficient town could be possible as it makes people easy to walk, bike or take public transit. People will enjoy the urban life with a much smaller energy and carbon footprint.

Improvement in Quality of Water

It is recommended to improve in quality of water so as to reduce energy consumption and achieve energy efficiency in the water sector. Highly energy-intensive purification methods for drinking water (either jar or municipal water) can be avoided by the supply of quality drinking water. It is recommended that both municipal water and jar water supply system should incorporate the appropriate purification system at the main supply point; as mass purification system requires less energy than done in individual households.

Mixed Land Use Development

It is possible to reduce travel distances, create more compact development and pedestrian- bicycle friendly environments by mixed land use development. So it helps to promote energy efficiency in town.

Household level

Energy Responsive Buildings

The development and implementation of energy responsive buildings are the necessary step towards further energy efficiency improvements in the built environment. Energy responsive buildings include optimization overall layout, orientation of building and integration of passive techniques. The focus is primarily on design of the building itself to minimize heat loss in winter, to minimize heat gain in summer, and to use light and fresh air efficiently in order to reduce energy demands for heating, cooling, lighting and ventilation. Also it is recommended to integrate building envelope (wall, floor, roof and fenestration) with building service functions such as heating, cooling, natural ventilation, sufficient daylighting and energy storage.

Rain Water Harvesting and Recharging Aquifer

Reduction in water demand is possible from rainwater harvesting and as a result it is possible to save energy needed for pumping for raw water extraction and pumping for distribution of water both at municipal level and commercial water suppliers. In case of commercial water suppliers, the travel trip for water supply also minimized and as a result, it reduces fuel consumption. Similarly at household level, due to reduction in demand of municipal as well commercial water, it can be saved energy that is needed for pumping for storage of water. Also roof based rainwater harvesting system is more energy efficient as no need of pump to fill roof tank and water distribution to lower floors is possible on gravity fed system. So rain water harvesting can save electricity consumption that is highest in demand to pump for water in domestic use.

Also it is recommended that if a household have water extraction/ storage well then it should also have recharge well. This concept is basically focused on making responsible the ground water users for recharging the natural aquifer. Recharge of well/ aquifer can be done by discharge of rainwater and waste water from bathroom sinks, bath tub shower drains, and clothes washing equipment drains. The pervious surface system on lawn, parking lot and walkways also need to be integrated into the planning for recharging the aquifer. So together with rain water harvesting and waste water recycling, it is possible to reduce demand of water and so on energy consumption.

Use of Renewable Energy

The energy responsive buildings also need to integrate with renewable sources of energy for achieving greater energy efficiency. Installation of solar photovoltaic panel, solar water heater and use of biofuel are the most popular and common practices.By installing these systems, it is possible to generate own energy that promotes less use of electricity and fuel, reducing carbon footprint as well as energy bills.

Use of Energy Efficient Appliances and Methods

Majority of households use electrical appliances extensively and will continue to use in near future. Appliances and equipments have a tremendous effect on home energy consumption. So the following recommendations are drawn for using energy efficient home appliances and methods:

- ✓ Use of CFLs or LED lights to replace less-efficient incandescent bulbs.
- ✓ Purchase energy-efficient appliances and products.
- ✓ Replace aging appliances with newer energy efficient ENERGY STAR models.
- ✓ Turn off the television, computer, fan and lights or lamps when when not in use.
- ✓ Use task lighting whenever possible instead of brightly lighting an entire room.
- ✓ Control outdoor lights with sensor timers so they stay off during the day.
- ✓ Replace a gas cooking appliance with a unit with an automatic system.
- ✓ Cook with small appliances. Small appliances use less energy.

Policy level

Encourage use of Public Transportation System

Providing only public transport is not sufficient for encourage using public transport mode. For this Government should encourage smart public transportation system. Providing monthly bus cards, semester cards, employed cards, student cards etc in discount cost will encourage them to use public vehicles. Besides this, the public transportation system needs effective and reliable management. This includes planning of integrated route networks, provision of mass transit, punctual service, safety and security as well as good manner of drive and conductor. Further the Bus stops should linked up with the non motorized transport system like bicycle sharing station , so that journeys can be continued without interruption and hence encourage people to use public transport. Besides this, operating public transportation even at late night hours can encourage people to use public transport. Also government should start again the trolly bus system and it should integrate with all the smart systems that are mentioned above.

Encourage Reduction in Electricity Consumption by Renewable Energy

For reduction in electricity consumption, government should regulate the mandatory rule; that high rise apartments, commercial and industrial buildings should generate minimum 15% of the electricity by installing renewable source of energy. For this, government should promote and support entrepreneurship in the renewable energies industry. Also government should provide incentives on solar panels, solar water heater, wind turbines and bio gas stoves. It should be emphasize on grid interactive solar PV system.

Encourage Development of Energy Responsive Building

Government should emphasize on a framework of technical and performance provisions for energy efficiency in new and existing residential and commercial buildings. An incentive should be given on construction materials for the construction of new buildings to energy responsive building.

Revise Bye-laws

Government should revise bye-laws to design and construct energy efficient buildings and neighborhoods. Revision of bye-laws need to include rainwater harvesting system and maintain pervious pavement/ surfaces of the open areas to some mandated percent as according to ground coverage area.

Other Policies

- ✓ Encourage smart solar street lighting system and traffic lighting
- ✓ Incentives on CFL and LED lights
- ✓ Higher the price of other energy intensive lights or increase tax to such lights
- ✓ Incentives on electric vehicles and provide attractive tax free schemes
- ✓ Penalize the tall buildings for casting shadows on neighboring building
- ✓ Homogenize the price of products, education fees and other service charges so that it encourage people to use services that are available at proximate.

Awareness Promotion

By Inspiration and Education Programmes

An informal continued conversation with community and networking can promote awareness to people and society about and its efficiency and importance of energy in every aspect of life. As the field data analysis shows that people's perception varies according to their occupation. So the inspiration and education programmes should be varies also among the different occupation groups. Educational materials about the energy and energy efficiency should be provided to the public to share successful solutions and to motivate others to make change. Behaviour and habits of people has great impact on energy consumption, so awareness programmes should also focus on behaviour change interventions.

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Sustainable Energy Demand Analysis for Nepal 2009 -2050

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Abstract: **This paper aims to project the energy demand for the period 2009-2050 in Nepal, a developing country with large hydropower potential. A bottom up energy system of Nepal based on Model for Analysis of Energy Demand (MAED) framework has been developed to access the effect of meeting part of end use demand in different sectors of economy with electricity. It shows that the final energy demand in Nepal will increase by 2.4 times to 963 PJ by 2050 as compared to 397 PJ in 2009 under reference scenario which have been developed based on a Gross Value Added (GVA) growth rate of 5.8 percent. With the increased penetration of electricity in the end use demand of various sectors the final energy demand will increase only by 1.2 times by 2050.The share of imported energy reduces to 21% of the total energy consumption by 2050 in the sustainable energy scenario as compared to 25% in the reference scenario from the base year share of 9%. The 2% electricity share in 2009 will increase to 5% by 2050 in the reference scenario whereas in case of the sustainable scenario it will increase to about 39% of the total energy consumption by 2050. The electricity consumption per capita will increase from 85 kWh in 2009 to 348 kWh in 2050 in the reference scenario. In case of sustainable scenario this value will rise to 1,227 kWh by 2050. Sustainable scenario will demand 49 TWh of electricity at the end of analysis period as compared to only 14 TWh electricity of the Reference scenario.**

Keywords: Petroleum products, Electricity, Energy demand

1. INTRODUCTION

Petroleum Product constitutes about 10% of total energy consumption in Nepal [1]. The consumption of petroleum products has increased by more than 2 folds in 15 years (1995/96 to 2010/11) with annual growth rate of 5.23% as compared to 2.81% growth rate of total energy consumption which has increased only by 1.5% [2].

Nepal has no proven resource of petroleum products and has been meeting its petroleum demand through imports from India. In fiscal year 2010/11 Rs 76.74 billion was spent on import of petroleum products which exceeded the total export earnings of Rs 64.33 billion by 2% [1]. Despite such huge expenditure on the import of petroleum products, the supply is not consistent with the demand. There are frequent shortages of petroleum products in the market.

The price of crude oil which is basically the raw materials for petroleum products such as petrol, diesel, kerosene, liquefied petroleum gas (LPG) etc., has been on a steady rise. The crude oil was below $23.12/barrel in 2001 which hit to $107.46/barrel in 2011 [3]. Nepal cannot stay aloof from such rapidly changing global oil price fluctuation as a result of which Nepal Oil Corporation (NOC), the state owned Oil Company, has increased price of petroleum products accordingly in the market. Increasing dependence on non-renewable energy is making the consumption pattern unsustainable in the long run. Owing to such rapid increase in the consumption rate, trade deficit and the price, the consumption of petroleum products needs to be replaced with alternative energy sources.

Despite the huge potential of hydropower resources in the country, the share of electricity in the national energy scenario is less than 3% [1]. The heavy dependence on traditional fuel such as fuel wood, agricultural residue and animal dung for cooking purpose is one of the major causes of indoor air pollution. Still 40% of the world population relies on unclean traditional resources for cooking and around 2 million people including 80,000 children lose their life annually by breathing in toxic smoke produced by unclean burning of traditional fuel [4].

There is a crucial need to change the present consumption mix dominated by traditional and imported fuel to a more desirable energy mix with high share of renewable energy especially electricity.

2. METHODOLOGY

Energy demand forecasting is an essential component for energy planning, formulating strategies and recommending energy policies. Projected energy demands are often found to deviate from the actual demands due to limitations in the model structure or inappropriate assumptions. The task is challenging especially in developing country like Nepal where necessary data, appropriate models and required institutions are lacking. Some common energy system characteristics of developing countries include poor performance of the power sector and traditional energies, transition from traditional to modern energies, and structural deficiencies in the economy, society and in the energy systems which result in “urban-rural divide”, inadequate investment decisions and misdirected subsidies [5].

The International Atomic Energy Agency (IAEA)'s energy planning tool MAED has been used for this study. MAED uses a bottom-up approach to project future energy demand based on medium- to long-term scenarios of socio-economic, technological and demographic development. Through scenarios, the model specifically captures structural changes and evolution in the end-use demand markets. For competing forms of energies, the demand is first calculated in useful energy form and the final demand is derived taking market penetration and end-use efficiency into consideration [6].

A. Energy demand calculations

Energy demand is disaggregated into a large number of end-use categories corresponding to different goods and services. The influences of social, economic and technological driving factors are estimated and combined in each different category to present an overall picture of future energy demand growth under the assumptions of that scenario. The energy demand is aggregated into four sectors: industry, transport, households and service.

Industry sector includes four economic sectors: Agriculture, Construction, Mining, and Manufacturing industries. Energy demand of each economic subsector is driven by the level of economic activity of the subsector evaluated in terms of its value added and the energy intensity of each energy form. The end-use categories considered for this sector are: motive power, thermal uses (boiler and process heat), specific uses of electricity (lighting etc.) and other uses.

The energy demand of transport sector is calculated directly in terms of final energy as a function of the total demand for transportation of passengers (passenger-kilometers) and freight (tonkilometers), the breakdown of this demand by competing modes (car, bus, plane, truck, train etc.) and the specific energy needs and load factors of each mode. For transport of passengers, the distinction is made for urban (intracity) and intercity transport. The total demand for transport is calculated separately for freight and passengers according to macro-economic and life-style factors. In the case of freight transportation, the demand is calculated as a function of the GVA contribution (tkm/NRs). On the other hand, the demand for transport of passengers is determined from total population, population living in large cities, and the average intercity and intracity distance travelled per person.

The scenario parameters and related equations which characterize the energy consumption in the Service sector are related to the economic level of activity of this sector (subsectorial value added and labor force in the sector). The end-use categories considered for the Service sector are: space heating, other thermal uses (essentially water heating, cooking), air conditioning, specific uses of electricity (motive power for small motors, computers, lighting etc.) and other uses. The energy consumption for space heating and air conditioning is calculated on the basis of the specific space heating and cooling requirements (kWh/sqm/yr), while that for other thermal uses, specific uses of electricity and other uses is calculated as a function of the value added and energy intensity at the subsector level within Service sector. When the demand of a given end-use category can be provided by various energy forms (space heating, other thermal uses and air conditioning), this is calculated in terms of useful energy. The final energy demand is then calculated from the penetration into the potential market and the efficiency of each energy form (relative to that of electricity for the same use) as specified in the scenario.

Household sector energy demand determining factors are of demographic nature (population, number of dwellings etc.) The categories of energy use considered in Household are: space heating, water heating, cooking, air conditioning and electrical appliances (refrigerators, lighting, washing machines etc.). When the demand of a given end-use category can be provided by various energy forms (space heating, water heating, cooking and air conditioning), this is calculated in terms of useful energy and not in terms of final energy. The final energy demand is then calculated from the penetration into the potential market and the efficiency of each energy form (relative to that of electricity for the same use) as specified in the scenario. The energy consumption for secondary appliances is calculated separately for electrified dwellings, for which the use of electric appliances is assumed, and for the non-electrified dwellings, for which alternative appliances using fossil fuels are considered (kerosene lighting, refrigerators on natural gas etc.).

The demand is essentially determined by relating the activity level of an economic activity to the energy intensity. The demand is first determined at the disaggregated level and then added up using a consistent accounting framework to arrive at the overall final demand. The model focuses only on the final demand and does not cover the energy used in the energy conversion sector.

Energy demand is driven by the GVA and population growth. Population projections were considered to reflect trends in population growth while GVA growth rate was used to develop economic growth scenario. These population and GVA figures were used to estimate end-use demand in the five sectors of the economy (agriculture, commercial, residential, industrial, and transport) over the modelling period. The modelling time frame is from 2009 to 2050, and 2009 i.e. fiscal year 2008/09 was taken as the base year for the study for reasons of data availability.

B. Demographic Assumptions

National Population and Housing Census 2011 put the national population of Nepal at 26.4 million with population growth rate of 1.35% per annum [7]. From an annual average of 2.62% during the period 1971-1981, the present population growth rate has fallen to 1.35%.

The United Nations estimated that by 2010 the population of Nepal had increased to 29.9 million [8] and by 2050 the population will grow to a 46.49 million. For the purpose of study, the population for base year 2009 has been calculated by considering annual exponential growth rate of 1.35% from total population of 23.15 million in 2001. Population for the base year 2009 has been calculated to be 25.79 million.

Population over the analysis period has been projected assuming the annual exponential growth rate as of United Nations Population Division (UNPD) i.e. 1.60% for 2010-20, 1.27% for 2020-30, 0.91% for 2030-40 and 0.60% for 2040-50. With such assumptions the 25.79 million populations is estimated to increase to 40.56 million by 2050 as given in Table 1.

The urban population constitutes 17% (4.5 million) of the total population [7]**Error! Reference source not found.**. Between 1952/54 and 2011, the urban population size has increased by 19 times whereas in terms of urban population as percent of total population it increased by more than fivefold [7][9].

Table 1: Population forecast 2010-2050

Year	Population in million	Annual exponential growth rate
2020	30.68	1.60%
2030	34.85	1.27%
2040	38.17	0.91%
2050	40.56	0.61%

The world population prospects, has projected the percentage of urban population in the total population to be 23.9% in 2020, 30.6% in 2030, 38.2% in 2040 and 46.3% in 2050 [8]. For the projection of urban population, same urban population growth has been assumed in this study. Through this assumption the urban population is expected to grow to more than 21 million by 2050. Table 2 shows the urban population projection over the study period.

Table 2: Projection of urban population

Year	Total population in million	% of urban population	Urban Population in million
2020	30.68	23.90%	8.4
2030	34.85	30.60%	12.2
2040	38.17	38.20%	16.7
2050	40.56	46.30%	21.5

As per the population census of 2011, the average household size in urban area has decreased to 4.32 in 2011 from 4.85 in 2001. Similarly in case of rural area the average household size has decreased from 5.55 in 2001 to 5.02 in 2001. The average household size of the urban and rural area has been projected to reach 3.03 and 4.0 by 2050 respectively.

C. Economic Growth Targets

GVA indicates the economic status of the country to a great extend. Nepalese economy grew at an average rate of 4.09% during the period 1994-2010[10]. Total GVA at current prices in the year 2010/11 was about NRs. 1369.43 billion. Per capita GVA has reached Rs. 57,726 or US$ 735 in the same year [1].

Table 3: Current price GVA for fiscal year 2010/11

	in billion rupees
Agriculture	475.4
Mining	7.0
Manufacturing	79.5
Electricity, gas, and water	15.3
Construction	89.4
Trade[1]	204.3
Transport and communications	102.7
Finance[2]	161.7
Public Administration	24.8
Others[3]	128.5
Gross Value Added	1,288.5

(Source: [10])

Table 3 shows the current price GVA structure of Nepal for year 2010/11. Observation of the structure of GVA shows that among the production sector of the economy, agriculture occupied 37 percent, followed by trade 15 percent, and finance 13 percent. Among other sub sectors transport and communication occupies 8 %, industry 6%, and construction and mining 7%. Likewise public administration and defense, electricity, gas and water and others have their respective 2% and %, 10% shares in GVA.

The structure of the economy has undergone significant changes during the last 16 years. Figure 1 shows the historical shares of GVA of the economic sectors.

The share of agriculture in GVA has declined from 39% in 1994 to 34% in 2010. In the same period, the share of the service sector has increased from 44% to 49%. There has been no significant change in mining, construction

[1] refers to wholesale and retail trade and hotels and restaurants

[2] refers to financial inte`rmediation, real estate, renting, and business activities

[3] refers to education, health, and social work; and other community, social, and personal activities

and energy. However the manufacturing GVA has decreased from 8 % in 1994 to 6% in 2010.

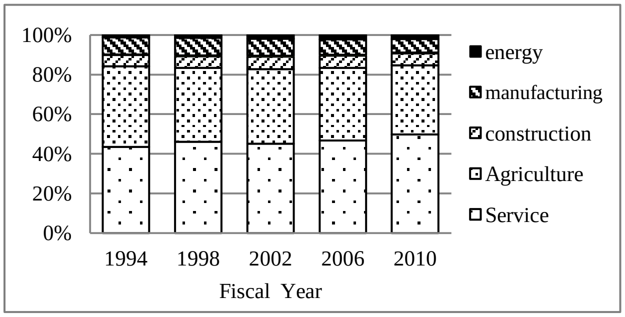

Figure 1: Historical GVA structure (source: [10])

The National Planning Commission has projected 5.8% annual growth of GVA during the period 2011-2013 in the Three Year Interim Plan. Of the overall economic growth rate, the agriculture sector is estimated to grow by 3.9 percent and non-agriculture sector by 6.4 percent. With this growth rate, per capita income will increase by 3.5 percent and employment will increase by 3.6 percent on an annual average basis [11].

In this study the GVA is assumed to grow at an annual rate of 5.8% i.e. same as that of Three Year Interim Plan. GVA has been calculated at 2000 constant price. With this assumption the 590 billion GVA (at 2000 constant price) in 2010 is expected to grow to 5,627 billion (at 2000 constant price) in 2050 i.e. almost by ten folds. For the purpose of GVA sub sector projection, the same sub sector growth as projected by NPC has been assumed. Further it has been assumed that the GVA is expected to grow at a constant rate to 2050.

According to this assumption, the share of agriculture in GVA will fall to 13.79% in 2050, and the share of the service sector will increase to 68.67%, while the share of the manufacturing sector will fall to 4.04% in 2050. Similarly construction, mining and energy will be contributing 6.27%, 0.26% and 6.98% respectively in 2050. In order to obtain the absolute vale of the sub-sectors of GVA, the GVA structure has been normalized against total GVA (which is expected to grow at annual rate of 5.8 %) for corresponding year. The projected absolute value of GVA at 2000 constant price along with its subsectors is given in Table 4.

Table 4: GVA forecast at 2000 constant price in billion NRs

Sectors	**2020**	**2030**	**2040**	**2050**
Agriculture	300	425	583	776
Construction	66	119	208	353
Mining	4	7	10	15
Industry	65	102	155	227
Service	570	1,094	2,071	3,865
Energy	32	76	176	393
Total	1,037	1,822	3,202	5,628

The manufacturing sector of GVA has further been divided into eight subsectors. The subsectors with their relative share in the manufacturing GVA is given in Table 5.

Table 5: Manufacturing sector GVA composition in fiscal year 2008/09

Manufacturing sub sector	**% share in manufacturing**	**GVA in billion**
Food beverage & tobacco	41.5	16.24
Textile & leather goods	12.2	4.77
Chemical, rubber & plastic product	16.9	6.61
Mechanical Engineering & metallurgy	12.6	4.93
Electrical engineering products	2.0	0.78
Wood products & paper	5.0	1.95
Other manufacturing	2.0	0.78
Cement and brick	7.8	3.05
Total		**39.13**

(Source: [12])

D. Energy Consumption Pattern in Nepal

Total energy consumption in Nepal was 425 million GJ in year 2010/11 [1]. Between 2001 and 2011 the total energy demand has increased with an average annual growth rate of 2.6%. The share of various fuels in the total energy is shown in Figure 2:. Traditional fuel such as fuel wood, agricultural residue and animal dung accounts for more than 80% in the energy mix which is followed by petroleum products with a share of 10%. Coal has a share of about 3% and electricity has a share of only 2%. Renewable energy has a very little share, less than 1% in the national energy mix. Between 2001 and 2011, traditional fuel consumption has increased with average annual rate of 2%, electricity by10%, petroleum product by 3%, coal by 6% and renewable by 15%.

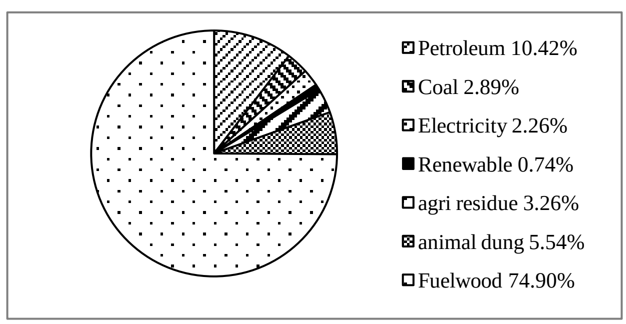

Figure 2: Energy consumption by fuel type 2010/11 (Source: [1])

Figure shows the sectoral energy consumption in Nepal. Most of the energy is consumed in the household sector. The sectors that contribute to the Gross Value Added i.e. agriculture, industrial and commercial sector has share of only 5.5% in the total energy. Transport sector account for 5% share in the energy mix

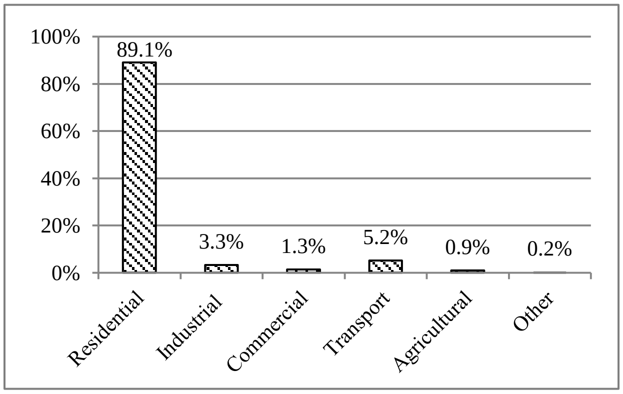

Figure 3: Sectoral energy consumption in Nepal 2008/09 (Source: [13])

3. RESULTS AND FINDINGS

This study analyses two scenarios: Reference scenario and Alternative Scenario.

A. Reference Scenario

This scenario assumes that the average GVA growth rate will be according to interim plan i.e. with an average GVA growth rate of 5.8 percent. It further assumes that the share of each demand technology in the energy supply in future years will be the same as in the base year.

With the assumed population and economic growth rates, the overall final energy demand is projected to increase 2.4 times over the study period 2009-2050, with an average annual growth rate of 3.5 %. The projected final consumptions of various fuels in this scenario have been given in Table 4.

Table 6: Total energy consumption in reference scenario (PJ)

Fuel Type	**2009**	**2020**	**2030**	**2040**	**2050**
Traditional fuels	348.9	426.5	510.2	589.8	667.6
Biogas	2.8	3.1	3.4	3.6	3.5
Electricity	7.9	14.4	22.5	34.1	50.7
Kerosene	2.5	4.0	6.1	9.1	13.5
LPG	5.6	11.0	19.2	32.7	54.5
Diesel	16.9	27.4	43.1	68.7	111.1
Petrol	3.6	6.2	8.9	12.2	15.7
Coke & steam coal	7.8	12.9	20.2	30.6	45.0
Other oil	0.1	0.2	0.3	0.5	0.7
Jet fuel	1.0	1.1	1.3	1.4	1.5
Total	397.0	506.8	635.3	782.7	963.7

The traditional fuel will grow at an average annual growth rate of 2.23%, electricity at 13.25% and petroleum product at 4.13% also shown in Figure 4.

In this scenario, traditional fuel will be dominant throughout the analysis period 2009-2050. However the share of traditional fuel will reduce from 88 %in 2009 to 83% in 2025 and 69% in 2050. The share of petroleum products will increase from 7 % in 2009 to 11% in 2025 to 20% in 2050. Similarly electricity share will increase from 2% in 2009 to 3% in 2025 and to 5 % in 2050 as depicted in Figure 5 and Figure 6.

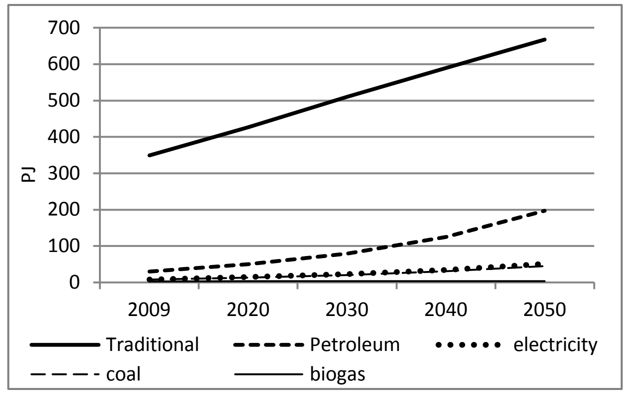

Figure 4: Total final energy demand 2009-2050 in Reference Scenario

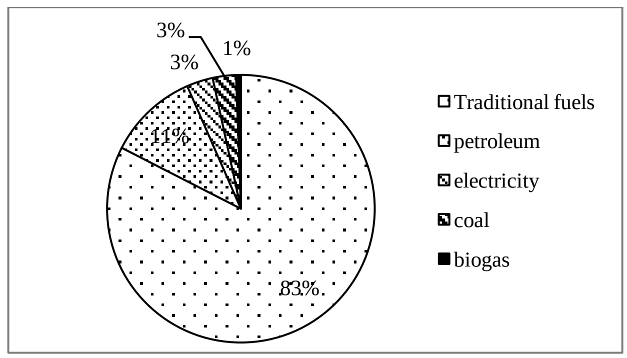

Figure 5: Energy mix by fuel type in 2025 in Reference Scenario

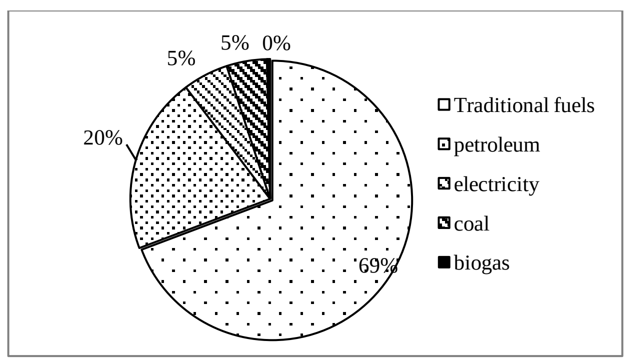

Figure 6: Energy mix by fuel type in 2050 in Reference Scenario

Table 7 shows the final energy demand of five economic subsectors over the study period in the reference scenario.

The share of residential sector in the total energy consumption reduces from 90% in 2009 to 85% in 2025 and 71% in 2050. Manufacturing sector energy share will increase to 4.8% in 2025 to 8%in 2050 as compared to 3% in 2009. The transport sector energy consumption will increase to 6% in 2025 to 11 % in 2050. Similarly, the share of agriculture sector and service sector will continue to rise to 5% and 3% in 2025 to 8% and 7.6% in 2050 respectively.

Table 7: Sectoral final energy demand in reference scenario

Sector	PJ				
	2009	**2020**	**2030**	**2040**	**2050**
Manufacturing	13.3	22.2	34.7	52.7	77.4
Agriculture	3.6	5.4	7.7	10.5	14.0
Transportation	17.9	29.3	45.6	71.6	113.9
Household	356.6	438.6	525.9	608.0	685.0
Service	5.5	11.3	21.4	39.9	73.4
Total	397.0	506.8	635.3	782.7	963.7

The per capita energy consumption will increase 1.5 times by 2050 to 23.76 GJ as compared to 15.50 GJ in the base year 2009. Similarly energy intensity of GVA will reduce by 4 folds till 2050 from 2009 value.

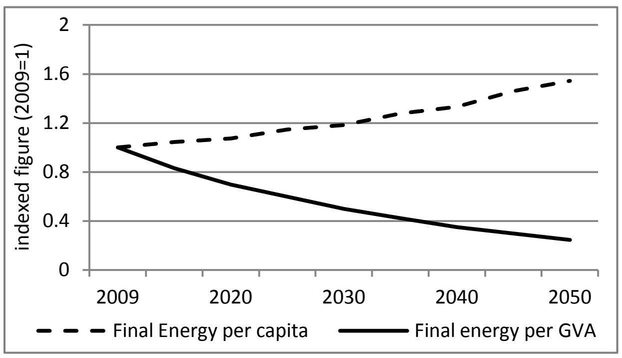

Figure 7: Energy intensity of GVA and per capita energy consumption

B. Sustainable Scenario

SUSTAINABLE ENERGY FOR ALL is an initiative launched by the United Nations Secretary-General to make sustainable energy for all a reality by 2030. Developed countries face the combined challenge and opportunity of transforming existing infrastructure, and developing countries have the opportunity to adopt cleaner, more efficient technology from the start. The three objectives of sustainable energy for all are as follows:

1. Ensure universal access to modern energy services
2. Double the global rate of improvement in energy efficiency
3. Double the share of renewable energy in the global energy mix.

These three objectives reinforce each other in many instances, and achieving the three together will power opportunity, maximize development benefits and help stabilize climate change [4].

The same demographic and economic assumptions considered in the Reference Scenario have been assumed in this scenario as well. In addition, energy demand grows with technological intervention.

As stated above in order to access clean energy access by 2030 various technological intervention in different sectors of the economy have been considered. The technological interventions are listed below:

Household Sector

Urban household

5. 100% electricity access by 2020
6. 100% penetration of electricity in space heating, water heating & cooking by 2030

Rural household

1. 100% electricity access by 2030
2. By 2035, 40% penetration of biogas in cooking along with 10% electricity and remaining improved cook stove

Service sector

1. Kerosene used in space heating completely replaced by electricity by 2030.
2. Kerosene used in lighting replaced by electricity by 2015.
3. Traditional fuel, kerosene and LPG used for cooking and water heating gradually replaced with electricity by 2030.

Transport Sector

1. Introduction of electric railway for freight transport
2. Introduction of electric metro and electric car in intra-city transport
3. Introduction of passenger trains for electric mass transport in intercity transport.

Industrial sector

1. Replacement of Traditional fuel, coal, diesel and other oil used in boiler with electricity by 50% until 2050.
2. Replacement of Traditional fuel, coal, diesel and other oil used in process heat completely with electricity by 2050.

With the assumed technological interventions in the reference scenario, the overall final energy demand is projected to increase 1.2 times over the analysis period 2009-2050. The projected final consumptions of various fuels in this scenario have been given in Table 6 and the growth pattern of the various fuel types over period 2009-2050 has been shown in Figure 8.

Table 8: Total energy consumption in sustainable scenario (PJ)

Fuel Type	2010	2020	2030	2040	2050
Traditional fuels	349	261	194	187	163
biogas	3	6	19	21	21
Electricity	8	32	69	114	179
Kerosene	3	2	1	1	1
LPG	6	7	5	5	6
Diesel	17	21	30	42	63
Petrol	4	5	6	7	9
Coke & steam coal	8	11	14	17	17
other oil	0	0	0	0	0
Jet Fuel	1	1	1	1	1
Total	**397**	**347**	**338**	**394**	**459**

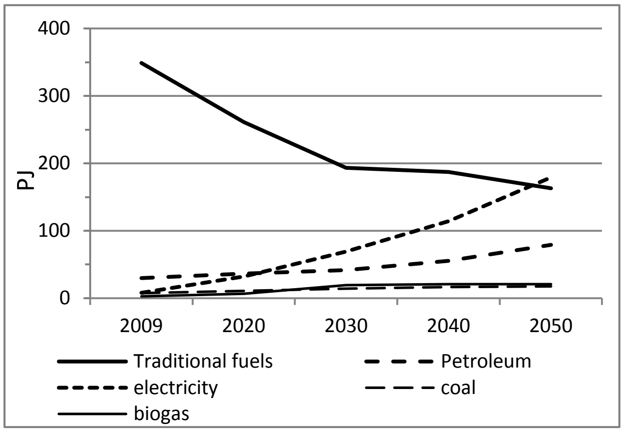

Figure 8: Total final energy demand 2009-2050 in Sustainable Scenario

Technology intervention in the household sector

Household sector that accounts for about 90% of the total energy consumption in Nepal spends most of the energy for cooking purpose as shown in Table 9.

Table 9: End use consumption pattern in household sector

End uses	Rural household	Urban household
cooking	65%	71%
space heating	8%	3%
space cooling	0%	1%
water boiling	2%	6%
electric appliance	0%	3%
lighting	1%	7%
others	24%	9%

(Source: [14])

Still 18 percent of the total household (including urban and rural) uses kerosene for lighting purpose [7]. With the increase in access to electricity, households will switch from kerosene to electricity for lighting. The luminous flux of electricity lamps is more than 20 times that of kerosene lamps [15].

Technology intervention in urban household

With 100% electricity access by 2020 in the urban household, all household is expected to switch to electricity for lighting. Further increasing the penetration of electricity in thermal uses is expected to completely replace other fuels (traditional, coal, kerosene and LPG) by 2030 with electricity. The comparison of the final energy demand for the Reference Scenario and Sustainable Scenario can be seen from Figure 9 and 10.

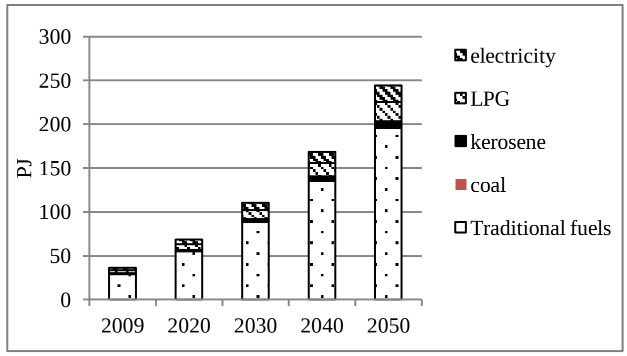

Figure 9: Final energy demand in urban household in reference scenario

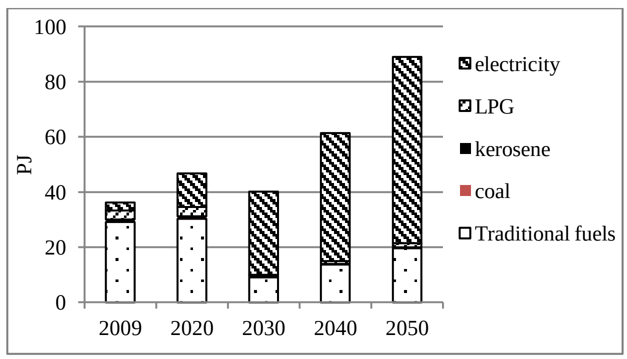

Figure 10: Final energy demand in urban household in sustainable scenario

From the figures it can clearly be seen that the traditional fuel dominated energy demand will switch to electricity dominated demand from 2030 onwards in the urban household sector. Electricity share will increase to 76% in the sustainable scenario as compared to 8 % in the reference scenario in 2050. Similarly the share of traditional fuel will drop to 22 % in the sustainable scenario as compared to 80% in the reference scenario. LPG share will also reduce to 2% as compared to 9% in the reference scenario in 2050.

Besides the changes in the energy mix, increasing the penetration of electricity will also reduce the final energy demand as depicted in Figure 11. The final energy demand in the reference scenario will be 244 PJ in 2050. The final energy demand in case of the sustainable scenario will reduce by 155 PJ to only 89 PJ in 2050. This reduction is mainly achieved because of the higher end use efficiency of electricity as compared to other fuels.

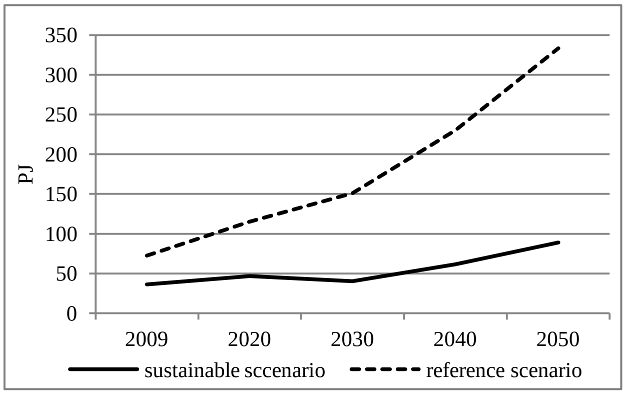

Figure 11: Comparison of final energy demand between reference and sustainable scenario in urban household

Technology intervention in rural household

In case of rural household, the electricity access is assumed to reach 100% by 2030 as compared to 49% in reference scenario. With such assumptions, kerosene used for lighting will be displaced completely with electricity by 2030. Nepal's 20 year Renewable Energy Perspective Plan has a goal to achieve 1.5 million household with biogas and 2 million household with improved cook stove by 2030.

Table 10: Renewable perspective plan 2011-2030 target

	No. of households in thousand			
Year	2015	2020	2025	2030
Biogas	300	500	900	1500
ICS	600	1000	1500	2000

(Source: [16])

With such penetration of renewable energy and increased access to electricity, the final energy demand in rural household for reference and sustainable scenario is shown in Figure 12 and 13.

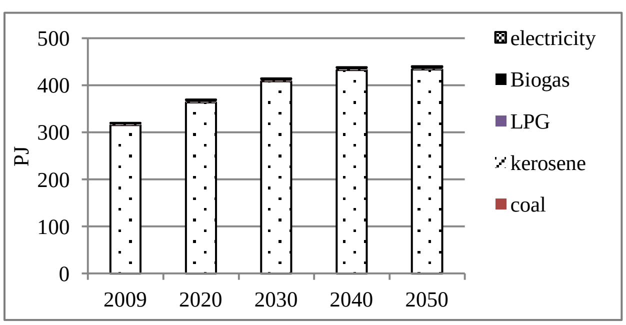

Figure 12: Final energy demand in rural household in reference scenario

From the figures it can be seen that the traditional fuel will continue to dominate the energy demand in the rural household sector. However electricity share will increase to 12% in the sustainable scenario as compared to 0.35 % in the reference scenario in 2050. Similarly the share of traditional fuel will drop to 74 % in the sustainable scenario as compared to 98% in the reference scenario.

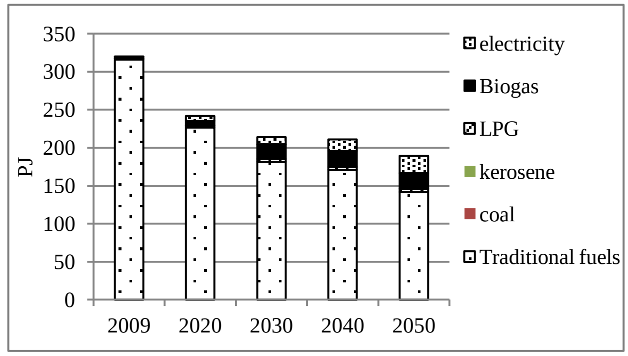

Figure 13: Final energy demand in rural household in sustainable scenario

Besides the changes in the energy mix, increasing the penetration of electricity will also reduce the final energy demand as depicted in Figure 14. This reduction is mainly achieved because of higher end use efficiency of electricity, biogas stove and improved cook stove as compared to traditional fuels (as shown in Table 11).

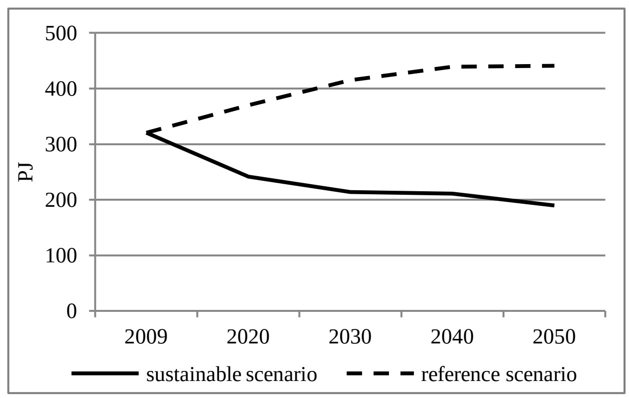

Figure 14: Comparison of final energy demand between reference and sustainable scenario in rural household

Table 11: Efficiency of different type of stoves

Type of stove	**Efficiency**
Biogas stove	45%
LPG stove	60%
Kerosene Stove	43%
Wood Stove	10%
ICS	20%
Electric stove	70%

(Source: [17])

Technology intervention in the service sector

Service sector consumes only about 1.3% of the total energy consumption in Nepal [13] whereas it accounts for 49% in the GVA in the country. Service sector has a high share of commercial fuel. 40% of the energy demand in the service sector is met by LPG and 20% by electricity. Traditional fuels meet about 32% of the service sector energy demand. The end uses in the service sector are given in Table 12.

Table 12: End uses in service sector

End Uses	Percentage share
Cooking	77.9%
Space Heating	6.2%
Space Cooling	1.6%
Water Boiling	0.9%
Electric Appliance	0.8%
Lighting	12.5%
Others	0.1%

(Source: [18])

With gradual increase in the penetration of electricity in the end uses in the service sector, most of the energy demand is expected to be fulfilled with electricity by 2030 and onwards. The comparison of the final energy demand for the Reference Scenario and Sustainable Scenario can be seen from Figure 15 and 16.

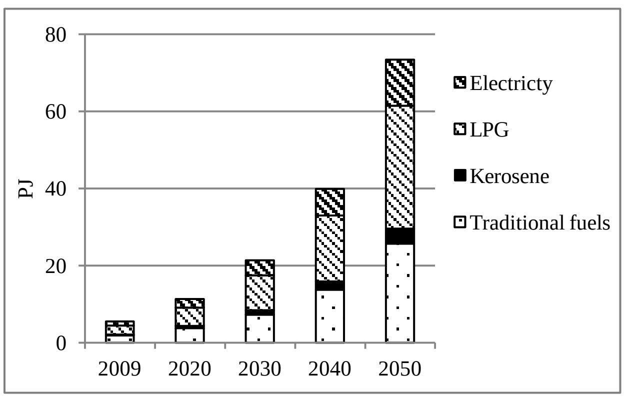

Figure 15: Final energy demand in service sector in reference scenario

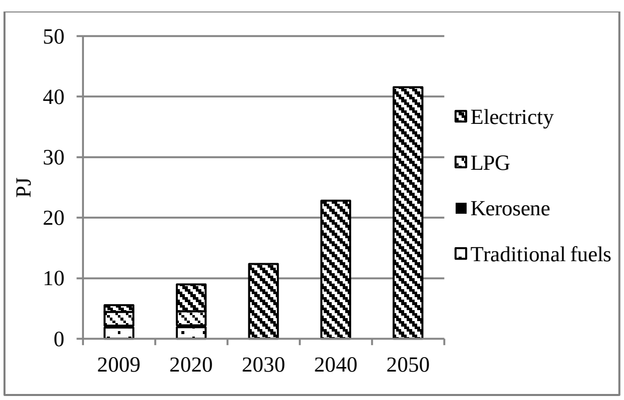

Figure 16: Final energy demand in service sector in sustainable scenario

From the figures it can clearly be seen that the LPG dominated energy demand mix in the reference scenario will change to electricity dominated energy demand mix by 2030. In addition, there will be considerable decrease in the final energy demand in the sustainable scenario by 40 PJ in the year 2050 as compared to that in the reference scenario (Figure 17).

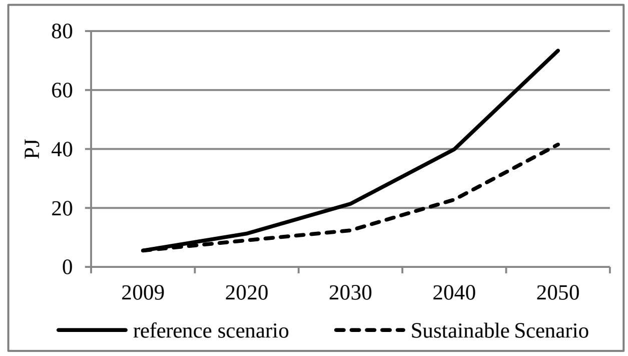

Figure 17: Comparison of final energy demand between reference and sustainable scenario in service sector

Technology intervention in the transport sector

About 5% of the total fuel consumed in the 2008/09 was spent on the transport sector [13]. A total of 1.17 million vehicles have been registered in Nepal by fiscal year 2010-2011 [19]. The various modes of the transport for the same year with their respective share is shown in the Table 13 and technical characteristics of transport technoloies considered have been listed in Annex I.

Table 13: Transport mode with fuel type with respective share

Transport mode	Fuel	% share
Freight		
truck, tankers	Diesel	84.8
tractors	Diesel	8.4
pickups	Diesel	6.8
Intracity		
Large Bus	Diesel	95.77
mini bus	Diesel	1.00
Car	Diesel	0.04
Car	Petrol	0.42
diesel micro	Diesel	0.35
Aviation	Aviation Fuel	2.42
Intercity		
Car	Petrol	8.3
Car	Diesel	0.9
taxi	Diesel	4.6
Minibus	Diesel	31.7
bike	Petrol	43.5
Van	Diesel	4.5
Van	LPG	1.2
three wheeler	LPG	2.0
three wheeler	Electric	3.2

In the sustainable scenario analysis, electric railway for freight and intercity passenger transport and electric metro for the intracity transport has been assumed to be available from 2020 onwards (10 years from the base year) considering the long lead time required for the infrastructure development. It has further been assumed that the share of electric car will increase from 5 % in 2020 to 15% in 2050 in intracity transport. Feasibility study of the Mechi-Mahakali and Pokhara-Kathmandu Electric Railway has estimated the share of traffic that would be diverted to electric railway after its commencement as given in Table 14.

Table 14: Traffic diverted to electric railway

	2020	2025	2030	2035
Freight transport	25%	30%	35%	40%
Car	25%	30%	35%	40%
Bus	40%	45%	50%	55%
Air transport	25%	35%	45%	45%

(Source: [20])

With such assumptions the final energy demand in the transport sector in the sustainable scenario will be as shown in Figure 18 and 19 explains the transport sector energy consumption in the reference scenario.

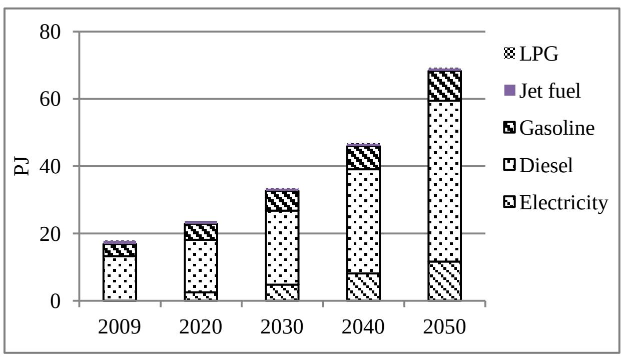

Figure 18: Final energy demand in transport sector in sustainable scenario

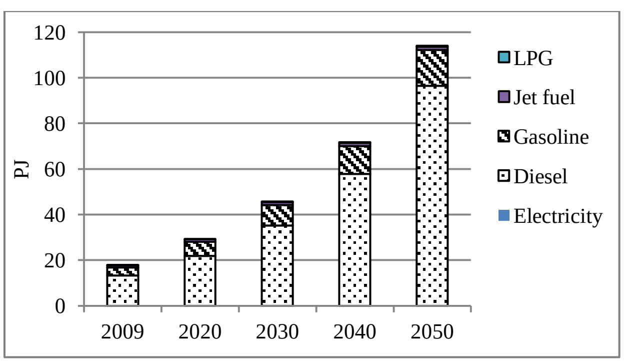

Figure 19: Final energy demand in transport sector in reference scenario

The above figures show that diesel fuel will continue to be dominant in both the scenarios. However the share of electricity will considerably increase in the sustainable scenario. The share of electricity in the sustainable scenario will be 17% in 2050 as compared to 0.014% in the reference scenario. Diesel fuel will account for 69 % in sustainable scenario as compared to 84 % in the reference scenario in 2050. The share of petrol will be 13% in both scenarios whereas the share of Aviation fuel will reduce to 1 % as compared to 1.3% in the reference scenario.

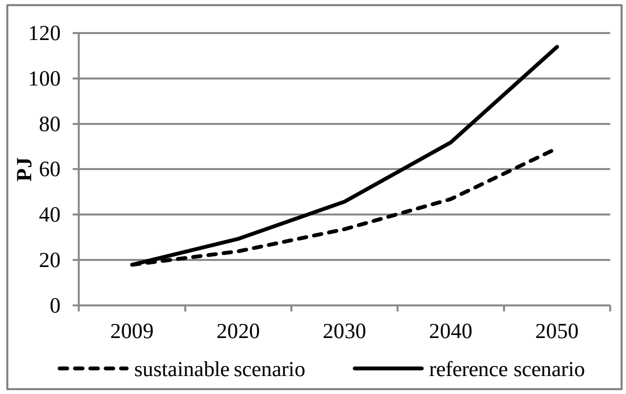

Figure 20: Comparison of final energy demand between reference and sustainable scenario in transport sector

Technology intervention in the manufacturing sector

Manufacturing sector accounted for 3.3 % of the total energy consumed in 2008/09 in Nepal. The various end uses considered in this sector is given in Table 15.

Table 15: End uses in the industrial sector in 2008/09

End Use	Percentage share
motive power	21%
boiler	6%
process heat	48%
lighting	3%
others	22%

(Source: [18])

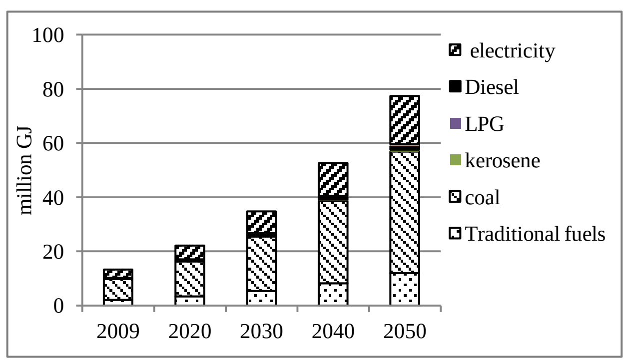

Figure 21: Final energy demand in manufacturing sector in reference scenario

With the increase in the penetration of electricity in the manufacturing sector, the traditional and fossil fuel will be gradually replaced with electricity as shown in Figures 21 and 22. Share of electricity will increase from 22% in reference scenario to 62% in sustainable scenario in

2050.The final energy demand in the industrial sector will reduce from 77 PJ in the reference scenario to 55 PJ in the sustainable scenario (i.e. reduction by 21 PJ) in 2050.

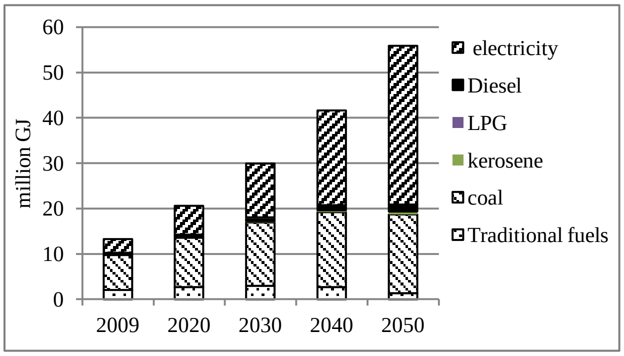

Figure 22: Final energy demand in manufacturing sector in sustainable scenario

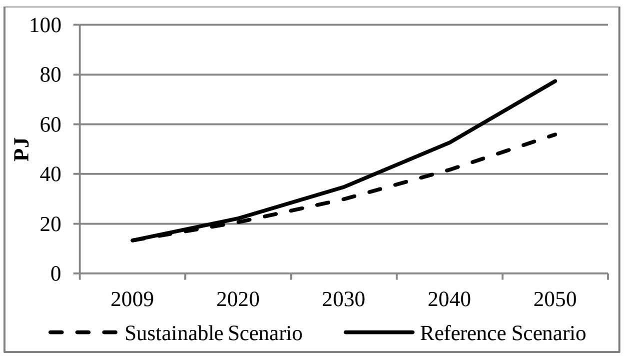

Figure 23: Comparison of final energy demand between reference and sustainable scenario in manufacturing sector

Reduction in final energy demand in the sustainable scenario

There is considerable reduction in the sustainable scenario through various technological interventions. The total reduction in the energy demand in different analysis period is given in Table 16.

Table 16: Total final energy demand reduction in the sustainable scenario as compared to refernce scenario

Sectors	**PJ**			
	2020	**2030**	**2040**	**2050**
Manufacturing	1.5	4.8	11.0	21.5
Service	2.4	9.0	17.1	31.9
Transport	5.6	12.3	24.9	44.8
Household	150.0	271.6	335.6	406.4
Total	**159.5**	**297.7**	**388.6**	**504.6**

With the increase in penetration level of electricity in household, service, transport and manufacturing, the level of electricity share in the total energy demand increases rapidly in the sustainable scenario. The 2% electricity share in 2009 will increase to 5% by 2050 in the reference scenario whereas in case of the sustainable scenario it will increase to about 40% by 2050.

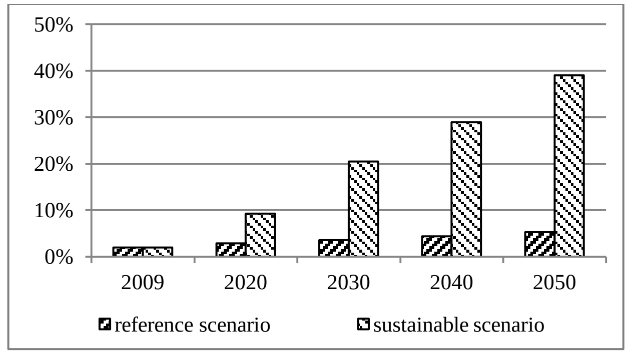

Figure 24: Share of electricity in the reference and sustainable scenario

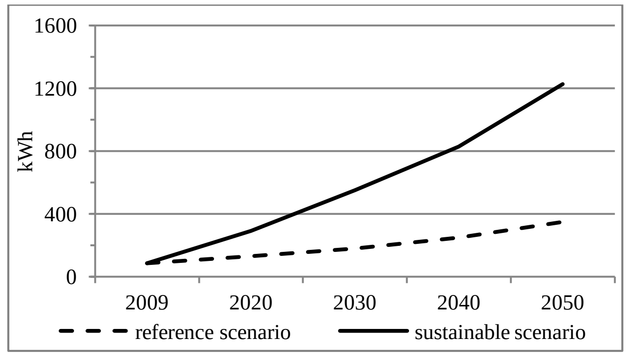

Figure 25: Electricity consumption per capita in the reference and sustainable scenario

The electricity consumption per capita will increase from 85 kWh in 2009 to 348 kWh in 2050 in the reference scenario. In case of sustainable scenario this value will rise to 1227 kWh by 2050.

Calculation of hydropower plant capacity required

Total NEA hydropower installed in 2011(including major & small hydro) = 477.53 MW [21]

Total Available Energy from NEA Hydro in same year = 2,122.08 GWh [21]

Capacity Utilisation Factor =

$$\frac{\text{Total Energy generated}}{\text{Installed capacity}} = 0.5072$$

Electricity requirement in 2050 in reference scenario

= 14 TWh

Required installation capacity = 3,150 MW

Electricity requirement in 2050 in sustainable scenario = 49 TWh

Required installation capacity = 11,026 MW

The share of imported fossil fuel will continue to increase in both scenarios (Figure 26). But the rate of increase is slower in the sustainable scenario. Imported fuel will account for 25% share by 2050 in the reference scenario as compared to 20% share in the sustainable scenario.

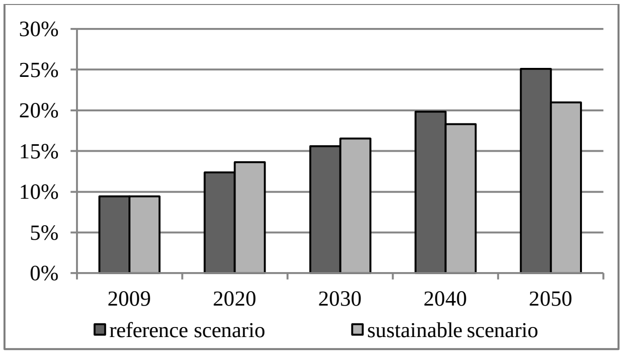

Figure 26: Share of imported fuel in the reference and sustainable scenario

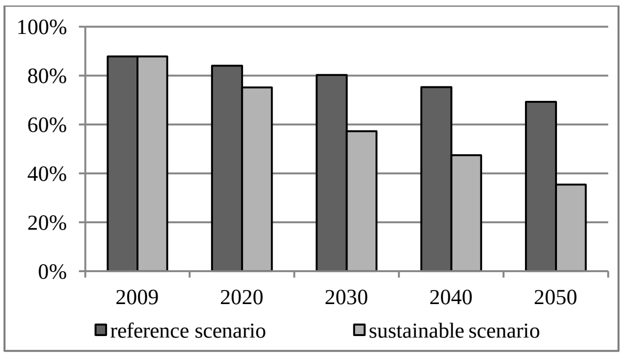

Figure 27: Share of traditional fuel in the reference and sustainable scenario

The share of traditional fuel will continue to decrease in both scenarios as explained by Figure 27. But the rate of decrease is much rapid in the sustainable scenario. Traditional fuel will account for 69% share by 2050 in the reference scenario as compared to 39% share in the sustainable scenario.

4. Conclusion

This paper has examined effects of sustainable technology intervention in the energy demand of Nepal over the period 2009-2050. This analysis shows that in the reference scenario, the energy consumption will increase by 2.4 folds during 2009-2050. The final energy demand in the reference scenario will reach to 963 PJ in 2050 from base year value of 397 PJ in 2009. In the case of sustainable scenario, the final energy demand will only be 460 PJ in 2050. This reduction is achieved due to increase in the electricity penetration in the energy system. Electricity has high end use efficiency as compared to other technologies presently being used that consume traditional and fossil fuel.

The share of imported fossil fuel will be 25% (241 PJ) in the reference scenario in 2050. Petroleum export already exceeds the country's export earnings. Owing to growing trend in the global fossil fuel market, Nepal may not be able to sustain the oil import with its export earnings only. This means that the country will need to arrange funding from other sources for import of petroleum product. The present analysis reveals that implication of sustainable technologies would reduce dependency on the imported fossil fuel. The share of petroleum product in the national energy system will reduce to 21% (96 PJ) in the sustainable scenario. Such large reduction can make noticeable improvement in the energy security of the country. This would reduce the burden of huge expenditure presently being spent on the import of fossil fuel by greater extent and contribute towards the import and export trade balance.

This paper also reveals that increase in the electricity penetration into the energy system would promote sustainable development of indigenous hydropower resource in the country. The reference scenario demands 14 TWh electricity by 2050 which is equivalent to 3,150 MW installed capacity (capacity utilization factor for hydropower plants taken as 0.5072, [21]). With the increase in electricity share in the sustainable scenario, the electricity demand will be 49 TWh in 2050 equivalent to 11,026 MW. Further electricity consumption per capita will increase from 85 kWh in 2009 to 348 kWh in 2050 in the reference scenario. In case of sustainable scenario this value will rise to 1,227 kWh by 2050.The present electricity generation capacity of Nepal is only 3.1 TWh with installed capacity of only 705.56 MW (includes hydro, thermal and solar) [21]. To meet the electricity demand of the sustainable scenario additional hydropower plants of 10,320MW need to be constructed in Nepal by 2050.

Over the analysis period, the traditional fuel will continue to decrease from base year share of 88% to 69% in the reference scenario and to 35% in the sustainable scenario by 2050.The share of electricity will increase from 2% in the base year to 5% in the reference scenario and to 40% in the sustainable scenario at the end of analysis period. This indicates a huge change in the consumption pattern of energy in Nepal in future years. From these figures it can be concluded that with the employment of sustainable energy technologies, Nepal will continue to climb up in the energy ladder rapidly.

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Annex I: Technical characteristics of transport technologies considered in the study

Transport mode	Life-time yrs	Energy intensity (GJ/1000 pkm, GJ/1000 tkm)	Annual km per vehicle	Occupancy (ton, passenger)
Truck	12	1.26	37,500	6
Tractor	10	2.68	18,000	2
Pickup	10	2.23	44,500	2
Large bus	14	0.16	33,522	50
Mini bus	12	0.23	31,790	30
Bike	7	0.3	10,950	1.6
Diesel car	8	0.91	16,349	2.6
Gasoline car	8	0.87	16,349	2.6
Taxi		0.87	37,125	2.6
Diesel van	12	0.14	37,125	12
LPG van	12	0.14	37,125	12
LPG three wheeler	7	0.2	29,848	10
Electric three wheeler	7	0.08	29,848	10
Electric car	8	0.25	16,349	2.6
Electric freight train	15	0.07		600
Electric passenger train	15	0.1		740
Electric metro	15	0.17		296

(Source: [22][23][24][25])

Perspective of Molasses Based Bioethanol-Blending in Gasoline for the Transportation Sector of Nepal (2013-2030)

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Abstract*: This paper intends to produce an overall perspective of the feasibility regarding the bioethanol blending in gasoline for the transportation sector of Nepal. Transport sector has about 40% share in the total commercial energy consumption in Nepal. Over 4.1 PJ of gasoline was consumed by this sector in 2009. With an upshot in number of vehicles across the nation in recent years, huge amount of national earning is spent on the import of petroleum, a serious strain on the country's economy. Nepal, like in any other agricultural country, has a notable potential of bio ethanol production, the possible fuel hugely based on sugarcane molasses. The country produced about 60,000 tons of sugarcane in year 2009 with the production density just over 43 tons/Ha. As much as 6 billion NRs can be saved with the optimistic scenario with the partial substitution of gasoline with bioethanol. Further, the use of bioethanol has a positive impact on reducing vehicle emission, the problem widespread in a crowded city like Kathmandu.

Keywords: Biofuel, Bioethanol, E10, Rectified spirit

1. INTRODUCTION

Nepal, a nation without any utilizable indigenous petroleum resource, completely depends upon the import to fulfill the fossil fuel demand across the nation. The country frequently has to deal with the problem of dependency on fossil fuel. It has become increasingly more dependent on fossil fuels and its energy security hangs on the fragile supply of imported oil that is subject to disruptions and price volatility. Due to the increase in number of fossil fuel based vehicles across the nation, every year a huge amount of national earning is spent on the import of petroleum. The oil import bill is a serious strain on the country's economy.

With the total primary energy supply of only 14.28 GJ/capita [1], in year 2009 (fiscal year 2008/09), traditional fuel accounted over 87% of the total energy with fuel wood sharing the highest proportion of over 89%. Consumption of commercial energy was over 12%. Within this, HSD contributed to over 36% followed by electricity and coal with the share of 16.6% and 15.9% respectively. The use of gasoline is about 8.5% in same year. Contribution of renewable energy is very less summing up to less than 1% of total consumption, biogas, so far being the most successful technology [2].

In the same year, among the sectors, residential sector consumes most of the share accounting up to over 89%. Transportation accounts over 5% of total energy consumption followed by Industrial and commercial sector accounting a share of nearly 1%. Transport sector is the largest consumer of imported petroleum product in the country. Nepal Oil Corporation (NOC), the State owned company, is responsible for the supply of petroleum products for transport in Nepal which in the past years, has accumulated astronomical debts the result of which is a long queue in gas station due to frequent shortage of transport fuels, public unrest due to rise in the price for petroleum products, and air pollution at prodigious rates. The government of Nepal in 2008, for the abatement of these ongoing problems, formed a high level committee with the task to find energy alternatives that will contribute to reduce oil consumption [3].

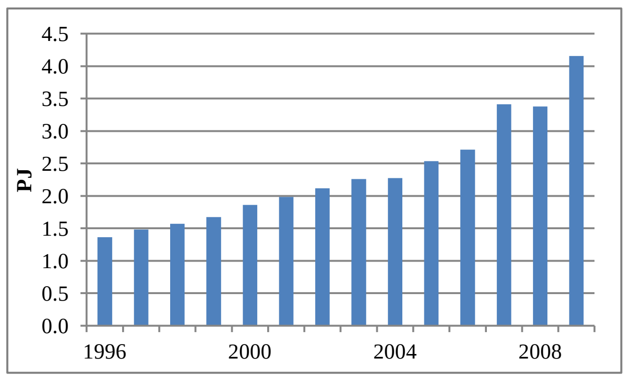

Figure 1: Usage of gasoline in transportation sector

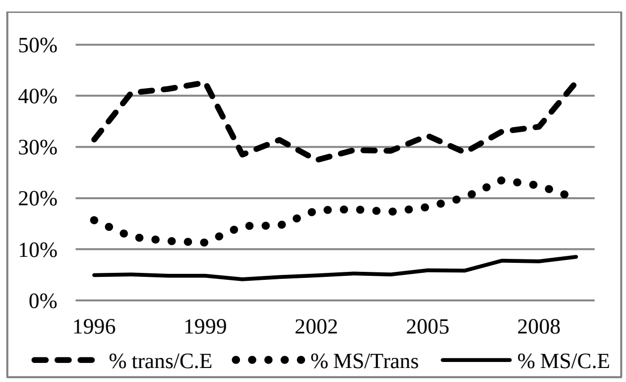

Figure 2: Share of transport for commercial energy and share of gasoline (WECS, 2010)

Trans ≡ energy used in transport sector, C.E ≡ commercial energy supply, M.S ≡ motor spirit

2. BIOETHANOL FUEL: A BRIEF OVERVIEW ACROSS THE WORLD

To reduce the dependence on fossil fuel and with the increasing concern of renewable energy technology to be included in energy usage, the annual production of fuel ethanol across the world has been ever increasing. In year 2012, the world ethanol production summed to over 322 billion liters, US being the largest contributor with a share of over 64%. South America stood the second largest producer with 25% of the share. Asia, Europe and Africa contributed about 4.7%, 5.8%, and 0.3% to the sum respectively [4].

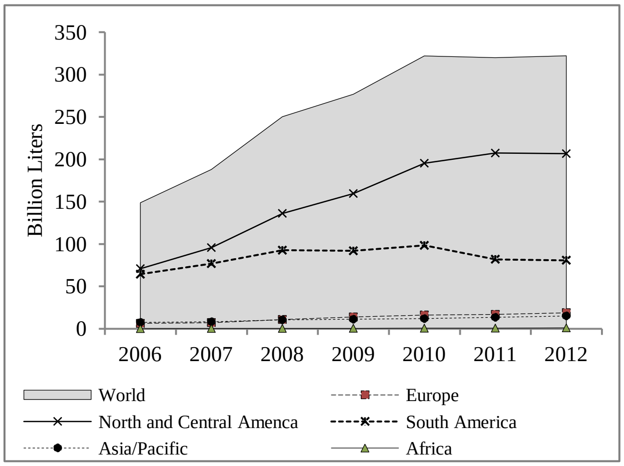

Figure 3: World ethanol production (RFA, F.O. Lichts)

South America

In Brazil, consumes nearly 4 billion gallons of ethanol annually [4]. In 1975 Brazil introduced the National Alcohol Program Pro alcohol focusing on the production of ethanol from sugarcane [5]. Blend of 5% hydrated ethanol to all imports of gasoline by volume was mandated in early 30's to reduce the dependence on fossil fuel [6]. In Argentina, Gasoline and diesel are required to contain a 5% biofuel share starting in January 2010. In 2009, 75% of total gasoline consumed in Colombia had 10% ethanol content [7].

North America

The Canadian EPA had mandated 5% of renewable energy source in gasoline by 2010 that would require a minimum of 1.9 billion liters of ethanol, a production hugely based on cereal grain in Canadian context. US, the largest producer of bioethanol, had almost 20% of the total corn supply reallocated to fuel ethanol production. In 1978 the Energy Tax Act established tax credits for ethanol blenders [8].

Europe

The German government fixed the share of ethanol in gasoline at 2.8% over the interval of 2009–2014. From 2015 onwards, the biofuel quotas will be determined on the basis of GHG emission reductions [9].

Asia

Chinese government, at the beginning of 2006, carried extensive pilot projects in five provinces and 27 cities had achieved the 10% blending target. In Indonesia, the ethanol component of gasoline is required to be 3% in 2010 and increase up to 15% by 2025. In Thailand where government is promoting E20 and E85 blends and fuel-compatible vehicles, tax exemptions are allowed in ethanol which makes ethanol blends to be significantly cheaper than regular gasoline [5].

India, in 2003, launched the first phase of their biofuel program in which 5% blending of ethanol in gasoline was mandated in certain areas of nine major sugarcane growing states and four union territories. In 2009 the GOI set an official target of at least 20% blending of ethanol with gasoline by 2010 [5].

Australia

In Australian context, in 2006, the state of New South Wales set a 10% binding share of ethanol in gasoline by 2011 and the state of Queensland required 5% ethanol content in gasoline by 2011 [5].

3. USAGE OF GASOLINE AND POTENTIAL FOR ETHANOL BLENDING

The nation has a total storage capacity of 71,558 kL. There are 10 storage facilities for gasoline that adds up to around 5,135 kL, the highest being Amlekhgunj depot in central development region [9].

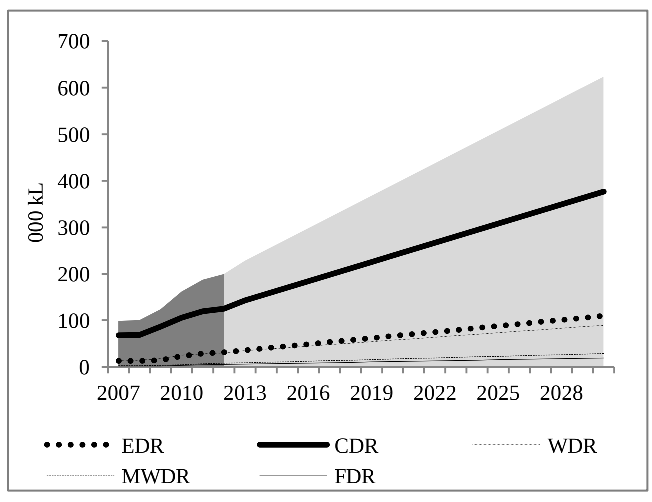

Figure 4: Projection for gasoline consumption (2012- 2030)

It is seen that the trend for gasoline consumption will be on rise in future year demanding even more quantity. With the current fashion, at the end of 2030, the total consumption of the nation is expected to cross 600 thousand kL.

4. OVERVIEW OF ETHANOL PRODUCTION IN NEPAL

Nepal has 8 operating sugar mills out of the 25 registered, out of which, only four claim to have capacity to produce ethanol. Three claim that they can produce ethanol by the cracking method and one has already the facility of dehydration plant through the molecular sieve technology [[10] and field survey]. The largest one, Sriram sugar mill has the production capacity of about 30 kL/day, the production which is not commercialized. However, there are 40 distilleries registered in government agency consuming ethanol. The supply of ethanol for fuel also depends on the demand of ethanol by these distilleries [10]. The utilization factor for Nepalese is very low, summing up to 53% in year 2005/06 [11].

Nepal, being an agricultural country, the potential of bio ethanol production from sugarcane molasses is worth noting. It is seen that the trend for cultivation area as well as the production of sugarcane has been increasing till date as is depicted in Figure 5. The country produced about 60,000 tons of sugarcane in year 2009. The production density is however lower, just over 43 tons/Ha, compared to the major producer of sugarcane like Brazil and India which have production yield over 75 tons/Ha. This signifies that Nepal has more potential of sugarcane production than in current situation.

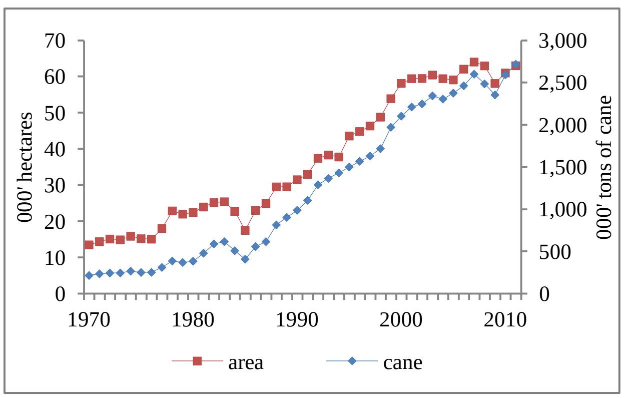

Figure 5: Trend of sugarcane production in Nepal (FAO, 2013)

Bio ethanol which is unsuitable for the human consumption can be used as a blend in gasoline for the use in transportation sector. This in turn has a positive impact primarily on the reduction of import of gasoline. Indirect effect on the use of ethanol in blending could be the reduction of GHG emission from the use of gasoline alone and the utilization of indigenous resources as well.

The study, using E10 (a mixture of 10% anhydrous ethanol and 90% gasoline), E20 and G100 (Pure Gasoline) fuels in cars and motorbikes in 10 most popular brands in Kathmandu, conducted in late 2007, observed increased combustion efficiency and reduction in amount of pollutants emission (CO) was reduced by 36.60 for E10 and 96.4 % for E20 by volume and HC reduced to 45 ppm for E10 and 46.62 ppm for E20) in ethanol blended fuel [12]. With then petrol price of NRs 73.5 the economic assessment states the cost of E10 and E20 to come cheaper by NRs 4/liter and NRs 8/liter respectively [13]. Ethanol also acts as an oxygen enhancer, increasing octane levels by approximately 2.0 to 3.0 at the 10v (volume)% level [14]. Experiment also indicates the increase in brake thermal efficiency for the blends when compared to that of sole fuel. [15]. With the increase in blend percentage, the amount of carbon monoxide and Non-methane hydrocarbons (NMHC) decreases. However, the ethanol emission, acetaldehyde, formaldehyde and NOx increase with the increasing quantity [16].

5. RESULTS

Under various assumptions, namely three scenarios are drawn. These scenarios provide information regarding the required quantity of ethanol to be produced to meet a given blend percent. Conversely, the ratio of blend that will be available can also be derived from the results.

Scenario 1 –SR1

In this scenario, all of the RS derived from sugarcane so produced and projected will be used to make bioethanol and will not fulfill the demand for liquor industries. This scenario provides the full blending potential of the nation; the viable side shall be derived from it by considering the demand of RS in the liquor production.

Given the potential of bioethanol production, when all rectified spirit is converted in RS, the nation wide blend can reach over 9% which diminishes to less than 6%.

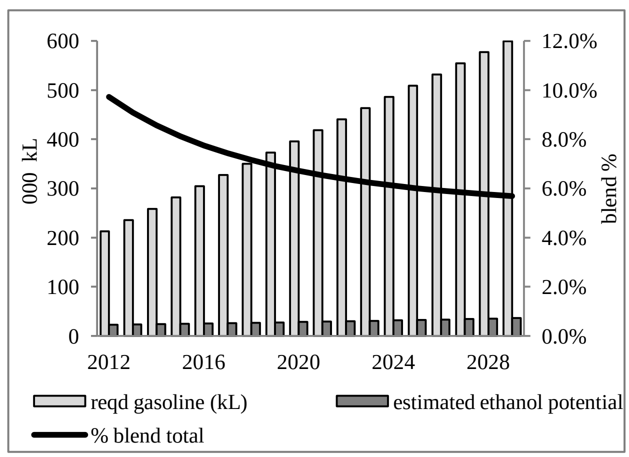

Figure 6: SR1 (all RS is used for bioethanol production, Ending year is 2030)

Scenario 2 –SR2

This scenario is based on the assumption that ethanol will be produced only in quantity defined by current installed capacity, i.e., 30kL per day by Sriram Sugar Mill.

The annual gasoline consumption increasing in usual rate, the available blend curve steeps down sharply to less than 2% for total gasoline and less that 3% for CDR at the end of analysis period as in Figure 7. With no increment in the capacity of ethanol production, with current capacity, 5% blend would not last for 4 years even only for CDR from this date. Hence, to increase the blending ratio, the ethanol production capacity needs to be increased.

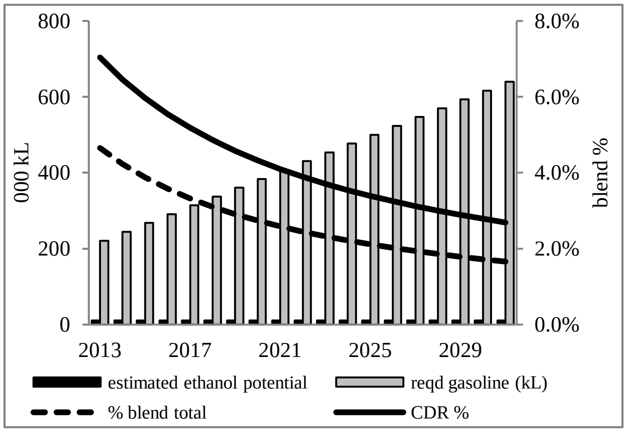

Figure 7: SR2 (Ethanol is produced based on current installed capacity)

Scenario 3 –SR3

SR3 is related to the production match of sugarcane. As it is expected for gasoline consumption to increase in future years, obviously, to blend of bioethanol to keep up with the rising trend, the production of sugarcane is the most critical input. Analysis regarding the current trend and future prospect under assumption imposed has been put forward in SR3.

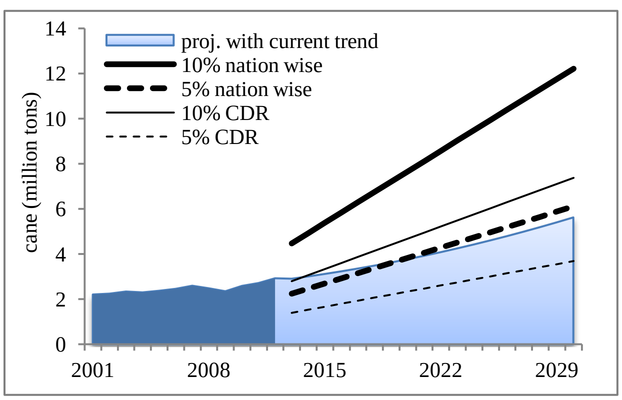

Figure 8: SR3 (Production match between current trend and future projection)

As from the analysis, the 5% blend will be able to keep up for no more than 5-6 years. However it should be noted that the scenario is based on assumption of RS (rectified spirit) being extracted efficiently and converted to anhydrous ethanol. With the share of liquor on hand, the gap widens even further.

With the same assumption, there seems no possiblility to blend 10% even for CDR. The 5% blend however seems can be achieved through out the analysis period.

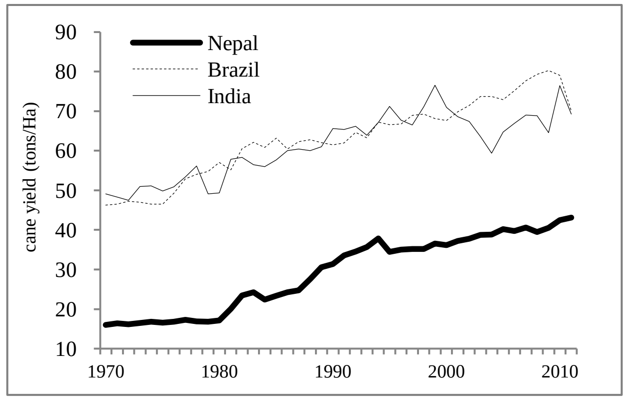

Figure 9: Comparison of cane yield (Source: FAO, 2013)

Figure 9 shows the comparison of trend of sugarcane yield of Nepal with two most leading producer, Brazil and India. Brazil has cane yeild reaching as maximum as 80tons/Ha. The figure for India also fluctuates around 60-70 tons/Ha for last decade. However, the cane yield for Nepal is way below that margin. Though the trend is rising since the beginning, there exists a huge gap between the yield figure compared to those of Brazil and India.

Scenario 4–SR4

SR4 depicts the scenario when the cane yield increases (50, 60, 70 tonsHa). The outlying assumptionsfor SR4 are as follows:

1. The cultivation area will remain constant (62,998 Ha as of base line 2011). It is based on the trend for 5 most recent years wherein the cultivation area seems to level off.
2. The demand for RS and ENA consumed by liquor industries of nation will be completely fulfilled by national production.
3. The ethanol production is made by surplus RS, being completely utilized.

The analysis has been made for two cases. First one considers the perspective of CDR as it is the region consuming most of the gasoline. The second one analyses the result with the whole nation.

Table 1: Surplus ethanol production for various yields

	50 tons/Ha	**60 tons/Ha**	**70 tons/Ha**
RS (kL)	25,199	30,239	35,278
RS reqd for liquor(kL)	19,211	19,211	19,211
Difference (kL)	5,988	11,028	16,067
Eth prod.Capacity (kL)	5,688	10,476	15,264

The analysis for blend for different cane yield has been made for CDR in addition with the current yield of 43.15 tons/Ha. Along with the assumptions, the result shows that with the current situation of sugarcane production in the nation, there is not enough potential for ethanol even for 2% blend. However, compared to the yield of other nation, there seems to be room for improvement for the yield. So far, with the increase in yield upto 50 tons/Ha, the blend ratio can just reach about 4% and declines to less than 2% at the end of analysis period (Figure 10). With the optimistic increase in yield of 70 tons/Ha, the idea of 10% blend can is justifiable in present context. It should be noted however that the result is based upon the surplus ethanol, the remains after the demand of liquor industries is fulfilled the nation itself.

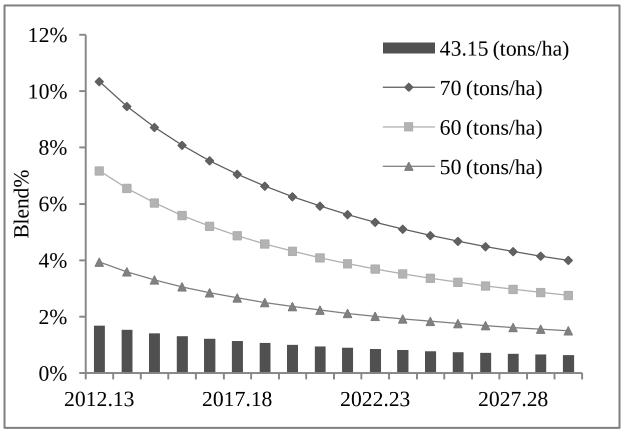

Figure 10: SR4 (a) (Blend ratio for different cane yield – CDR)

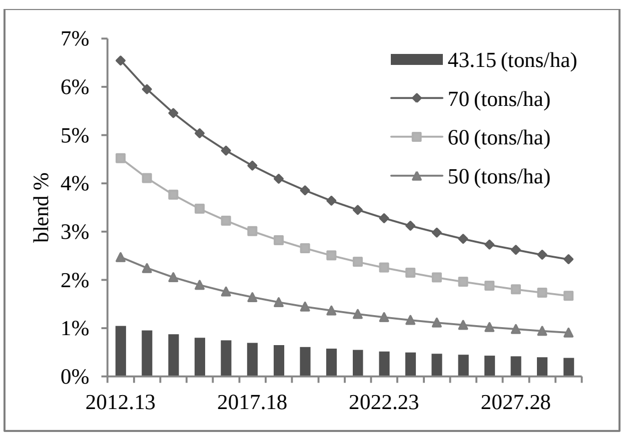

Figure 11: SR4 (b) (Blend ratio for different cane yield – all regions)

The scenario with different cane yield with similar sets of condition when taken for all regions is exhibited in Figure 11. The results shows that the with current yield condition, the blend ratio just reaches about 1% and declines sharply in consecutive years. With the optimistic yield of 70 tons/Ha, over 6% of ethanol can be blended when the consideration is made for whole nation.

6. ETHANOL BLENDING AND OPTION OF REDUCING IMPORTS

When ethanol is blended with gasoline, there is saving in import of gasoline across the border. In a nation like Nepal where the total export is not enough even for the import of petroleum product, (in year 2012/13, the import of petroleum product has exceeded 100 billion NRs in its first 11 months but the total export merely crossing 70 billion NRs) [17], the saving can be even more considerable. Figure 12 shows the saving from blending ethanol in various scenarios.

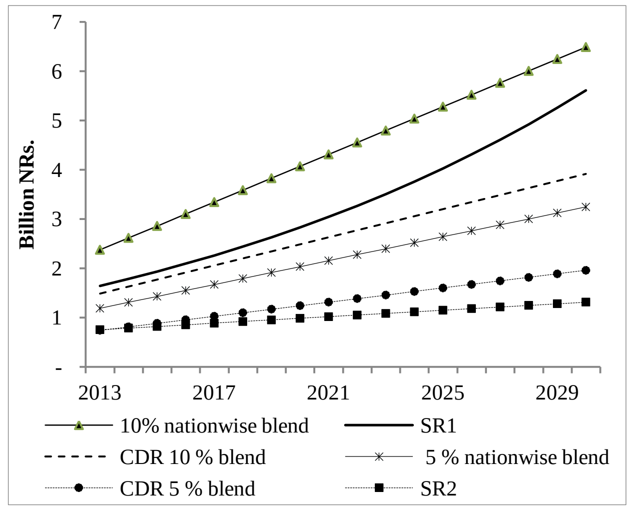

Figure 12: Saving in import from substitution by ethanol

For SR1, when all RS is used to produce ethanol and used in blend, and 10% nation wise blend, the saving is very noticeable, amounting to over four billion and six billion Nepalese rupee in year 2030. It should be noted however that the saving is based on the selling price of gasoline and not the actual cost price for NOC. For more accurate result, later price should be used.

The result with 5% nation wise blend and 10% blend in CDR is satisfactory, creating a saving between 3 and 4 billion Nepalese rupee in year 2030. The figures for remaining situation may not be noticeable in long run.

The Kathmandu Valley could save 4,860 m^3 of gasoline per year, which is a reduction in imports of 6.8% if gasoline automobiles went for E10. Opting E20, a reduction of 14% in gasoline imports, i.e. an annual saving of 10,078 m^3, can be achieved, which corresponds to an ethanol requirement of 15,315 m3 in a year, which is still lower than the total potential capacity of the sugar mills, given the availability of molasses for ethanol production [3].

7. CONCLUSION

The transport sector is one of the major consumers of commercial energy. There seems to be huge potential for the bioethanol to be used as blend in gasoline in the nation. This however depends on many pillars like the price of gasoline, the price of ethanol and the policy of the government. With the present case however the available quantity seems inadequate for the blends to be made commercially viable. This is also supported by the price of ethanol and gasoline in present context, the latter being cheaper to the energy trading company of the nation. It is seen that the result of bioethanol blending is quite enticing, both in terms of saving import and environmental. With the price of gasoline on rise, the possibility of making an ethanol blend however can rise in future where strict policy of the government is essential.

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Optimal Under Frequency Load Shedding Scheme Considering Load Frequency Characteristics of Integrated Nepal Power System

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***Abstract*: Under-frequency load shedding is the last defensive line to assure system security as an emergency measure. A new method of optimizing under-frequency load shedding is proposed in this paper with the idea that loads having lower frequency regulation factor should be shed earlier than those with larger frequency regulation factors. Therefore power absorbed by the loads will be more effectively reduced and power balance will occurs more quickly in the transient process. Digital simulation with justification is presented in this paper.**

Keywords:* *Power System; Under Frequency Load Shedding (UFLS); Load Frequency Characteristics; Frequency Regulation Factor

1. INTRODUCTION:

In any power system network when there is shortage of energy due to imbalance in demand and generation, it causes declination in system frequency. If the extent of deficiency of energy is large then frequency reduces beyond the acceptable limit called under frequency condition. Persistence of under frequency situation would impose harmful effect on machines connected to it. To protect the machines from hazards, machines undergo under-frequency tripping which will propagate and cascaded outage of other machines will occur leading to system collapse.

Several blackouts per year in Integrated Nepal Power System (INPS) are due to under frequency tripping of machines. The instantaneous mismatch in generation and demand is the sole cause of these blackouts. Since energy neither can be created nor be destroyed, Load shedding at transient period is only the defensive action to avoid the under frequency situation and protect the power system. Hence under-frequency load shedding scheme is needed for reliable operation of power system during under-frequency conditions.

The mechanism to curtail the electrical loads to avoid the under frequency condition is called Under Frequency Load Shedding (UFLS). The chief feature of UFLS should be to curtail minimum amount of load with faster recovery to normal operation. Load shedding must be executed in such a way to reduce the effect on consumers as well as utility as far as possible.

The self adaptive Under Frequency Load Shedding Scheme [1]makes use of frequency change rates and can achieve rapid removal of loads in case of sever power shortage. Conventional Load Shedding (CLS) [2-3] cuts the pre-set amount of load at each stages of declining the system frequency below the pre-defined threshold value. Unfortunately, these methods exclude the load frequency characteristics of loads.

In actual operation of power system, different loads have different frequency regulation factors. With the conventional load shedding scheme, the pre-set frequency can't be achieved as quickly since loads are not same as pre calculated. The active power of electrical loads depends upon frequency of supply called frequency dependent loads. Whenever there is change in frequency the active power consumption of electrical component is altered. The frequency dependent loads are characterized by the frequency regulation factor (K_{pf}) which signifies how much active power is changed per unit change in frequency. This characteristic of loads has a considerable effect on load shedding mechanism which affects the amount of load to be curtailed and recovery time.

This paper proposes a new methodology to optimize the conventional load shedding considering load frequency characteristics.

2. FREQUENCY DEPENDENT LOADS

A. Load Frequency Characteristics

In general, power system loads are composed of a variety of electrical devices. For resistive loads, such as lighting and heating loads, the electrical power is almost independent of the frequency. In case of motor loads, such as fans and pumps, the electrical load changes with frequency due to change in motor speed. The dynamic response of frequency dependent load can be expressed by the following relation.

$$P_{load} = p_o * \left[1 + K_{pf} \frac{(f - f_o)}{f_o} \right] \qquad \ldots \text{(i)}$$

Where, f_o = Base frequency

f = system frequency

K_{pf} = Frequency regulation factor

P_o = active power at frequency f_o

P_{load} = active power consumption at frequency f

Frequency Regulation factor is defined as percent of the load variation from the total load for one percent of frequency deviation from the nominal value.

$$K_{pf} = \frac{\Delta p}{\Delta f} \quad \text{… (ii)}$$

Typical values of frequency regulation factors (Kpf) [13] for various loads are given in Table 1 below.

Table 1: Typical values of frequency regulation factors

Equipments	**Frequency Regulation Factor (Kpf)**
Cooking heater	0.1
Hot plate	0.1
Oven	0.1
Rice cooker, Electric kettle	0.1
Water heater	0
Fan	2.9
Pump set Domestic	2.9
Television	0
Fridge	0.53
Iron clothes	0.1
Air condition	0.6

Let us consider two load components having regulation factors K_{pf1} and K_{pf2} such that $K_{pf1}>K_{pf2}$. Suppose the loads at frequency f_o be $P_{L1}(f_o)$ and $P_{L2}(f_o)$ then for a frequency $f < f_o$ implies $P_{L1}(f) < P_{L2}(f)$. It shows that when frequency decreases by Δf then active power absorbed from the power sources by the load with bigger frequency regulation factor will decrease more.

The frequency dependent loads can be categorized into several types on the basis of type of consumers. Some examples of load category are Residential, Commercial, Industrial, Agricultural etc. Each category consists of a variety of load components having their own frequency regulation factor. Equivalent frequency regulation factor of each load category can be calculated which is required for simulation.

B. Calculation of Aggregate Load Frequency Regulation Factor

The component–based approach [13] is followed to calculate frequency regulation factor of each load category. It involves the following steps:

i. Determine the load category composition, i.e., the fraction of each component belonging to particular load category.

ii. Use the load category composition fractions as weighting factors to compute a weighted average of the individual component frequency regulation factors.

Each load category is defined by its percentage composition of load components, such as window air conditioner, incandescent lighting, refrigeration, etc. And each load components has its frequency regulation factor. With these data applied to following equation can yield equivalent frequency regulation factor.

$$K_{pf,\ Equivalent} = \sum_{i=1}^{nlc} K_{pf,i} . L_i \quad \text{… (iii)}$$

Where, $K_{pf,i}$ is frequency Regulation Factor of i^{th} component.

L_i is fraction of i^{th} load component in load category considered.

nlc is total no of load components considered in particular load category.

3. CONVENTIONAL LOAD SHEDDING SCHEME

In the conventional load shedding scheme, when the frequency is lower than the first setting value, the first stage of load shedding will be employed where pre-defined amount of load is curtailed from the system. If the frequency continues to decline, it is clear that the first load shed amount is insufficient. When the frequency is lower than the second setting value, the second stage of load shedding will be implemented. If the frequency continues to decline, the further load shed stages will be activated until the normal frequency value is restored.

It has a number of stages with smaller load in order to minimize over shedding and a time delay is employed to stabilize the frequency.

The stages of Under-frequency Load Shedding (UFLS) are as follows:

Stage 1: 10% load is shed when frequency drops to 49.5 Hz

Stage 2: 15% additional load is shed when frequency drops to 48.8 Hz

Stage 3: 20% additional load is shed when frequency drops to 48 Hz and so on.

4. METHODOLOGY

To optimize the CLS considering load frequency characteristics following steps were followed during the paper works:

1. Data describing the Generation and load of Test system were prepared.
2. The total frequency dependent loads were categorized into different groups and their

equivalent frequency regulation factors were calculated.

3. The generation deficiency was set such that system goes to under frequency condition.
4. Conventional load shedding stages were employed if frequency declines beyond the threshold values.
5. During Load curtailment, same amount of calculated load of different category was at different run of simulation.
6. The frequency responses obtained from curtailing different categories of load were compared.
7. Based on the frequency output of system, develop the optimal under- frequency load shedding scheme.

5. SIMULATION AND RESULTS

To optimize the Under Frequency Load Shedding Mechanism, simulation has been done in MATLAB Simulink. The Simulation model consists of a generator having capacity 500MVA, 40MW spinning reserve capacity and inertia constant of 5s. Initially the system is operating at 50 Hz generating 400 MW. The simulation model is illustrated in the Figure 1.

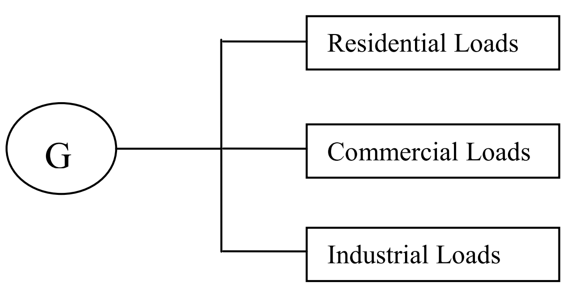

Figure 1: Block Diagram of Simulation Model

The total load is composed of three categories; Residential, Commercial and Industrial whose equivalent frequency regulation factor is calculated in contest of INPS.

In this paper, percentage load composition of load category is determined on the basis of Nepal Electricity Authority Leakage Control Act 2059 [14]. This act is applied to charge the consumers for non-technical loss calculation. The Act provides the data consisting of demand factor, load factor, daily operating hour, effective operating days per year and rating of each load components. These data are separately defined for residential and commercial consumers in average.

The available data can be manipulated to find the percentage sharing of each load component over a year for different load classes. The following two expressions are used to evaluate yearly percentage of load composition.

$$\%\text{ Load share of a component} = \frac{\text{Total Kwh consumed by the component per year}}{\text{Total Kwh consumed by all the components per year}}$$

$$\begin{array}{l} \text{Total Kwh consumed} \\ \text{by the component per year} \end{array} = \begin{array}{l} \text{Rating of Load Component x Demand factor x} \\ \text{Load factor x Daily Operating Hour x} \\ \text{Effective Operating Days per Year} \end{array}$$

Total KWhr consumed by each component is calculated and summed up to get total consumption and % share of components. Then Equation (iii) is implemented to determine frequency regulation factor of each category. Table 2 and Table 3 present the detail calculation of frequency regulation factor of Residential Loads.

Table 2: Load Composition of Residential Category

Equipments	Demand Factor	Load Factor	Operating Hrs.	Yearly Operating Time (Days)	Ratings of Equipments in Watt	Yearly Consumption (kWh)	% Sharing
Lights	0.5	0.7	5	365	600	383.25	6.98
Cooking heater	1	0.75	2	365	1000	547.5	9.97
Hot plate	1	0.5	2	365	1500	547.5	9.97
Oven	1	0.5	1	365	1500	273.75	4.98
Rice cooker, electric kettle	1	0.5	2	365	750	273.75	4.98
Water heater	1	0.75	1	150	1000	112.5	2.05
Fan	0.8	0.8	10	150	750	720	13.11
Pump set Domestic	1	0.8	1	365	1000	292	5.32
Television	1	1	4	365	120	175.2	3.19
Fridge	1	0.6	12	365	250	657	11.96
Iron clothes	1	0.4	1	365	750	109.5	1.99
Air condition	1	0.6	3	240	2200	950.4	17.30
computer	1	1	2	365	450	328.5	5.98
Vacuum cleaner	1	0.75	1	90	1800	121.5	2.21
Total						5492.35	100

Table 3: Determination of Load Frequency factor of Residential Load of INPS

Equipments	% Sharing	K_{pf}	Weighted K_{pf}
Lights	6.9779	1	0.0698
Cooking heater	9.9684	0.1	0.0100
Hot plate	9.9684	0.1	0.0100
Oven	4.9842	0.1	0.0050
Rice cooker , Electric kettle	4.9842	0.1	0.0050
Water heater	2.0483	0	0.0000
Fan	13.1091	2.9	0.3802
Pump set Domestic	5.3165	2.9	0.1542
Television	3.1899	0	0.0000
Fridge	11.9621	0.53	0.0634
Iron clothes	1.9937	0.1	0.0020
Air condition	17.3041	0.6	0.1038
computer	5.9810	0.85	0.0508
Vacuum cleaner	2.2122	2.1	0.0465
Total	100		0.900

Here, the average frequency regulation factor obtained for Residential load is 0.9. Similarly, the values obtained for commercial and industrial loads are 1.4 and 2.6 respectively.

Now for the simulation of test system the load share among three frequency dependent load category is depicted in the Table 4. The system is simulated with load shedding and without load shedding scheme for proper illustration.

Table 4

Load Type	$K_{pf}\left(\frac{dp}{df}\right)$	Representative type share	Load
Residential	0.9	40%	160 MW
Commercial	1.4	20%	80 MW
Industrial	2.6	40%	160 MW

Case 1: Disturbance without Load Shedding Mechanism

In this case we analyzed how the system behaves if there is no load shedding mechanism for different level of disturbances. We imposed loss of generation at 30MW, 50Mw and 90 MW respectively in different runs of simulation. The output frequency response obtained at each runs is plotted in a single graph which is show in Figure: 2. The steady state frequencies in curves are tabulated in the Table 4.

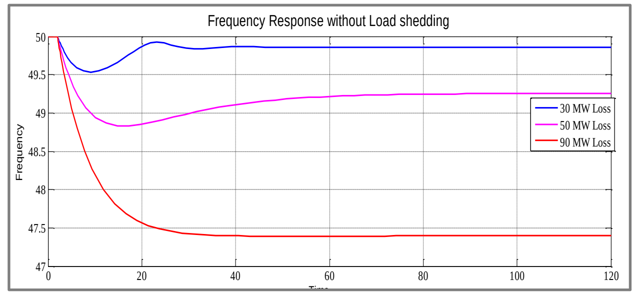

Figure: 2 Frequency Response without Load shedding mechanism

Table 4: Results of Case 1 in tabular form

Loss of Generation	Steady state Frequency
30 MW	49.86 Hz (Normal)
50 MW	49.25Hz (Normal)
90 MW	47.39Hz (Under frequency)

It is observed that frequency has restored to acceptable limit when disturbance is 30MW loss of generation but steady state value is not equal to 50Hz because of drooping characteristic of system. Drooping forces the system to operate at different frequency according to power output from generators. We can see that frequency is restored within the acceptable limit which is obvious because quantity of generation loss is met by the system reserve capacity.

The second curve which is due to loss of 50MW shows that frequency over-shoot during transient exceeds the minimum threshold value 48Hz but finally stabilize at 49.25 Hz which is acceptable value. Here, the spinning reserve fails to meet loss of generation but system is stable. The system is stable due to behaviors of frequency dependent loads. Whenever generation is deficit and reserve capacity doesn’t meet the requirement then frequency goes on declining continuously. During this transient period, frequency dependent loads also reduced till there is exact match between generation and demand. The frequency stabilizes after this exact match. But, this phenomenon of frequency stability would not be possible if there were no any frequency dependent loads.

If the amount of loss of generation is increased to 90 MW then frequency output is out of range than acceptable limit at both transient and steady state condition. This proves that frequency drops considerably if the generation of active power is not equal to active power demand.

Inspite of severe disturbance of 90 MW, the system is stable and operating but has gone to under-frequency condition. Under Frequency condition will affect several loads and generators in a harmful manner. So for 90 MW generation losses, the load shedding stages must be triggered.

Case 2: Disturbance with First Stage of Load Shedding

It is proposed that first stage of load shedding is triggered if the frequency of the system is declining and reaches to 49.5Hz. The criteria for load curtailment are on the basis of actual value of frequency and rate of change of decline in frequency. Also, it is defined that 10% of total load in the system is thrown off at first stage. That means during loss of generation, 40MW (10% of 400MW total load) should be thrown off at this stage.

The total system load is composed of three different types of frequency dependent loads. They are residential, commercial and industrial load which are frequency dependent with frequency regulation factor 0.9, 1.4 and 2.6 respectively. We simulated our frequency response model by curtailing each type of load at different runs separately and compared the results.

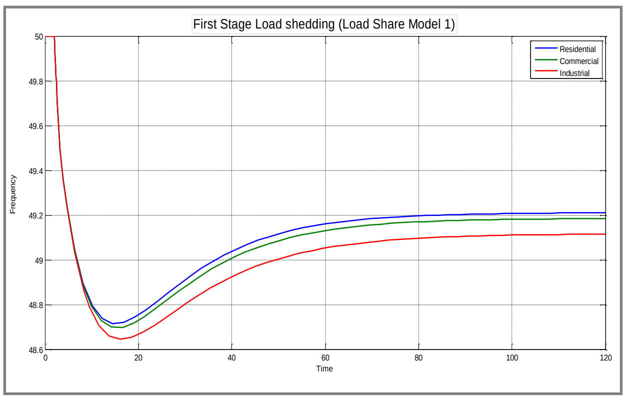

Figure 3: Output frequency responses by shedding different types of load

Table 5: Results of Case 2

Load type	$K_{pf}\left(\frac{dp}{df}\right)$	**Steady state Frequency**
Residential	0.9	49.21 Hz
Commercial	1.4	49.18 Hz
Industrial	2.6	49.11 Hz

Figure 3 clearly show that curtailing residential loads are more desirable in comparison to other loads. The frequency regulation factor of residential loads is smaller one compared to others loads. The steady state frequencies while throwing residential, commercial and industrial loads are tabulated in Table 5. Also the frequency deviations of residential load are the least one among other loads.

Proposed Under-Frequency Load Shedding Scheme

To optimize the conventional load shedding mechanism, the priority of loads for shedding could be specified in advance. Two basic principles of the load shedding priority in each stage are detailed below:

1) Loads are first divided into n categories, i.e. $L = i(i = 1,2,3,...)$, respectively. The smaller the category number, the less important the load will be.

2) Loads with the same category are shed in the order of increasing K_{pf} values. The load with the smaller K_{pf} value will be shed earlier.

The Flow chart of Load Shedding in each stage is shown in Figure 4.

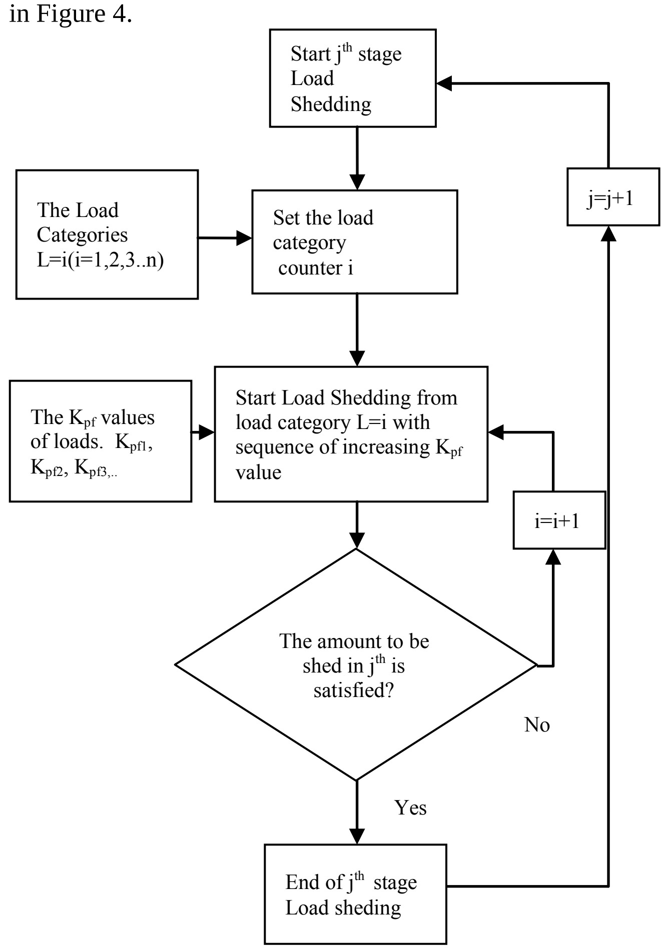

Figure 4: Flow Chart of Load shedding in each stage

The load shedding steps in each stage are described below:

Step 1: Set the load category counter i.

Step 2: Start load shedding from the load category $L = i$ with the sequence of increasing values. In this process, the specified shed load level must be respected. If the shed load in this class is sufficient, then stop; otherwise, go to the next step.

Step 3: Set $i = i + 1$, and go back to Step 2.

6. CONCLUSION

The paper has proposed a optimization scheme for Conventional load shedding mechanism. The method has fast recovery of system considering loads characteristics. When significantly lower percentage load of the system was thrown only form residential loads which have lowest value of Kpf among other types of load, then frequency restoration was faster with minimum over-shoot and lesser deviation in steady state frequency.

Hence it can be concluded that during the Under-frequency load shedding process, shedding the load with the smaller K_{pf} is more beneficial in restoring the system frequency than shedding the load with the bigger K_{pf}. And new optimized Under Frequency Load shedding mechanism was developed.

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Short-Term Generation Scheduling with Minimized Total Cost of Generation as well as Transmission Loss of Power System Using Genetic Algorithm

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***Abstract*: Operating an interconnected power system with optimum operation is still a challenge for the planners/operators. Even if the power system is operating with optimal generation cost, some of the other factors such as power loss in the transmission line might be higher. In this paper an innovative approach for minimizing total cost of generation and transmission loss is proposed. In this work, Genetic Algorithm (GA) is applied as an optimization tool considering transmission loss in account in a power system. The result shows that generation cost, average cost of generation per unit and hence total cost of generation and power loss decreases significantly with proper generation scheduling using GA.**

Keywords:* *Power generation scheduling, security constraints, transmission losses, Genetic Algorithm

1. INTRODUCTION

In an electric power system, the total load on the system has significant variation over different hours in a day. Loads in the system also vary in different days in a week and month according to the season. Power loss in the transmission line varies accordingly as the load varies. This variation in hourly and daily system load imposes a problem in operation of an electric power system. A simple way, just to meet the system load adequately may be to operate enough units to cover the maximum system load. But, in such operation practice, the problem lies in the economics of operation. Generation scheduling problem deals with determining the optimal operation strategy of power plants for a predefined scheduling period subject to a variety of constraints.

In thermal based system cost function of all generators are available whereas in hydro based system average cost of energy is calculated in the basis of different costs associated with plants such as royalty to be paid to the government, operation & maintenance cost, interest and depreciation of the plant in annual basis. This paper focuses on daily generation scheduling and doesn't cover weekly or monthly or long-term model for generation scheduling.

The quantification and minimization of losses in generation scheduling is important because it determines the economic and efficient operation of the power system. If the most affecting factor for transmission line loss is realized then necessary steps can be taken to minimize loss accordingly.

Several research works have been carried out to solve the generation scheduling problem and power loss reduction problem using many different solution techniques. Genetic Algorithm (GA) approach is proposed in [1] to determine optimal power flow for loss minimization in Nepalese power system and it could be interpreted as modifying in dispatching way of active power generation in order to meet the certain specified load demand with loss minimization as the objective function. The parameters that are used as control variable are the active power generations of all the generating station. [2] also proposes GA approach to solve short term generation scheduling of hydro-dominated power system. Based on the concept of unit commitment and economic load dispatch, a best combination of available power sources is searched, for an optimum total cost of generation, satisfying several constraints. Besides considering all the cost components associated with power generation and power loss, optimization focuses on the minimum usage of water.

Dual Dynamic Programming (DDP) approach is proposed [3] to solve a network constrained short term hydrothermal scheduling problem with transmission losses. The DDP methodology approximates the cost function in each stage as Benders decomposition. It includes cascaded reservoirs, several hydraulic constraints. A novel nonlinear approach is proposed [4] to solve the short-term generation scheduling problem under deregulation, considering head-dependency. The co-evolutionary algorithm (CEA) based on the Lagrangian method is proposed [5] for hydrothermal generation scheduling to minimize the overall operation cost and the constraints satisfied by scheduling the power outputs of all hydro and thermal units under study periods, given electrical load and limited water resource. Genetic Algorithm (GA) technique is proposed [6] which yield global minima. It is proved that the GA approach for optimum scheduling of generators, yields a substantial saving/ economy in operating cost over the derivative approach.

Using genetic algorithms (GAs), [7] handles simultaneously the sub-problems of short-term hydrothermal coordination, unit commitment, and economic load dispatch. Considering a scheduling horizon period of a week, hourly generation schedules are obtained for each of both hydro and thermal units. Results for a real system are presented and discussed.Paper [8] presents superiority of the applications of GA technique over conventional quadratic programming to economic load dispatch problems for both continuous and discontinuous fuel cost equations.

2. Mathematical Formulation

A. Objective Function

The problem of the proposed work is to minimize total cost of generated energy and the energy loss in the transmission lines. The objective function can be written as:

Minimize $F = F_1(P_g) + F_2(P_g)$

Subject to the both equality and inequality constraints

Where,

F = Total Cost

F_1 = Cost of energy loss in transmission lines

= Energy loss in transmission lines x Average Cost of energy per unit

F_2 = Cost of energy generated

$F_2 = \sum P_{gi} \times R_i$

Where,

P_{gi} = Energy generated by i^{th} power plant in the scheduling hour

R_i = Cost of energy per unit of i^{th} generating station

Here both F_1 and F_2 are functions of active power generation (P_g).

B. Equality Constraints

Equality constraints used in this paper are the load flow equations.

$P_i = \sum Y_{ik} V_i V_k \text{Cos}(\theta_{ik} + \delta_k - \delta_i)$

$Q_i = -\sum Y_{ik} V_i V_k \text{ Sin}(\theta_{ik} + \delta_k + \delta_i)$

Where summation is for 'n' number of buses for n-bus power system network, Y_{ik} is admittance, V_i and V_k are the voltages at buses i and k respectively, θ_{ik}, δ_i and δ_k are the phase angles of admittance Y_{ik}, bus voltages V_i and V_k respectively.

C. Inequality Constraints

Inequality constraints normally reflect the limits on physical devices in the power systems and the limits created to ensure system security. Inequality constraints used in this thesis are:

i. Real power generation limit:

   $P_{gi}^{min} \le P_{gi} \le P_{gi}^{max}$; where P_{gi}^{min} and P_{gi}^{max} are respective minimum and maximum values of real power generation allowed at i^{th} bus.

ii. Reactive power generation limit:

   $Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}$; where Q_{gi}^{min} and Q_{gi}^{max} are respective minimum and maximum values of reactive power generation allowed at i^{th} bus.

iii. Voltage magnitude limit:

   $V_i^{min} \le V_i \le V_i^{max}$; where V_i^{min} and V_i^{max} are respective minimum and maximum values of voltage magnitude allowed at i^{th} bus.

iv. Line flow (MVA) limit on transmission line.

D. Control Variables

These are quantities whose values can be adjusted for minimization of the objective function while satisfying all of the constraints. Active power generations in different power plants are the control variables in this work.

3. Methodology

A. Proposed Approach

Figure 1 shown below depicts the flowchart for the proposed approach. To complete the generation scheduling with minimum total cost following procedure is adopted.

1. Formulating GA for solving generation scheduling problem.
2. Performing OPF for test power system using MATPOWER incorporated in MATLAB.
3. Solving for the solution of generation scheduling problem with optimum total cost of generation and transmission loss of the system by re-dispatching of active power generation from different plants.
4. Data collection
5. Analysis of the obtained results.

B. Modeling Assumptions

1. Load (Active and reactive power demand) is assumed to be constant during an hour.
2. All the available generating station are hot spinning and can operate to its maximum value.

3. Power plants either may be turned off (i.e. 0 output) or is operated in between maximum and minimum limits of power output.
4. Efficiency of the power plants is independent of active power generation.

C. Calculations of Generation Cost

For generation scheduling, we first need to identify all the possible sources of power supply and their generating cost per unit. In this study, mainly, two types of sources of power have been used which are described below.

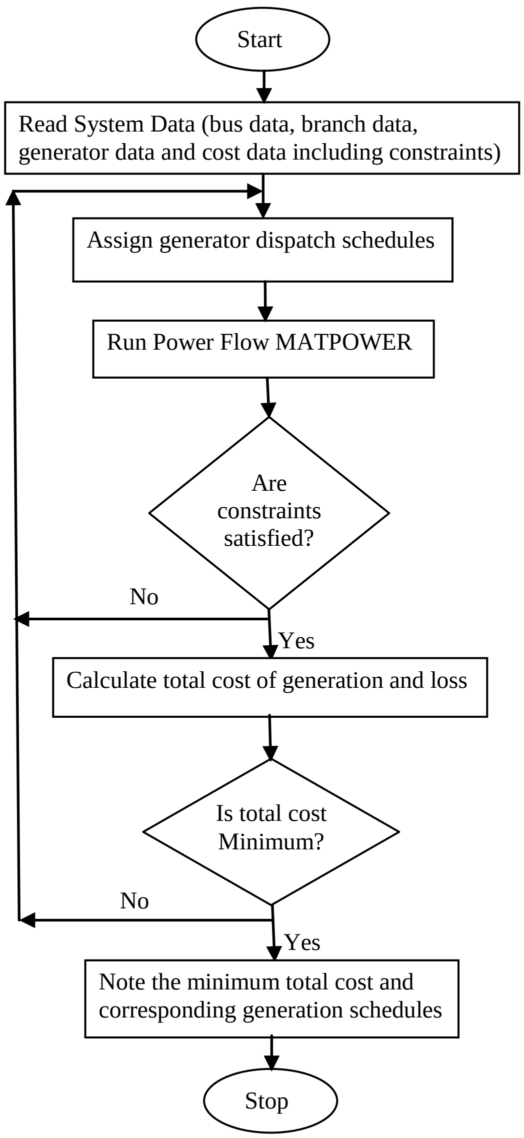

Figure1 Flowchart for the proposed approach

i. Power from Independent Power Producers (IPP):

Cost of energy to be paid to the IPP is governed by the power purchase agreement between the authorities (such as NEA) and IPP. Power for any particular hour from an individual private power plant shall be taken as per its power availability declaration.

ii. Power from the utility owned power plants:

Generation cost of energy shall be calculated based on individual plant's historical cost data.

$$\text{Rate of Energy} = \frac{(A+B+C+D)}{G}$$

A = Operation & Maintenance Cost

B= Royalty to be paid to the government

C= Interest on capital investment

D= Depreciation of the plant

G= Total energy generation

Generation cost of thermal power plants mainly depends upon the cost of fuel guided by the cost function of the plants whereas generation cost of hydro power plants is normally lower and mainly depends on royalty (both capacity based royalty and energy based royalty) to be paid to the government, operation and maintenance (O&M) cost, interest, depreciation and overhead cost.

D. Genetic Algorithm (GA)

Genetic Algorithm is a family of computational models inspired by genetics and evolution theory [2]. It is a parallel, global search technique that emulates natural genetic operators. It was first proposed and investigated by John Holland at the University of Michigan. Nowadays, Genetic Algorithms are being used as powerful tools in optimization problems. These algorithms encode a potential solution to a specific problem on a simple chromosome like data structure and apply recombination operators to these structures so as to preserve critical information. The algorithms differ from other search techniques by the use of concepts taken from natural genetics and evolution theory.

First, the algorithm works with a population of strings, searching many peaks in parallel. The information between peaks is exchanged by employing genetic operators. Secondly, it works with a coding of the parameters, not the parameters themselves (encoding). Thirdly, the algorithm only needs to evaluate the objective function to guide its search (fitness evaluation). No other auxiliary knowledge or derivatives are required. The value of fitness or performance measure of the population is only the available feedback. Finally, the transitions rules are probabilistic rather than deterministic. By the use of operators taken from population genetics, the algorithm efficiently explores parts of the search space where the probability of finding improved performance is high.

E. Load Flow Solution

In a three phase ac power system active and reactive power flows from the generating station to the load through different networks buses and branches. The flow of active and reactive power is called power flow or load flow. Power flow studies provide a systematic mathematical approach for determination of various bus voltages, phase angle, active and reactive power flows through different branches, generators and loads under steady state condition.

Once the load flow is solved, further analysis such as OPF can be easily performed. In this study power flow analysis is used to determine the power loss on each-iteration of the GA using MATPOWER incorporated in MATLAB.

In load flow analysis, first voltage at each bus is determined after that line flow from one bus to other is determined.

The complex powers S_{ij} from bus i to j and S_{ji} from j to i are:

$$S_{ij} = V_i \, I_{ij}^{*}$$

$$S_{ji} = V_j \, I_{ji}^{*}$$

The power loss in line i -j is the algebraic sum of the line power flows:

$$S_{Loss} = S_{ij} + S_{ji}$$

F. MATLAB & MATPOWER

MATLAB ("MATrix LABoratory") is a tool for numerical computation and visualization. The basic data element is a matrix, so if a program that manipulates array-based data is needed it is generally fast to write and run in MATLAB. In this thesis MATLAB R2008a version is used for programming of GA based Optimal Power Flow (OPF) problem.

MATPOWER is a package of MATLAB M-files for solving power flow and optimal power flow problems. It is intended as a simulation tool for researchers and educators that are easy to use and modify. MATPOWER is designed to give the best performance possible while keeping the code simple to understand and modify.

In this twork MATPOWER 3.2 version is used in MATLAB R2008a. Commonly used files of MATPOWER in this research work are runpf.m, printpf.m, ga.m including other user created files.

4. CASE STUDY

A. Study Case I: IEEE 30-bus test system

The study case I is applied for IEEE 30-bus system as depicted in Figure 2 which consists of 6 generators, 24 load buses and 41 branches. Table I shows the daily demand for a day for the system. Load demand varies from 116.8 to 258.1 MW. Daily load curve for the system is plotted as shown in Figure 2. Bus data, branch data and generator data and other constraints of the network are input parameters taken from the system whereas minimum and maximum generation limits of generators and generator cost functions are available as in Table II. All the generating stations are coal fired thermal power plants.

Table 1: Load demand for IEEE 30-bus test system

Hour	Load, MW	Hour	Load, MW
1	116.2	13	206.1
2	131.1	14	211.4
3	142.8	15	213.1
4	147.2	16	206.9
5	166.5	17	219.4
6	179.1	18	249.8
7	212.1	19	258.1
8	199.6	20	252.6
9	194.3	21	206.1
10	202.0	22	189.2
11	205.0	23	145.4
12	195.9	24	119.8

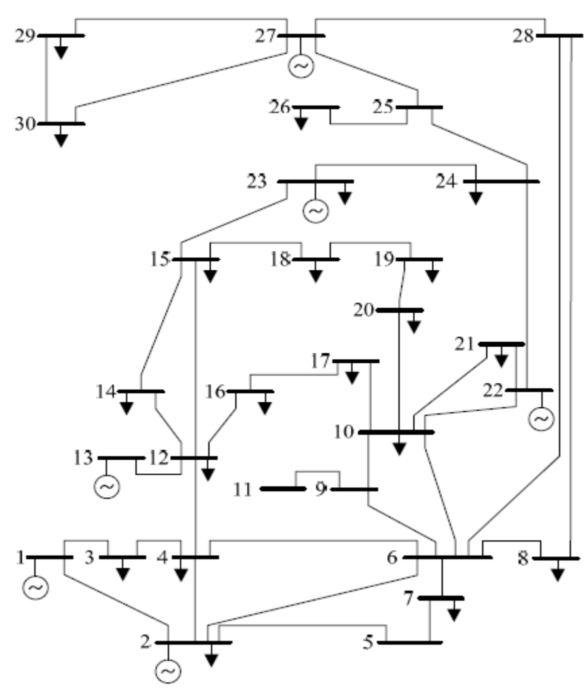

Figure 2: Single line diagram of IEEE 30-bus system

TABLE 2: Cost Functions of Generators

S.N.	Active Power	P_{min} –P_{max}, MW	Cost function
1	P_{g1}	0-80	$0.02* P_{g1}^2 +2.0* P_{g1}$
2	P_{g2}	0-80	$0.0175* P_{g2}^2 +1.75* P_{g2}$
3	P_{g3}	0-50	$0.0625* P_{g3}^2 + P_{g3}$
4	P_{g4}	0-55	$0.00834* P_{g4}^2 +3.25* P_{g4}$
5	P_{g5}	0-30	$0.0625* P_{g5}^2 + 3.0* P_{g5}$
6	P_{g6}	0-40	$0.0625* P_{g6}^2 + 3.0* P_{g6}$

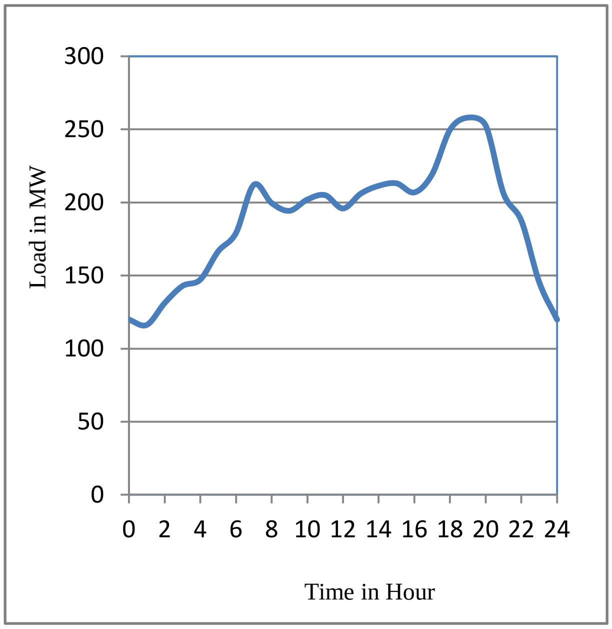

Figure 3: Daily Load Curve for IEEE 30-bus system

B. Study Case II: Integrated Nepal Power System (INPS)

For testing and verification of the developed model the scenario of Nepal Electricity Authority has been taken. The power demand and generation scenario of B.S. 2068/069 has been considered (including some power plants and transmission lines under construction assuming that they were under operation in the scheduling period). Name of plant, ownership of the plant, minimum and maximum generation limits, and average cost of energy for each plant is shown in the Table III. Cost of energy of the diesel plants and plants like Khimti and Bhotekoshi operated by IPP are higher whereas cost of energy of NEA owned plants are lower. Power loss is obtained by load flow solution.

Table 3: General Scenario of INPS

SN	Name of Plant	Owner of the Plant	Pmin, MW	Pmax, MW	Cost of Energy, Rs./ unit
1	Marsyangdi	NEA	25	69	1.96
2	Gandak	NEA	5	15	5.15
3	Kulekhani-I	NEA	25	60	2.31
4	Multifuel	NEA	10	39	69.59
5	Hetauda	NEA	4	14.1	63.55
6	Chilime	IPP	4	20	6.47
7	Khimti	IPP	25	60	8.5
8	Bhotekoshi	IPP	10	36	7.83
9	Kaligandaki 'A'	NEA	40	144	2.79
10	Midmarsyangdi	NEA	30	70	4.93
11	Andhikhola	IPP	1	5.1	4.22
12	Devighat	NEA	4	14.1	1.77
13	Trishuli	NEA	8	24	2.34
14	Jhimruk	IPP	2	12	5.85
15	Kulekhani-II	NEA	8	30	2.46
16	Sunkoshi	NEA	2	10.05	2.11
17	Modi	NEA	4	14	4.91
18	Puwa	NEA	1	6.2	2.29
19	Indrawati	IPP	1	7.5	4.83
20	Piluwa	IPP	1	3	3.9
21	Khudi	IPP	1	4	3.9
22	Mardi	IPP	1	3.1	3.9
23	Lower Modi*	IPP	1	15	3.9
24	Up. Tamakoshi*	IPP	100	456	4
25	Kulekhani-III*	NEA	1	14	4.5
Total Installed Capacity= 1134.8 MW, Total Load = 841.2 MW					

5. Results and Discussions

When the collected information from IEEE 30-bus test system and INPS was processed and fed as input data to the developed model, it was successful in searching the optimum solution to give the following outputs:

- Hourly status (on or off) and power output for all generating units
- Hourly cost of energy generation for each generating plant and total cost of energy generation
- Average generation cost per unit
- Transmission loss of the network
- Total cost of generated energy and power loss

A. Results for IEEE 30-bus test system

i. Daily generation scheduling without using GA

Without using GA, load flow has been run for base case using MATPOWER incorporated in MATLAB. Generation schedules for a day (24 hours) are as shown in Table 4 shown below. Total cost of generated energy and transmission loss is $ 14805.8 for 24 hours in the scheduling day. Power loss is obtained from the load flow solution. Outputs of all of the generators are considered within the maximum and minimum power limits. Calculations of cost of generation of all generators are according to their cost function given in Table 2.

Table 4: Daily generation scheduling without using GA

Hour	Load, MW	Output From Different Generators, MW						Total Cost, $
		G1	G2	G3	G4	G5	G6	
1	116.2	17.1	41	10.6	12.9	9.2	27	333.94
2	131.1	32.4	41	10.6	12.9	9.2	27	381.07
3	142.8	44.1	41	10.6	12.9	9.2	27	423.5
4	147.2	27.6	51	11.6	12.9	19.2	27	440.65
5	166.5	48	51	11.6	12.9	19.2	27	515.34
6	179.1	60.9	51	11.6	12.9	19.2	27	570.32
7	212.1	64.4	51	21.6	22.9	19.2	37	700.76
8	199.6	51.3	51	21.6	22.9	19.2	37	641.76
9	194.3	45.7	51	21.6	22.9	19.2	37	619.17
10	202	53.7	51	21.6	22.9	19.2	37	651.62
11	205	56.8	51	21.6	22.9	19.2	37	665.34
12	195.9	47.4	51	21.6	22.9	19.2	37	625.87
13	206.1	58.1	51	21.6	22.9	19.2	37	671.86
14	211.4	63.8	51	21.6	22.9	19.2	37	698.3
15	213.1	55.3	53	26.6	25.9	19.2	37	698.25
16	206.9	20.9	53	36.6	35.9	27.2	37	697.05
17	219.4	62	53	26.6	25.9	19.2	37	729.14
18	249.8	65.4	53	36.6	35.9	27.2	37	868.63
19	258.1	74.3	53	36.6	35.9	27.2	37	913.63
20	252.6	68.5	53	36.6	35.9	27.2	37	884.22
21	206.1	19.7	53	36.6	35.9	27.2	37	692.84
22	189.2	26	61	21.6	26.9	19.2	37	601
23	145.4	33.3	33	20.5	24.9	17.9	18	428.35
24	119.8	14.2	22.9	24.5	22.9	13.5	23	353.16
Total Cost for 24 hours (without using GA)								14805.8

ii. Generation Scheduling after Implementation of GA

Results of daily generation scheduling for IEEE 30-bus test system considering both generation cost and loss is as shown in Table V.

Results shows that total cost can be decreased in significant amount (from $ 14805.78 to $ 14453.87) with proper generation scheduling using GA. When load in the system is less power loss in the network is also less but power loss increases rapidly as load increases and hence generators have to generate additional power to meet both load and loss. For smaller loads total cost is mainly dependent on the fuel cost associated with the individual plant. However contribution of cost of loss in total cost increases as load increases.

Table 5: Daily generation scheduling using GA

Hour	Load, MW	Output From Different Generators, MW						Total Cost, $
		G1	G2	G3	G4	G5	G6	
1	116.2	31.2	20.8	16.7	19.8	12.4	16.3	327.3
2	131.1	31.5	36.9	20.1	19.0	9.5	15.6	371.0
3	142.8	35.0	53.6	20.8	10.0	10.3	14.8	409.1
4	147.2	35.9	46.8	20.7	22.5	12.6	10.7	424.5
5	166.5	38.0	51.7	23.9	19.8	11.6	23.7	499.6
6	179.1	41.4	60.1	22.2	22.2	14.3	21.9	549.3
7	212.1	43.7	56.2	27.2	49.2	21.2	18.7	686.5
8	199.6	44.7	64.7	21.8	36.0	14.0	23.4	633.3
9	194.3	42.5	45.4	23.2	37.5	25.4	23.9	615.3
10	202.0	43.3	56.3	23.1	28.2	20.6	33.7	644.9
11	205.0	46.7	65.0	30.1	22.5	16.4	27.7	657.9
12	195.9	42.4	47.5	21.5	38.3	25.3	24.5	621.6
13	206.1	44.5	69.4	24.9	28.8	19.1	23.0	660.4
14	211.4	47.7	64.2	24.8	32.3	20.2	26.2	682.0
15	213.1	58.7	59.7	32.8	21.6	20.4	24.0	652.1
16	206.9	44.8	69.6	25.0	29.1	19.2	23.0	662.5
17	219.4	45.0	61.4	22.4	49.9	19.4	26.4	720.1
18	249.8	50.1	71.7	28.2	52.2	20.5	33.2	855.0
19	258.1	55.8	67.9	28.7	50.4	29.3	32.4	892.1
20	252.6	51.1	75.3	33.8	50.2	17.0	31.5	872.9
21	206.1	44.5	69.4	24.9	28.8	19.1	23.0	660.4
22	189.2	40.4	56.7	21.4	36.2	18.6	20.6	585.5
23	145.4	32.4	53.9	20.6	10.6	15.2	14.9	421.4
24	119.8	31.7	40.7	13.7	12.1	11.5	11.6	329.9
Total Cost of Energy Generation and Energy Loss for 24 hours, $								14434.6

B. Results for INPS

i. Generation scheduling for INPS without using GA

The result of generation scheduling for base case is as shown below in Table VI. Total cost of generation per hour is Rs. 6362.02 (in thousands) whereas average cost of energy generation is Rs. 7.06 per unit.

Table 6: Generation scheduling for INPS without using GA

S. N.	Name of Plant	Generation Cost, Rs./ unit	Generation, MW	Cost of Enery, Rs. ('1000)
1	Marsyangdi	1.96	60.00	117.60
2	Gandak	5.15	15.00	77.25
3	Kulekhani-I	2.31	40.00	92.40
4	Multifuel	69.59	30.00	2087.70
5	Hetauda	63.55	10.00	635.50
6	Chilime	6.47	20.00	129.40
7	Khimti	8.5	60.00	510.00
8	Bhotekoshi	7.83	36.00	281.88
9	Kaligandaki 'A'	2.79	120.00	334.80
10	Midmarsyangdi	4.93	50.00	246.50
11	Andhikhola	4.22	4.00	16.88
12	Devighat	1.77	14.00	24.78
13	Trishuli	2.34	24.00	56.16
14	Jhimruk	5.85	12.00	70.20
15	Kulekhani-II	2.46	20.00	49.20
16	Sunkoshi	2.11	10.00	21.10
17	Modi	4.91	14.00	68.74
18	Puwa	2.29	6.00	13.74
19	Indrawati	4.83	7.00	33.81
20	Piluwa	3.90	3.00	11.70
21	Khudi	3.90	3.00	11.70
22	Mardi	3.90	3.00	11.70
23	Lower Modi*	3.90	5.00	19.50
24	Up. Tamakoshi*	4.00	294.12	1176.48
25	Kulekhani-III*	4.50	10.00	45.00
Total Generation Cost per hour, Rs. ('1000) =				6143.72
Average Cost of Generation, Rs./kWhr = 7.06				
Power Loss, MW = 30.92				
Cost of Energy Loss per hour, Rs.('1000)= 218.298				
Total Cost of Generation and power loss, Rs.('1000)= 6362.02				

Table 7: Generation scheduling for INPS using GA

S. N.	Name of Plant	Generation Cost, Rs./ unit	Generation, MW	Cost of Enery, Rs. ('1000)
1	Marsyangdi	1.96	60.68	118.94
2	Gandak	5.15	13.10	67.44
3	Kulekhani-I	2.31	57.66	133.19
4	Multifuel	69.59	10.00	695.90
5	Hetauda	63.55	4.52	287.29
6	Chilime	6.47	4.11	26.59
7	Khimti	8.5	27.45	233.29
8	Bhotekoshi	7.83	10.00	78.30
9	Kaligandaki 'A'	2.79	76.77	214.20
10	Midmarsyangdi	4.93	54.98	271.04
11	Andhikhola	4.22	3.34	14.09
12	Devighat	1.77	12.60	22.29
13	Trishuli	2.34	22.82	53.39
14	Jhimruk	5.85	7.78	45.49
15	Kulekhani-II	2.46	19.78	48.67
16	Sunkoshi	2.11	9.10	19.19
17	Modi	4.91	9.04	44.37
18	Puwa	2.29	5.40	12.37
19	Indrawati	4.83	6.07	29.31
20	Piluwa	3.90	1.95	7.59
21	Khudi	3.90	3.97	15.49
22	Mardi	3.90	2.53	9.85
23	Lower Modi*	3.90	6.67	26.03
24	Up. Tamakoshi*	4.00	436.96	1747.82
25	Kulekhani-III*	4.50	11.54	51.92
Total Generation Cost per hour, Rs. ('1000) =				4274.0482
Average Cost of Generation, Rs./kWhr = 4.86				
Power Loss, MW = 37.58				
Cost of Energy Loss per hour, Rs.('1000)= 182.80				
Total Cost of Generation and power loss, Rs.('1000)= 4456.85				

ii. Generation scheduling for INPS using GA

With proper generation scheduling using GA, generation cost and total cost (per hour) of generation and power loss has been decreased significantly (Table VI and Table VII) with same load scenario. Generation cost decreases from 6143.72 to 4274.05 and total cost of generation and power loss from 6362.02 to 4456.85 (Rs. in thousands). This is due to the fact that per unit cost of different generators varies significantly and power loss is less if the generation is done near to the load centre if possible.

Results obtained are slightly different from the real scenario of the INPS as some of the additional generating power plants and transmission lines under construction are used because actual system has not sufficient generation capacity to meet all of the demand in the present scenario. Some of the reactive compensators are added to the real system to improve bus voltages. However, total cost can be minimized with proper generation scheduling, even in the present scenario of INPS.

6. Conclusion and Recommendation

Conclusion

In this research work, a methodology for proper generation scheduling with the objective function of minimization of total cost of generation and power loss has been proposed. The proposed model is applicable for the system consisting of different power plants namely hydro, thermal etc. The method does not have any limitation on generation mix. Genetic Algorithm with some modification has been used for optimum generation scheduling. The developed model has been successfully implemented and tested on IEEE standard 30-bus system and Integrated Nepal Power System (INPS).

The results has shown that generation cost, average cost of generation per unit and hence total cost of generation and power loss decreases significantly with proper generation scheduling using GA.

Recommendation for Future Work

Present work covers only short term generation scheduling considering generation cost and loss minimization as a single objective function. Long term generation scheduling problem can be solved in future considering seasonal variation of discharge in hydroelectric plants including large reservoir type plants and seasonal variation of load.

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Transportation Network of Pokhara Sub-Metropolitan City

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Abstract: **This paper is an attempt to study the Bus Distribution and requirement scenario of Pokhara Bus Entrepreneurs' Association, Pokhara, Nepal. The forecast of the required number of buses is done to assist the Pokhara Bus Entrepreneurs Association to maintain their distribution of the bus and for the effectiveness of its transport system, so as to accommodate the needs of all the people within the region. The optimization of distribution system of Bus is done by using Premium Solver, in the Microsoft Excel spreadsheet platform. The result clearly shows that the requirement of the buses in the sub-metropolitan city is inadequate in some routes, whereas, in some routes the number of buses exceeds maximum number of buses required. Optimization of number of buses needed for each area according to the population distribution at different time intervals is done, for efficient management of the system and also to help gain more profit from public transportation.**

Keywords: Pokhara, Transport Network Optimization, Transport distribution, Node optimization, vehicle scheduling problem (VSP)

1. INTRODUCTION

A. Demography of Pokhara and the Tourism Industry

Among many cities of Nepal, Pokhara is one of most beautiful city due to its scenic view of snow-covered mountains and beautiful lakes surrounding the city. The undergoing change in the world has affected Pokhara as well transforming it from scenic beauty city to one of the favourite tourist destination.

Pokhara has annual population growth rate of 5.6%. At present, 45% population of Pokhara use private vehicle. The economy of Pokhara sub-metropolitian city is dependent on tourism industry. Pokhara sub-metropolitan cities are facing serious environmental problem due to growing air pollution caused by fuels used in vehicles. So, Pokhara must have lower level of pollutants so as to boost its tourism industry and to attract maximum number of tourists. Due to the escalating price of oil, to reduce greenhouse gas emission we should focus on use of public transport. It has brought lots of changes in population, housing, transportation, commercial and other sectors.

During the 1980s, more than 700 houses were built each year. Similarly, the number of vehicles has also rapidly increased. Tourism is flourishing in Pokhara day by day. It is estimated that 69,049 tourists arrived in Pokhara in 1992. In 1997, the number stood at 92,717 (MTCA 1997) and increased to 03,895 in 1998 (PSMC 1999) and their numbers have increased significantly in the last decade. The expansion in tourism has boosted the hospitality industry in Pokhara. There are now about 176 hotels and lodges and 574 restaurants in this town, and the number of travel and trekking agencies has also grown. This development of an urban environment also indicates that employment opportunities in the non-farm sector are growing rapidly.

Table 1: Population size and growth rate of Pokhara

Year	Population size	Population growth rate (annual)
1952/54	3,755	-
1961	5,413	5.0 per cent
1971	20,611	18.0 per cent
1981	46,642	8.5 per cent
1991	95,268	8.5 per cent
1998	157,000	7.4 per cent

Source: (Gurung et al. 2048 v.s.:4, CBS 199, PSMC 1999).

B. Pokhara Bus Entrepreneurs Association

It is a private organization and leading public transport Service provider in Pokhara. This organization was established on 2049B.S. and its main office is situated at Sita Tole, Pokhara-9. It operates a large fleet of buses to provide various public transportation services in Pokhara and some places nearby it. However, the organization has extended its services to nearby city area as well. The facilities of the organization also cover the rural villages like Kahu, Siklesh, etc.

The major objective of the organization is to provide a better public transport service for passengers in turn up and use in Pokhara and nearby this valley. This organization was initially set up to provide transport services within the valley only. There are altogether 251 (Micro & Big) buses in this organization which run to a fixed route and schedule, serving different places of Pokhara and the people of Pokhara. Bus services are run to a specific timetable giving specific times of departure and arrival at waypoints along the route. The bus owners are contracted to Pokhara Bus Entrepreneurs Association and it operates the buses on behalf of the authorities (municipal, transit authority etc.) on a franchise basis. In this organization, transport services are subjected to legal control of government policy in terms of vehicle safety standards, and the level of fares charged and routes operated.

C. Financial Position of the Organization

The following chart presents the comparative analysis of the annual gross income and gross expenditure of the organization over last few years.

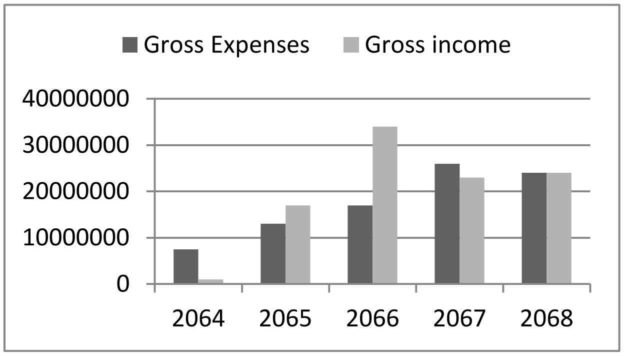

Figure 1: Financial Position of the organization

2. NEED OF PUBLIC TRANSPORTATION

Public transport is very crucial for a nation as it provides access to employment, community resources, medical care and recreational opportunities[1]. There must be proper management of the public transport system, if public transport is to play a significant role in the life of a city.

Public transport is often quicker and cheaper than using private transportation - especially in congested urban areas where parking is limited. Moreover, it causes less pollution and congestion, greater use of public transport has benefits for the environment and our communities too.

The benefits to of using public transport are:

1) It assists cities in their wealth creation: Dependence on private transportation is expensive.
2) It reduces the external costs (environmental, social and economic externalities) of private vehicle dependence.
3) It reduces oil vulnerability: The biggest looming problem of car dependence is oil vulnerability.
4) It saves time.
5) It saves space.
6) It lowers travel costs.
7) It reduces the need for expensive parking lots.
8) Demonstrate commitment to protecting the environment.

[1] http://www.vtpi.org/tdm/tdm103.htm

3. NEED OF OPTIMIZATION IN POKHARA

City efficiency largely depends upon the effectiveness of its transport systems. Transport infrastructure must be able to accommodate the needs of all the people within the region. Poor transport systems stifle economic growth and development, and the net effect may be a loss of competitiveness in both domestic as well as international markets. So, transport system of a city must be well managed so as to boost its economic growth.

At present there is inadequate transport infrastructure and its sub-optimal use within the Pokhara sub-metropolitan city. Due to inefficient Public transport systems within the city due to rapid population, people have turned towards personalized modes such as, scooters, motorcycles, and cars.

The number of buses used for public transportation is fixed randomly by the Pokhara Bus Entrepreneurs Association without detailed study about the number of people using the public transport within the city. As a result, there is inadequate public buses in some routes, whereas, in some routes the number of buses exceeds maximum number of buses required. So optimization of the number of buses needed for each area according to the population distribution of the region is the necessity of the city. This will lead to efficient management of the system and also help gain more profit from public transportation.

A. Objectives

The main objectives of this study are:

- The forecast of the number of buses required for further years.

  Sub-Objectives:

  - Optimizing the Shortest path for the tourist to visit Pokhara in shortest time interval and shortest time interval save the money.

B. Limitations

Following are the limitation of our research project:

1) This study has excluded taxi and mini-micro bus service.
2) The study covers only urban areas.

4. LITERATURE REVIEW

A. Transportation Problem

The transportation problem is generalized network flow problem in which products are supplied to certain number of destination in such a way as to maximize profit and minimize the cost. The objective in a transportation problem is to fully satisfy the destination requirements within the operating production capacity constraints at the minimum possible cost. It aims at providing assistance to the top management in ascertaining how many units of a particular product should be transported from each supply origin to each demand destinations to that the total prevailing demand for the company's product is satisfied, while at the same time the total transportation costs are minimized.

B. Mathematical Model of Transportation Problem

Mathematically a transportation problem is nothing but a special linear programming problem in which the objective function is to minimize the cost of transportation subjected to the demand and supply constraints.

Let,

a_i = quantity of the commodity available at the origin i;

b_j = quantity of the commodity needed at destination j,

c_{ij} = transportation cost of one unit of a commodity from origin I to destination j,

x_{ij}= quantity transported from origin I to the destination j.

Mathematically, the problem is

$$\text{Minimize } z = \Sigma\Sigma\, x_{ij}\, c_{ij}$$

s.t.

$$\Sigma x_{ij} = a_{i,}\ i= 1,2,\ldots..m$$

$$\Sigma x_{ij} = b_{j,}\ j= 1,2,\ldots..,n$$

$$\text{and } x_{ij} \geq 0 \text{ for all i and j}$$

A typical transportation problem is shown in table 2.

Table 2: Transportation Matrix

					Supply
		D_1	D_2	D_3	5
	s_1	3	1	M	7
	s_2	4	2	4	3
	s_3	M	3	3	
Demand		7	3	5	

It deals with sources where a supply of some commodity is available and destinations where the commodity is demanded. The classic statement of the transportation problem uses a matrix with the rows representing sources and columns representing destinations. The algorithms for solving the problem are based on this matrix representation. The costs of shipping from sources to destinations are indicated by the entries in the matrix. If shipment is impossible between a given source and destination, a large cost of M is entered. This discourages the solution from using such cells. Supplies and demands are shown along the margins of the matrix. As in the example, the classic transportation problem has total supply equal to total demand.

The network model of the transportation problem is shown in Fig 4 below. Sources are identified as the nodes on the left and destinations on the right. Allowable shipping links are shown as arcs, while disallowed links are not included.

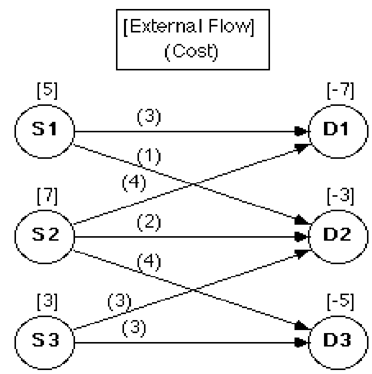

Figure 2: Network Flow Diagram

The circles in fig 2 are called nodes in the terminology of network flow problems and the lines connecting the nodes are called arcs. The arcs in a network indicated the valid paths, routes or connections between the nodes in a network flow problem. When the lines connecting the nodes in a network are arrows that indicate a direction, the arcs in the network are called directed arcs. The nodes S1,S2 and S3 are supply nodes and D1,D2 and D3 are demand or receiving nodes.

C. Forecasting

In statistics, signal processing, econometrics and mathematical finance, a time series is a sequence of data points, measured typically at successive times spaced at uniform time intervals. Time series analysis comprises methods for analysing time series data in order to extract meaningful statistics and other characteristics of the data. Forecasting or Time series forecasting is the use of a model to forecast future events based on known past events to predict data points before they are measured. An example of time series forecasting in econometrics is predicting the opening price of a stock based on its past performance. Time series are very frequently plotted via line charts.

There are different methods for analysing time series data. There are several techniques appropriate for stationary when there is no significant upward or downward trend in the data over time and non-stationary time series where there is some upward or downward trend in the data over time.

The appropriate forecasting techniques for stationary data series are:

1) Moving Average
2) Single Exponential Smoothing

The appropriate forecasting techniques for non-stationary data series are:

1) Double Exponential Method (Holt's Method)
2) Holt's Winter Method
3) Linear and Quadratic Trend Model
4) Quadratic Trend Model with seasonality indices

D. Regression

Regression analysis is a modelling technique for analyzing the relationship between a continuous (real-valued) dependent variable Y and one or more independent variables X1, X2, … Xk. The goal in regression analysis is to identify a function that describes, as closely as possible, the relationship between these variables so that we can predict what value the dependent variable will assume given specific values for the independent variables. Examples of application include:

1) Calculating the best possible value of the given data
2) Estimating an errors in the calculations
3) Comparison of the given data with the estimated result.

5. METHODOLOGY

The necessary data required for the development of model was collected from Pokhara Bus Entrepreneurs Association which was arranged and complied to develop a networking model. The above mentioned regression and forecasting models of transportation problem were used for the determination of the optimum numbers of public buses.

A. Types of Service

The types of buses are under operation in this organization are mini micro buses, micro buses, big Buses. The types of Services provided are

1) Urban/Suburban Services: It is the most common type of public transport bus service and the organization also implements this service to transport large numbers of people in urban areas, and to and from the suburbs to population centres.

2) Flexible Bus Services: It also provides flexible bus services under limited constraints. Bus reservation is also provided by the organization, this service is usually utilized for picnic, educational excursion and also in marriage ceremony.

B. Time of Operation

Bus services of the organization are normally implemented for operation in the time duration of 6 am to 8 pm. However, during special occasion (festivals, fair etc.) late night services are also provided as per the situation.

C. Categorization of Consumers

The consumers of the services provided by the organization are categorized as:

1) Children (below 5 yrs)
2) Students
3) Disabled
4) Others

There is discount for children, students (45%) and disable peoples on bus fares depending upon their identification card. However, other general people do not get such discounts on bus fare.

D. Data Requirement

The data required for the development of modeling framework are:

1) Data of population distribution of Pokhara sub-metropolitan city in each ward from central bureau of statistics.
2) Data of total number of buses that are providing service in Pokhara from Pokhara Bus Entrepreneurs Association.
3) Data of numbers of population using public vehicle in each route/node at certain time from survey.

E. Model Development

The main elements of the model are Decision Variable, Objective Function and Constraints – The decision variable are those variables in model which are subject to change and optimized and calculated by the solver. A mathematical optimization model consists of an objective function and a set of constraints in the form of a system of equations or inequalities which should be satisfied. The objective of the model is to minimize the total number of buses in Pokhara city.

6. RESULTS AND FINDINGS

The increasing trend of number of buses operated by Pokhara Bus Entrepreneurs Association up to year 2075 B.S is forecasted using linear regression technique. From the regression table, the values obtained are:

Table 3: Slope and Y intercept for prediction of number of buses

	Coefficients
Intercept	-35027.1
Year	17.05263

Using the values of slope and y-intercept from the regression table, the data of population of Pokhara and total number of buses in each year, the following graph of increasing trend of number of buses (357 upto 2075) is obtained.

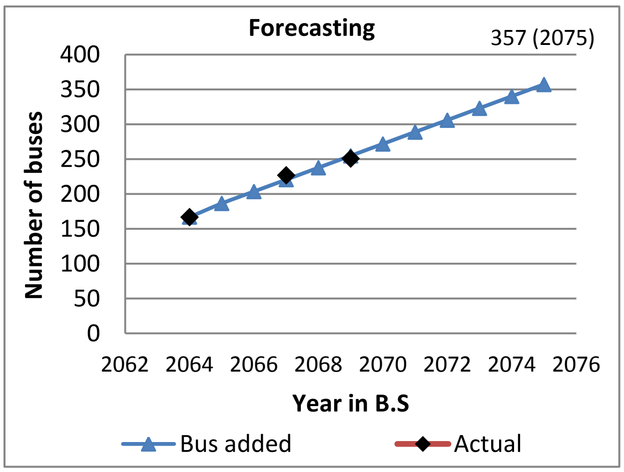

Figure 3: Forecasting of Number of buses

The data of public transport routes of Pokhara was obtained which includes the total distance of each route, average round trip per day, total number of buses in each route, total nodes in each route, bus fare between all nodes. The data thus obtained was used to calculate the total number of buses required in a day. Moreover, the frequency of bus needed at different time in a particular route was also calculated.

The population distribution at different time slots of each ward was calculated using the percentage weightage of each ward.

Table 4: List of important landmarks, schools, hospitals in Pokhara Sub-metropolitian city

Ward No.	**Important Places**		
1	Buspark	Bagar	PN Campus
2	Bindabasini temple	Baglung Buspark	
3	Kanya Campus	School	
4	Chipledhunga	Main Bazaar	Mahendra pul
5	Bijuli office		
6	Lakeside		
7			
8	Janapriya Campus	Ratna Chowk	
9			
10			
11	Manipal Hospital	Gandaki hospital	
12			
13	Kalika Campus		
14	Chautthe		
15			
16	Engineering Campus	Mahendra Cave	Lamchaur
17	Davis fall	Chorepatan	
18	Kaji Pokhari		

A. Effective Population of Each Node

Effective population mean here to the population in a particular node that use public transportation. The data of population that use private cars, motorbikes and the population that do not use public transportation in a particular node was deducted.

From the data, it is concluded that the effective population in each node is 50% of the total population of each node.

Table 5: Effective population of each node

Total no cars in Pokhara	15000
Average occupancy rate	2.5
Population using car	**37500**
Total motorbikes	70000
Average of car	1.5
Population using motorbike	**105000**
Total pop using private vehicle	**142500**
Total population of Pokhara	317412
% of pop using private vehicle	45%
Total population not using transport	5%
Effective public vehicle users	**50%**

B. Optimization of Number of Buses Needed At A Particular Route

The total number of bus currently operated by Pokhara Bus Entrepreneur Association is 251. The calculation of number of buses needed in each route was done to find out whether addition or reduction is needed in total number of buses under service at present situation. Calculation of total number of buses is done at occupancy rate of 30 people per bus. The total number of buses needed is found 234 numbers i.e., 17 numbers of buses is possible to reduce from present scenario of transportation route.

Table 6: Optimization result of number of buses needed at a particular route

Routes	buses available / day	Average buses required	Addition/ deduction needed
Route 1:Bagar to fewa taal	28	16	-12
Route 2: Bagar to chhorepatan	28	14	-14
Route 3: a. Bagar to lamachaur	20	12	-8
3b. Bagar to Khaltemasina	10	10	0
3c. Bhunpure to Bagar	20	8	-12
3d. Jogmani to Sahidchowk	10	10	0
Route 4: Bagar to Khaltemasina	20	17	-3
Route 5: Simpani to chauthe	15	13	-2
Route 6: Simpani to eye hospital	15	12	-3
Route 7: Camping chowk to Kaunkhola	20	28	8
Route 8: a. Manipal to fulbari chowk	15	12	-3
8b.Manipal to Tutunga	10	28	18
8c.Manipal to Kahundada	12	8	-4
Route 9: Manipal to Sahidchowk, Belghari	8	17	9
Route 10: Miyapatan to Harichowk	20	29	9
Total	251	234	-17

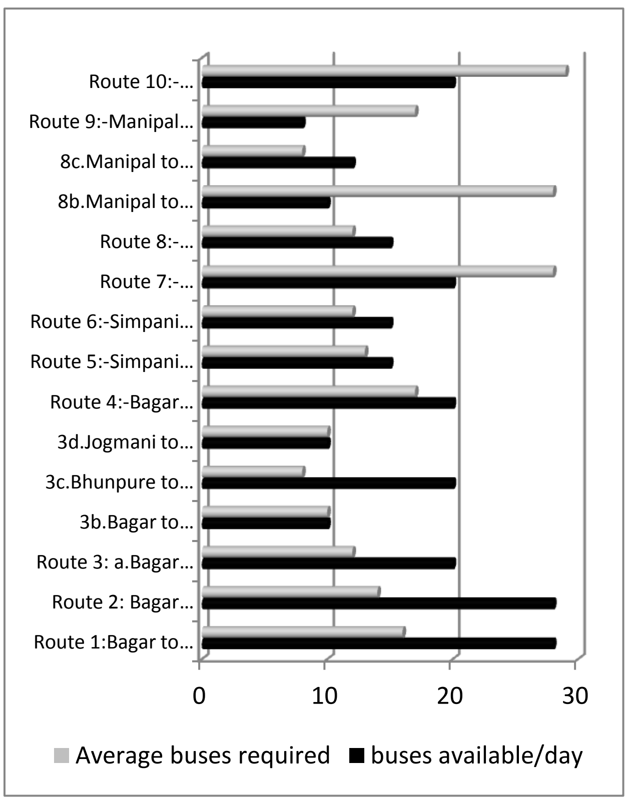

Figure 4: Average number of buses needed Vs available buses

C. Optimization of Number of Buses Needed At Different Time Slots

The public transport of Pokhara operates 14 hours a day from 6a.m to 8 p.m. The population distribution of each ward at different time interval was calculated. Total seven time slots of 2 hours were selected and during each slot population distribution is calculated (percentage weightage) on the basis of important landmarks, school, colleges, major tourist destination and governmental offices.

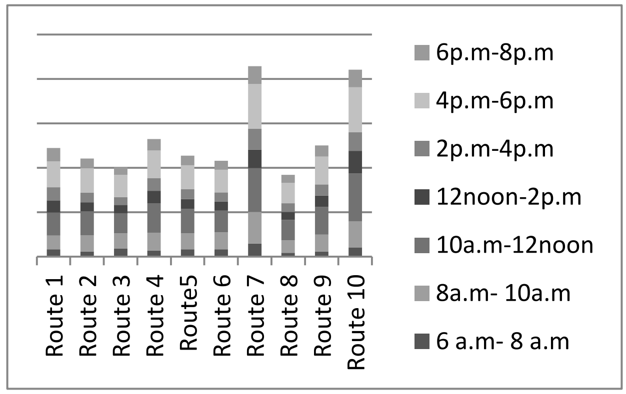

Figure 5: Time distribution of number of buses

Actually, the total number of buses throughout the day in a particular route is evenly distributed at regular time interval. But according to our finding, the total passenger utilizing the public transport is not same throughout the day.

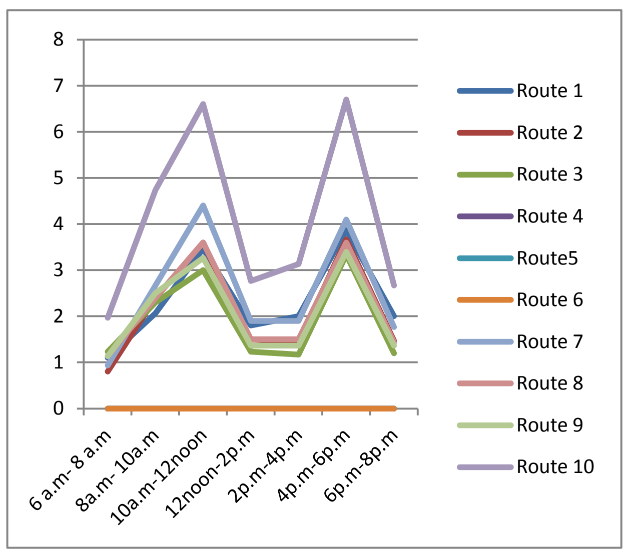

Figure 6: Average number of buses required at different routes

From figure 6 we can conclude that flow of buses in peak hour varies from 3-7 numbers whereas off peak hours are only 1-3 numbers. If we can manage number of buses in time basis we can further manage/reduce required number of buses below 234 in present scenario.

7. DISCUSSION AND CONCLUSION

Pokhara Bus Enterpreneurs Association is a leading public transport Service of Pokhara which operates a large fleet of buses to provide various public transportation services in Pokhara.

As according to the forecast data, Pokhara needs 357 numbers within 2075 BS. But, optimization was done to fulfill our major target i.e. ,the optimize, the required number of buses of Pokhara Valley, whether the available were meeting their demands or not by using Premium Solver using the Microsoft Excel spreadsheet platform. If the optimization of the transportation isn't done surely the number of buses will increased in the same ratio and the traffic system will be totally haphazard.

Our findings show that the requirement of the buses number is less than the buses available by 17 numbers. The extra buses can also be used as spare buses or for other purpose but using more number of buses than the required numbered is costly project.

The number of buses required in the time interval is also not the same since the departure time of the buses are in the uniform interval of time. 10 am to 12 noon and 4pm to 6pm is the peak time intervals where the people's transitions are very high. If we manage required number of buses in peak hour and off peak hour accordingly, the buses required could be further minimized and hence maximizing the profit and of course helps to maintain beauty of Pokhara by clean environment.

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Selection of appropriate Renewable Energy Technology in household sub-sector for Climate Mitigation and Adaptation

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Abstract: **In this paper, Multi-Criteria Decision Analysis (MCDA) was used to select the appropriate Renewable energy Technology for Climate Mitigation and Adaptation. The analysis of household energy consumption survey in the two districts of far-western region of Nepal was conducted. More than 90% people were directly associated with traditional energy. The energy consumption is mainly through fuel wood and biomass energy. Per household greenhouse gases (GHG) emission is 2.1 MT CO2e/year from bottom up approach in rural High hill and 0.4 MT CO2e/year in urban terai. Similarly, per capita energy consumption in lightning, cooking and space heating is nearly 4 GJ in urban terai and nearly 14 GJ in rural High hill. The people of hilly region are at most vulnerable condition in terms of carbon emission and environment issues, so the traditional approach for selecting technology for this region might not be successful, for which multi criteria decision analysis has to be adopted considering costs, economic, environmental and social criteria. The multi criteria decision analysis found the renewable energy intervention with Improved Cooking Stove (ICS) technology for high and mid hills and biogas technology for terai be best option for mitigation of GHG emission with social and economic benefits and fuel switching through solar cooker might be the best option for this region to have climate adaptation as one time solution.**

Keywords: ***Carbon dioxide equivalent (CO_2e), GHG emission, Multi-criteria decision analysis, Mitigation, Adaptation***

1. INTRODUCTION

Current energy consumption data shows the majority of energy consumption in household sector with more than 89% of share, but the quality of energy supply in this sector is basically traditional [1]. Occupying the majority of share, household sector largely uses inefficient technology and energy with large emission of greenhouse gases (GHG) causing high indoor pollution and other social and economic disadvantages. Renewable sources of energy can make a significant contribution, but their role and potential in the short term should not be overstated. It has been estimated that renewable energy contribution at present meets only 1% per cent of Nepal's energy-requirements, which hopefully rises in days to come.

Similarly, regarding the climate vulnerabilities, National Adaptation plan of Action (NAPA) has considered 14 districts in the mid and far-western Nepal (Humla, Mugu, Dolpa, Bajura, Jumla, Jajarkot, Rukum, Achham, Dailekh, Rolpa, Kailali, Bardiya, Kalikot and Dang) which have high risk of climate change with low adaptive capability [2]. So, addressing the climate vulnerabilities in these districts with Renewable Energy intervention can play the vital role in reduction of GHG emission in household sector. In order to have the climate change impacts in lower level and for global GHG to be grown in required trend, necessary plans, adaptation and mitigation options has to be encouraged and studies has to be done.

Renewable energy is a high priority sector of the government, with a goal of increasing existing 1% share of total energy supply to 10% in next 20 years. Also, access of electricity from alternative energy is targeted from 10% to 30% within the same time span. Complementing these goals, the government plans to invest USD 1,076 million in renewable energy by 2020, which will include support for hydropower, solar PV and biogas technologies [3].

Hence, research in Renewable Energy Technologies penetration for Mitigation and Adaptation helps in developing ideas for mitigating climate change issues and recommending suitable adaptation measures.

A. Climate change issues

Usage of fossil fuels has major consequences around the world. A main environmental problem is the emission of toxic chemical pollutants, greenhouse gases like CO_2 and other air pollutants [4]. These cause climate change and environmental pollution of air, land and water, which has a negative impact on the health and the living quality of humans [5].

With average rise of 0.060 ^{0}C surface temperature, Nepal is ranked the fourth most vulnerable country in the world. Nepal is facing the problem of "too much water, too little water'. It is projected that rise of temperature by 3^{o}C will severely change the crop pattern in country. The poor people are most vulnerable to impacts of climate change in Nepal [6]. For the year 2008/09, the residential sector accounts for the major share of energy consumption (89.1%) among total energy consumption being 401 million GJ. This sector used about 356.7 million GJ where biomass resources are the major fuels used. More than 99 % of the total fuel wood is consumed only in the residential sector. Similarly 90.8% of the agricultural residue is consumed and animal dung is being used in biogas generation which is being increased by about 15 % in annual basis [1], 43.4% of electricity is consumed out of total 8.1 million GJ. Figure below shows the household energy consumption share by various fuel types.

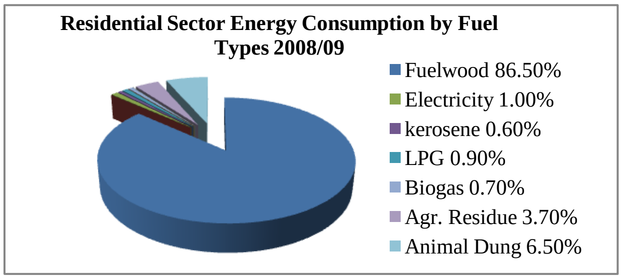

Figure 1: Residential sector Energy Consumption by fuel types

CO2 is mainly responsible and is expected to account for about 60% of the warming over the next century. Fuel wood and other low grade energy consumption in household sector carries potential for high emission of CO_2e, so the mitigation options is required for addressing climate change issues. Mitigation option might not be sufficient for cent percent address of these issues. So, adaptation options have to be made as one time effort.

B. Methodology adopted

Methodology consists of studying the literature and published data, report from which the needs for technologies intervention in Local Adaptation plan of Action (LAPA) districts has been found, at first the top-down calculation of GHG emission has been done with energy pattern and then to find the actual effects, bottom-up calculation with sample data has been studied by primary survey. Along with that 20 years projection for GHG level and energy consumption has also been modeled in LEAP, since the emission from the bottom-up model has been taken for further calculation as real scenario for selection of appropriate technology using MCDA tool. MCDA tool has been considered for both mitigation and adaptive technology for climate resilience with more than eight criteria for adaptive option and eight criteria for mitigating option. This criterion includes costs, economic, environmental, social, market penetration and vulnerable issues for technology selection. Finally, one technology each for both mitigation and adaptation has been selected following their plan of intervention. Then, these technology identified for intervention are again compare with the LAPA identified technology priority with due recommendation for best option.

C. Climate Mitigation and Adaptation

In 1992, the Rio summit produced the first international agreement on GHG emissions, in the form of a Framework Convention on Climate Change (FCCC), which established the obligation for partner countries to present inventories of greenhouse gas emissions and removals [7].

Since, Nepal is a signatory to more than 20 environment related International Conventions and agreements including the UN Convention on Biological Diversity (CBM), 1992 and Kyoto Protocol, 1997, it has also address the issues related to climate adaptation and mitigation by making GHG inventory.

Intergovernmental Panel on Climate Change (IPCC) defines adaptation as 'adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'.

Whereas mitigation as 'technological change and substitution that reduce resource inputs and emissions per unit of output with respect to climate change. Mitigation means implementing policies to reduce GHG emissions and enhance sinks'.

Adaptation and mitigation are complementary to each other. For example, if mitigation measures are undertaken effectively, lesser will be the impacts to which we will need to adapt. Similarly, if adaptation measures (or the degree of preparedness) are strong, lesser might be the impacts associated with any given degree of climate change. Mitigation will have global benefits, whereas adaptation benefits are from local to regional in scale. However, adaptation benefits can be immediately visible as compared to mitigation, where the effects may not be noticeable until around the middle of the 21st century.

There are some differences between adaptation and mitigation, but if the key vulnerabilities to climate change are to be addressed, adaptation is more vital as even after the most rigorous mitigation efforts, climate change will continue in the next few decades. At the same time, mitigation is necessary because reliance on adaptation alone could eventually lead to a magnitude of climate change to which effective adaptation is possible only at very high social, environmental, and economic costs.

D. MCDA approach with cost benefits analysis for technology selection

A Cost Benefit Analysis (CBA) on mitigation looks at short-term action because of potentially detrimental long-term developments. A CBA on adaptation looks at short-term action in the context of short to medium-term developments. Again, this implies that, in practice, a CBA on mitigation would be done very differently than one on adaptation. It is therefore not practical to look at the trade-offs between adaptation and mitigation, as no study can do right to both.

Instead, CBA studies like [8], [9] and [10] make the trade-off between the costs of emission reduction on the one hand and the costs of adaptation plus the residual damages on the other hand. The costs of adaptation and the residual damages of climate change are lumped together in a single ''damage function''.

Traditional single-criterion decision-making is no longer able to handle these problems. The technology selection approach by RE must be addressed in a multi-criteria context. The complexity of energy planning and energy projects makes Multi-criteria analysis a valuable tool in the decision-making process. MCDA methods provide an approach that is able to handle a large amount of variables and alternatives assessed in various ways and consequently offer valuable assistance to the decision maker in mapping out the problem [11].

MCDA consists of a group of methods suitable for decision making affected by various stakeholders and conflicting criteria [12], [13] and [14]. Measurements in the MCDA are derived as indicators of the strength of various preferences. Different MCDA methods are applicable in different problem solving contexts [15], and it has been observed that different methods may produce dissimilar results [16].

Thus, MCDA should not be considered as one single objective tool to reach an unambiguous truth, but it helps individuals to learn about and discuss the problem in a transparent way. The multi-criteria decision aid do not replace the decision makers, but rather support them in all the stages of the decision making process by providing useful data information to achieve decisions that are clear [17].

MCDA and CBA, validation seen as a threat if analysts engage in academic planning or decorative planning, multi criteria validation could be seen as a legitimating challenge for the analysts. The idea that multiple criteria can be left out until the last stages and many institutions coordinating studies are used to dealing mostly with monetary indicators, because that is the kind of data that international institutions traditionally required [18].

2. ENERGY CONSUMPTION PATTERN

Primary data has been surveyed for household energy consumption from VDC and municipality of two districts Achham and Kailali respectively to represent LAPAs districts of Far and Mid-western Nepal for Renewable Energy Selection for climate mitigation and adaptation. The energy consumption data of cooking, lightning and space heating has been considered during survey ignoring the animal feeding and social rituals and other consumptions. Since, the potential for energy efficiency or renewable energy intervention is more successful for basic end uses.

Energy resources in LAPA district has been identified by desk assessment through different literatures and has discovered the tremendous in the field of renewable energy. Some of the major Renewable energy potential is present in table I below with their technical and feasible potential.

Table 1: Potential of RE technology in respective district

Technologies	Unit	Potential
Biogas [1]	m^3	51,682,248
Solar PV (kWh/m^2/day) [19]	kwh/m^2/day	5.1 (avg)
ICS (forest area in Ha) [1]	ton	5,186,948,880
Wind Power Density(w/m2) [19]	w/m^2	53.6 (avg)
MHP (Kw) [20]	kw	5339.7

A. Energy consumption in cooking

Energy consumption for cooking in terai region is based on fuel wood, agro residue and LPG with nearly half- half share in fuel wood and LPG. Since, the consumption of LPG is there, energy required is also low. Energy consumption in average household is nearly 12 GJ for cooking. But talking about the Rural High hill fuel wood is the main type for cooking and occupies nearly 100% of total consumption with average household consumption of 96 GJ. Average household energy consumption for rural high hill and urban terai can be representing in figure 2.

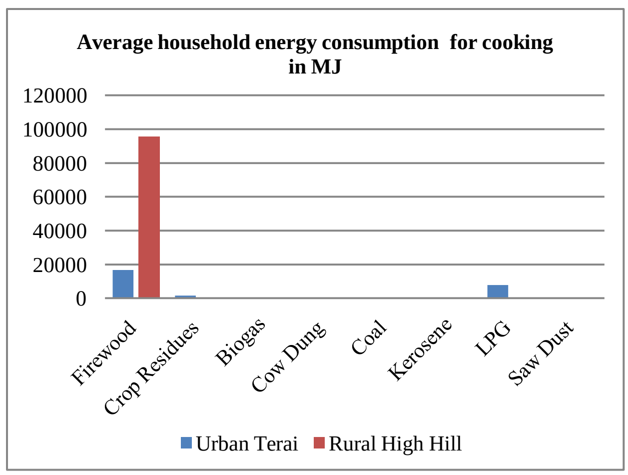

Figure 2: Energy consumption for cooking in two districts

B. Energy consumption in lightning

The Average energy consumption of urban terai is mainly grid electricity with 0.9 GJ per year and for the Rural High hill average household consumption for lightning is 1.412 GJ per year with kerosene t*uki* mainly which are represent in the figure 3 below.

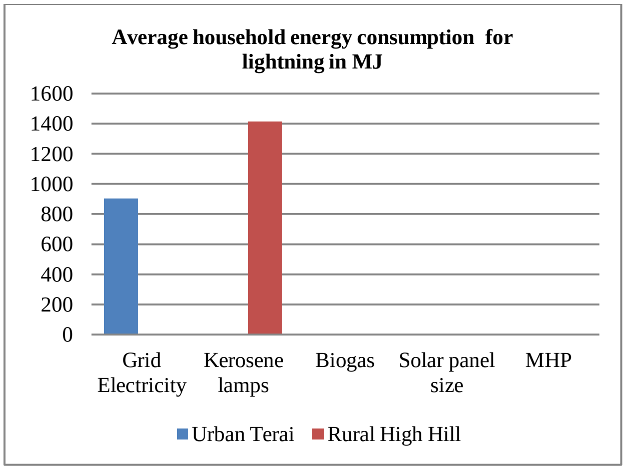

Figure 3: Average energy consumption for lightning in two regions

C. Energy consumption in space heating

Average energy consumption in household of urban terai for space heating is basically through fuel wood and electricity. Energy consumption in urban terai household is 2.2 GJ per year and in Rural High hill energy consumption is done mainly through fuel wood with 9.14 GJ per year.

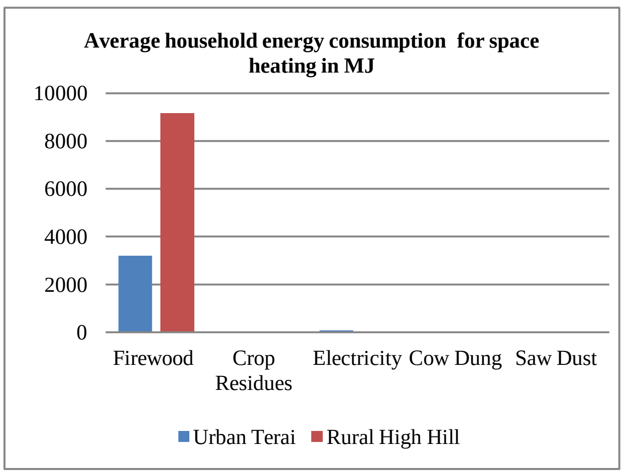

Fig 4: Average household energy consumption for space heating

D. Leap model for GHG emission level

Leap model has been used to forecast the GHG emission and energy consumption for 20 years with 2011as baseline energy consumption. And it has been found that Average household GHG emission from bottom-up approach in High hilly region is found to be 2.1 MT CO_2e/year and 0.4 MT CO_2e/year in urban terai of studied districts and the business as usual scenario for modeling 20 years shows projection of 16 MT CO_2e /year rural high hill and 3.5 MT CO_2e /year in urban terai as represent in figure 5 and 6 below.

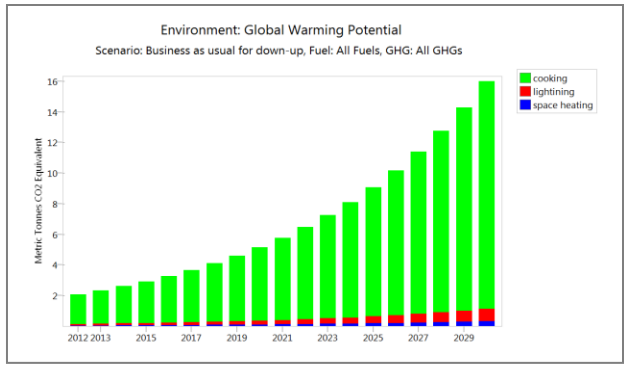

Figure 5: GHG emission per household of High hill in different end use

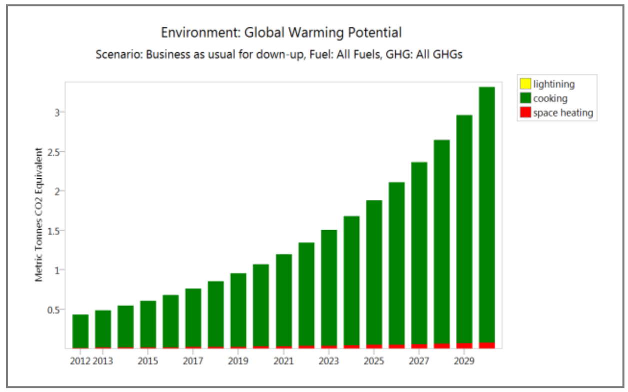

Figure 6: GHG emission per household of urban terai in different end use

3. TECHNOLOGY SELECTION

Multi-Criteria analysis, often called Multi-Criteria Decision- Making (MCDM) or Multi-Criteria Decision Aid methods (MCDA), is a branch of a general class of Operations Research models which deal with the process of making decisions in the presence of multiple objectives.

These methods, which can handle both quantitative and qualitative criteria, share the common characteristics of conflict among criteria, incommensurable units, and difficulties in design/selection of alternatives [21].

As mention above the traditional approach of single criteria (costs) only cannot addressed the sustainability of any project, so more than eight criteria for adaptation and eight criteria for mitigation for technology selection has been taken in accounts. Although all the criteria does not give the actual figure for decision-criteria, some percentile approach has also been adapted and author has also followed the experts' advices and stake holders input for making his study authentic. These two technologies selected are on the basis of all eight mitigation criteria and nine adaptive options, total weighted for these criteria and adaptive option are on the basis of study (surveyed), for which forty Master's students of Energy and two PhDs. students of Energy were surveyed.

A. Mitigation Technologies

Technologies for mitigation are selected for the considered districts on the basis of cost, economic, environmental, social criteria weight age by stakeholders which are describe below in Table 2.

Table 2: Criteria for technology selection (Mitigation)

SN	Criteria/ assign weight age	Specifications
1	Costs	Criteria in deciding which technology will be invested and how they are going to be invested to receive the desired results using IPCC defined cost or market cost.
1.1	Capital cost-10%	It is based on initial costs such as technology fees, facility building costs, transfer fees, etc. to attain the technology. Less capital intensive technologies are preferred most.
1.2	Operation and Maintenance (O&M) cost-5%	It is based on other costs such as annual maintenance cost, technology operation cost, etc. Lower cost results in higher scores
1.3	Cost effectiveness for mitigation-10%	It is based on cost estimation of the technology to reduce GHG emissions. Lower cost result in higher scores
2	Environmental benefits	Technology must generate environmental benefits, through GHG reduction potential and mitigation cost.
2.1	GHG emission reductions in 2030- 15%	Technologies with higher potential of GHG emission reduction will have higher scores.
2.2	Reduced air pollution-20%	Improving indoor air quality by reducing air pollutants
3	Social Benefits	These are the benefits from the technologies good enough in economic and social terms in a long run and short term has to be defined including local social benefit
3.1	Improved Health Condition-15%	This criterion will assess the potential to reduce health risks
4	Economic Benefits	Development of a new technology should satisfy the overall objective, that is, to ensure development of all three aspects: economic, social and environmental
4.1	Employment and new skills-15%	Creation work opportunities and reducing the rate of unemployment. This criterion is used to assess the overall societal objectives.
4.2	Security of energy supply-10%	Fulfilling the energy demand of the nation is the key requirement to fulfill the current situation of energy deficit.

Table 3: Development benefits versus costs

SN	Techno-logy Option	Costs (Nrs)	Develop ment benefits	Benefit / cost ratio	Rank
1	Solar PV	7,380,896,250	5.65	0.08	Fourth
2	Biogas plant	44,937,491,850	52.95	0.12	Second
3	ICS	6,134,429,957	56.05	0.91	First
4	Boiler stove	211,566,587,604	15.5	0.01	Fifth
5	Electric stove	28,031,184,000	34.95	0.12	Third

After the weight age of each mitigating technology, cost benefit analysis has been done for ranking the technology and thus observed the following results in table 3.

B. Adaptation Technologies

Technologies for adaptation are selected for the considered districts on the basis of cost, economic, environmental, social, vulnerability, market penetration criteria weight age by stakeholders which are describe below in Table 4.

Table 4: Criteria for technology selection (Adaptation)

SN	Criteria	Specifications
1	Costs	Criteria in deciding which technology will be invested and how they are going to be invested to receive the desired results using IPCC defined cost or market cost.
1.1	Capital cost-10%	It is based on initial costs such as technology fees, facility building costs, transfer fees, etc. to attain the technology. Less capital intensive technologies are preferred most.
1.2	Operation and Maintenance (O&M) cost-5%	It is based on other costs such as annual maintenance cost, technology operation cost, etc. Lower cost results in higher scores
2	Environmental benefits	Technology must generate environmental benefits, through GHG reduction potential and mitigation cost.
2.1	GHG emission reductions in 2030- 15%	Technologies with higher potential of GHG emission reduction will have higher scores.
2.2	Reduced air pollution- 10%	Improving indoor air quality by reducing air pollutants
3	Vulnerability	This includes the vulnerable issues associate with applied technology
3.1	Environmental vulnerabilities-15%	Environmental vulnerabilities associate with the technology or chance for similar issues are address here for example landslides, flooding are the drawbacks for implementation of some technology
4	Social Benefits	These are the benefits from the technologies good enough in economic and social terms in a long run and short term has to be defined including local social benefit
4.1	Improved Health Condition-10%	This criterion will assess the potential to reduce health risks
5	Penetration Potential	These benefit includes the technology diffusion and market potential of technology
5.1	Market Penetration-10%	This criterion includes the technology penetration rate and its potential in those area. Which means the technology which has high technical potential and easily diffuse in market are score highest and those which are less feasible technically and have potential for diffusion are score least.
6	Economic Benefits	Development of a new technology should satisfy the overall objective, that is, to ensure development of all three aspects: economic, social and environmental
6.1	Employment and new skills-15%	Creation work opportunities and reducing the rate of unemployment. This criterion is used to assess the overall societal objectives.
6.2	Security of energy supply-10%	Fulfilling the energy demand of the nation is the key requirement to fulfill the current situation of energy deficit.

Like as in mitigation steps, various adaptive technology has been weighted and then cost benefit analysis has been done among them for ranking the appropriate one as mention in table 5.

Table 5: Development benefits versus costs

SN	Technology Option	Costs (Nrs)	Develop ment benefits	Benefit/ cost ratio	Rank
1	Micro hydro	117,356,250,375	47	0.40	3rd
2	Solar passive	323,623,912,500	33	0.10	4th
3	Solar cooker	22,142,688,750	57	2.55	1st
4	Electric stove	28,031,184,000	22	0.79	2nd

4. RESULTS

Selection of technology by studying 14 districts of far and mid-western Nepal with 644,870 household energy consumption on the basis of above mention criteria, MCDA analysis found the ICS (Improve Cooking Stove) be the best option from hilly to terai region of Nepal for cooking and space heating end uses followed by biogas technology to be best option in terai for cooking.

Similarly, like as mitigation approach, most preferred adaptive technology has found to be Solar Cooker in rural hilly with national manufacturer followed by Electric Stove for cooking in urban regions.

Finally, selected technologies for renewable energy intervention are compared with LAPA priority technologies mention in LAPA report for validation of the technologies option, and thus found that same option mention for highest frequency for intervention plan in various vulnerable household of these regions.

5. CONCLUSION

The following conclusion has been drawn from the research study:

- The energy scenario of most vulnerable region of Nepal shows that, per capita energy consumption of those regions are less than the average Nepalese energy consumption value of 14 GJ per year.
- Though, they have less energy consumption but have high per household GHG emission of more than 2 metric ton CO_2e which is nearly five times greater than that of study found from literature.
- Though, from secondary data it was believed to have some penetration of renewable energy but in actual field this value is nearly zero.
- The projection of emission from household shows the huge GHG level nearly 16 metric ton CO_2e per household by 2030 in future in that region though it has very small level at present.
- Technology selection from MCDA has found the ICS as mitigating and Solar Cooker as adaptive technology for short term climate resilience in those regions.

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Empirical Model for the Estimation of Global Solar Radiation at lowland Region Biratnagar (NEPAL)

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***Abstract*: This study proposes the coefficient equation of Angstrom type of model for the estimation of global solar radiation in lowland Biratnagar (Lat. 26.45º N, Long. 87.27º E and Alt. 72m) using relative sunshine duration. The model constants a and b obtained in this research are 0.40 and 0.15 respectively. The performance parameters of the model are: Root Mean Square Error RMSE = 0.14, Mean Bias Error MBE= 0.10, Mean Percentage MPE= 0.088 and coefficient of determination R^2= 0.80 respectively. These finding regression coefficients can be used with confidence for other locations with similar climatic conditions.**

Keywords: radiation estimation, sunshine duration, clearness index, empirical model, correlation coefficients

1. Introduction

The global solar radiation (GSR) data are fundamental input for solar energy applications such as photovoltaic, solar thermal systems and passive solar design. The data should be reliable and readily available for design, optimization and overall evaluation of solar energy technology for specific location. However, for many developing countries including Nepal solar radiation measurements are not easily available because of not being able to afford the measuring equipments and techniques involved. Thus, it is necessary to develop methods to estimate the solar radiation on the basis of widely available meteorological parameters. [1].

There are various models for estimating GSR using sunshine durations and other meteorological data. The most commonly used model which relates the GSR to sunshine duration was first time developed by Angstrom [2]. Subsequently other more models were introduced. at various climatic parameters, such as sunshine duration, maximum and minimum temperature, relative humidity, rainfall, wind speed and so on.

Nepal is located in favourable latitude, receives ample solar radiation throughout the country. The result of different research groups confirmed that the average GSR is about 4.7 kWh/m^2/day and the sun shines for about 300 days in a year .The national average sunshine duration is about 6.8/day [3,4,5].

It is feared that the world will soon run out of its energy resources. This is a matter of concern for the developing countries whose economy heavily depends on imported petroleum products. At this critical situation of energy crisis, it is highly desirable that renewable energy resources should be utilized with maximum conversion efficiency to cope with the ever increasing energy needs [6].

There are several types of empirical formulae for estimating the monthly mean daily global solar radiation as a function of readily measured climatic data [7]. It is known that the simplest regression relation is Angstrom-Prescott which relates the monthly mean daily GSR to the number of hours of bright sunshine. [2,8].

The GSR changes from place to place due to the variation of latitude as well as local weather condition. Thus, a solar radiation measurement parameter is obtained and defined as the ratio of the actual number of duration of sunshine received at a site to the day length. The ratio is known as fraction of sunshine hours n/N varies day to day and season to season [9, 10]. The H_0 is the amount of extraterrestrial GSR which is found at the top of the atmosphere of the site. It varies with latitude, declination, day length and seasion. Similarly H_g is GSR which is the fraction of the extraterrestrial radiation at the ground surface after reflection, scattering, and absorption in the atmosphere. The ratio of H_g/H_0 is a possible measure of the transparency of the atmosphere to the solar radiation. It is called clearness index [11]. In addition that, the latest and easily available RadEst 3.0 version model has approved with validation on the basis of statistical tools and coefficients hence this approved model could be further applied for the estimation of GSR in this region of Nepal [12].

The main purpose of this paper is to determine through statistical analysis the coefficients a and b from Angstrom's model that can be utilized for the estimation of GSR at the similar climatic conditions of Nepal.

2. Methods and Instrumentation

The GSR on a horizontal surface was measured using first class CMP6 Pyranometer at lowland region of Nepal. The instrument was installed at Biratnagar (26.45°N, 87.27°E), which is about 72m above from the sea level. The spectral range of instrument is from 310nm to 2800nm. The operating temperature is from -40 °C to 80°C. Similarly, the instrument sensitivity and field of view are 5 to 15 μV/W/m2 and 180° respectively. All the measuring data are recorded by LOGBOX SD data logger within a minute resolution for 24 hours. It features low noise, high resolution and low power consumption. It can be used in all weather conditions. It collects the data at real time for the needs of meteorology and slow signal analysis. For data logging 128 KB of memory is available. We can insert the SD memory card for long-term data storage. For the communication LOGBOX uses either RS232 or RS485 communication port [13].

The diagram of CMP6 Pyranometer is given in Figure 1.

Figure 1: First Class CMP6 Pyranometer

The first correlation proposed for estimating the monthly mean daily global solar radiation on a horizontal surface H using the sunshine duration data is due to Angstrom [2] and Prescott[8] have put the Angstrom correlation in more convenient form as

$$\frac{H_g}{H_0} = a + b(\tfrac{n}{N}) \tag{1}$$

where, constants *a* and *b* are estimated using regression coefficients. The physical significance of the regression constants is that 'a' represents the case of overall atmospheric transmission for an overcast sky condition. It means that n/N is nearly equal to zero. In other hands, 'b' is the rate of increase of mean of H_g/H_0 with mean of n/N. The sum of a and b (a+b) significantly represents the overall transmission under clear sky index. N is the is day length (hours), *n* is bright sunshine hours, H_g is measured GSR (MJ/m^2/day) and H_0 is extraterrestrial GSR (MJ/m^2/day). For, the value of H_0 is calculated using equation (1.10.3) [14, 15].

$$H_0 = \frac{24}{\pi} H_{sc}(1 + 0.033 Cos\frac{360n}{365})(Cos\phi Cos\delta Sin\omega_s + \omega_s Sin\phi Sin\delta) \tag{2}$$

where φ is the latitude (rad) and δ is the solar declination angle (rad). ω is sunset hour angle for typical day and n is mean day of each months

where, n is the day of the year. January first n=1 to 365 days.

$$\delta = 23.45 Sin(\frac{360}{365}(284 + n)) \tag{3}$$

The relation of day length is,

$$N = \frac{2}{15} Cos^{-1}(-Tan\phi Tan\delta) \tag{4}$$

$$\omega_s = Cos^{-1}(Tan\phi Tan\delta) \tag{5}$$

where ω is the sunset hour angle

The Angstrom-Prescott regression equation which has used to estimate the monthly average daily global solar radiation on a horizontal surface in Kathmandu The solar radiation reaching the earth's surface can be estimated by empirical model when measured data are available. The simplest model commonly used to estimate the average global solar radiation on horizontal surface is the well known Angstrom, Prescott equation [2, 8].

3. RESULTS AND DISCUSSION

The input parameters are used for the estimation of daily and monthly average global solar radiation at lowland region Biratnagar. The parameters used are given in Table 1 and are found sufficient to generate the solar energy at Biratnagar.

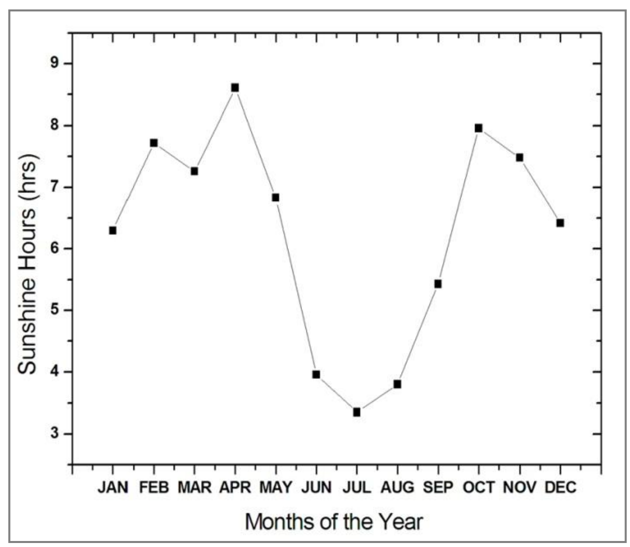

Figure 2: Monthly Variation of Sunshine

Figure 2 shows that the sunshine duration (SSD) varies rotation of earth and local weather condition. Its maximum and minimum values 8.61 hours and 3.35 hours are found on April and July. Data in table 1 shows that the sunshine duration is more than 6 hours per day is found except in June, July, August and September. In those months the sunshine hour and GSR is comparatively lower due to clouds and rainfall.

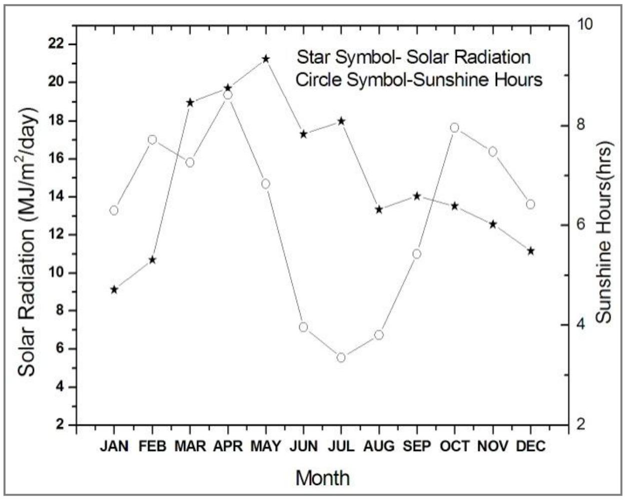

Figure 2: Comparative Study of monthly average sunshine hours to monthly average measured values of solar radiation at Biratnagar, 2009/2010

Table 1: Meteorological Data and Solar Radiation at Lowland Biratnagar, 2009/2010

Month	n (hours)	N (hours)	n/N (Unitless)	Hg (MJm^2/ day)	Ho (MJ/m^2/ day)	Hg/Ho (Unitless)
JAN	6.3	10.55	0.5981	9.12	20.17	0.4781
FEB	7.72	11.1	0.6958	10.69	26.31	0.2512
MAR	7.26	11.84	0.6105	18.96	32.03	0.5923
APR	8.61	12.64	0.6799	19.7	37.51	0.524
MAY	6.83	13.3	0.514	21.24	40.82	0.5205
JUN	3.96	13.64	0.2907	17.31	42.13	0.4109
JUL	3.35	13.49	0.2482	17.98	41.65	0.4318
AUG	3.8	12.93	0.2929	13.34	38.97	0.3446
SEP	5.43	12.16	0.4456	14.04	34.35	0.4087
OCT	7.96	11.36	0.702	13.52	28.42	0.4813
NOV	7.48	10.7	0.6986	12.56	23.12	0.5421
DEC	6.42	10.54	0.6076	11.16	21.91	0.5066

Figure 3 shows that there is strong consistency in between GSR and sunshine duration at lowland Biratnagar. Mostly the more sunshine duration means there should be more GSR values in each day however there is less amount of GSR is found even at the highest sunshine duration it is due to the changing the meteorological parameters like wind speed and local weather condition.

Figure 4 shows that both measured and predicted values of GSR vary only on May, and August. It is happened due to the variation of local weather and rainfall. However most of the time there is strong agreement in between measured and predicted data of GSR. At the same time the coefficient of determination is about 0.8 which proves that there is good agreement between measured and empirical relation predicted values of GSR.

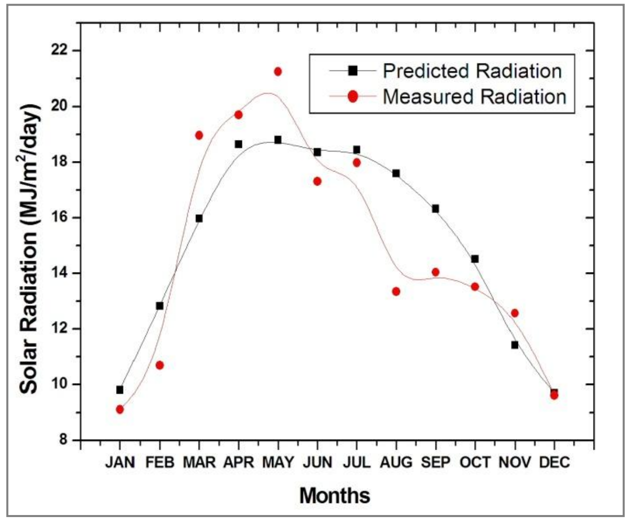

Figure 3: Relationship between measured and predicted GSR at Biratnagar

4. CONCLUSION

The main conclusion of this research work is that the monthly mean daily GSR on a horizontal surface at Biratnagar may be predicted by the correlation equation:

$$\frac{H_g}{H_0} = 0.40 + 0.14(\frac{n}{N}) \quad (6)$$

The prediction model is developed using monthly average daily values of clearness index, relative sunshine hour, and measured global solar radiation. The maximum and minimum measured values of monthly average GSR are found 21.24 MJ/m^2/day and 9.12 MJ/m^2/day on May and January respectively. The overall performance of parameters RMSE, MBE, MPE and R^2 are found 0.14, 0.10, 0.088, and 0.80 respectively. These statistical indices value showed that this research work is meaningful for the estimation of GSR on the basis of sunshine hour. It indicates that the estimated values of global solar radiation can be very efficiently used to compensate for the energy deficit. At the end, the linear empirical equation (6) can be employed for the estimation of global solar radiation in the similar climatic locations.

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Future Energy Scenario and Implications for Technological Interventions for Nepal

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***Abstract*: Energy situation of Nepal at present is very critical. Lingering energy crisis holds back economic advancement of the nation. Hours of power cut even in wet season depict perilous living standard of people. To estimate the future energy scenario, MARKAL modeling framework was used based on current energy statistics. Four scenario were assessed, business-as-usual (BAU), reference case, accelerated growth rate and combined policy scenario, former three are based on socio-economic assumptions and the later is policy intervention case. Beside large share of traditional energy in energy mix, share of imported petro-products is accelerating making the national economy more dependent. To substitute the imported fuel and hence contribute national economy through exploitation of indigenous resources and efficient technology policy interventions are implied in this model. To promote sustainable and indigenous energy resources are explicitly preferred during scenario assumptions. Glimpses of future energy scenarios are given in this paper for energy policy analysis of Nepal.**

Keywords: Energy model, Scenario, MAED, MARKAL

1. INTRODUCTION

A. Current Energy Scenario

Energy is the crucial element for sustainable development of country. Energy resources are regarded as the key strategic natural resources having the potential to be the catalyst for all round development and economic growth of the country. Unless the energy sector is geared up for efficient and indigenous sustainable resources along with their sustainable harnessing, the economy cannot move forward on a higher growth path. Every advanced economy requires secure access to modern sources of energy to fortify its development and growing prosperity. While many developed countries may be focused on domestic energy security or decarbonising energy fuel mix, many other developing countries like Nepal are still seeking to secure enough energy to meet basic human needs [1]. According to Human Development Index, Nepal rank 157th[1]position. Access to reliable and affordable energy services is fundamental to reducing poverty and improving health, increasing productivity, enhancing competitiveness and promoting economic growth.

The economy of Nepal is based mainly on agriculture with more than 76 percent of people engaged in it. According to the economic survey and statistics on Nepal by Asian Development Bank, the contribution of the agricultural sector has declined to 35 percent and that of the non-agricultural sector increased to 65 percent showing a positive sign of improving economic status of country [2].

Energy being a crucial enabler, energy consumption data indicates the living standard of country. Developed countries have significantly higher per capita energy consumption. For example, the United States has a per capita energy consumption of 314 GJ/year, Japan has 163 GJ/year, and United Kingdom has 142 GJ/year. For Nepal, the per capita total primary energy supply (TPES) is just 15 GJ/year, which is far less than world's average per capita TPES of 77 GJ/year [3]. Energy consumption per capita of Nepal is lowest among south Asian countries and electricity consumption per capita is 104 kWh [4]. The EDI (Energy development Index)[2] ranks Nepal at 74th position with EDI of 0.08. One of the main reasons for this fact is that about 37 percent of households do not have access to electricity that can boost economic indicator [5]. The total primary energy consumption in the year 2008/09 was estimated to be about 401 PJ [6] [7]. Energy statistics of Nepal infer large dominance of traditional non-commercial forms of energy such as fuel-wood, agricultural residue and animal waste. Energy carriers like petroleum fuels, coals and electricity contributes only 9 percent, 3 percent and 2 percent [7] respectively in total energy consumption [Figure 1]. Energy sector is basically categorized into three major sub-sectors namely traditional, commercial and renewable. Historical trend of energy consumption pattern by fuel types reveals a shift in consumption pattern from traditional to commercial and renewable sources [8]. At the same time annual increase in energy consumption is observed to be 2.4%. Significant rise of annual electricity consumption by around 10% implies

1 http://hdrstats.undp.org/en/countries/profiles/NPL.html

2 EDI is devised by IEA, as an indicator that tracks progress in a country's or region's transition to the use of modern fuels. (http://www.iea.org/publications/worldenergyoutlook/resources/energydevelopment/theenergydevelopmentindex/)

growing demand for electricity as household income is rising. However, 25% annual surge of imported LPG fuel consumption seems perilous to national economy. As of WECS data 2008/09, fuel wood consumption share is 87% of total energy consumption [Figure 2] and almost 99% of which is consumed in residential sector.

Nepal has huge potential for hydropower development with an estimated potential of 83GW and feasibility of 42GW[3]. However to our dismay, only 2% of it has been harnessed. Electricity contributes only 2% of the total energy demands [5]. At present Nepal has a total installed capacity of 762 MW. Of the total installed capacity of the hydropower, 478 MW is contributed by NEA hydro, 5 MW by NEA thermal, 0.10 MW by solar and 2301 MW-all Run-off-the River (ROR) by IPP hydro [9] [10].

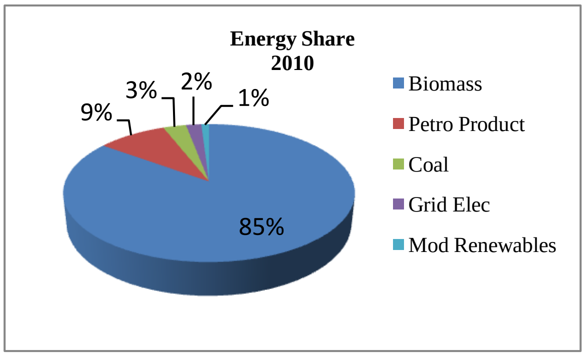

Figure 1: Calculated Energy Mix by fuel type in 2010 based on (MoF, 2012; WECS, 2010)

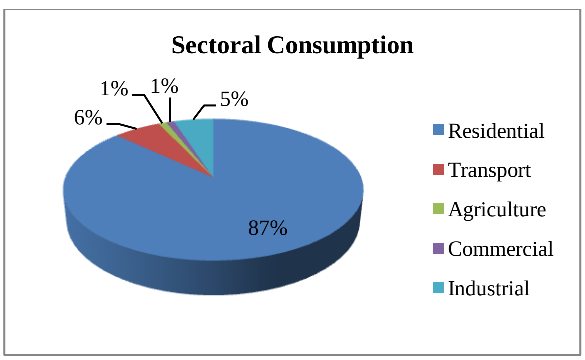

Figure 2: Final Energy consumption by Economic Sectors in 2010 (MoF, 2012; WECS, 2010)

Nepal is totally dependent on imported petroleum fuels. Soaring international oil market price is making countries economy vulnerable. The nation spent approximately 126 percent of its commodity exports in 2010/11 on import of petroleum products which was just 27 percent of the exports earnings in 2000/01 [2] [11]. If Nepal can properly surmount the barriers of domestically producing sufficient and reliable electricity, it does not have to bear the avoidable costs of importing petroleum products for electricity generation and capital costs of generating sets.

[3] Estimation was done by Dr. Hari Man Shrestha some 44 years ago in his Ph.D. research dissertation(Shrestha, H.M., 1966)

However, Nepal could just produce 2 percent of its commercially viable hydropower resources. Without proper vision, strategies, and action plans for the sustainable development of energy sector, Nepal's economy could be in jeopardy in the coming years.

2. METHODOLOGY

A. Energy model

Energy modeling is a meticulous process that needs spacious tools and techniques. As a model represents a foresight on the basis of past data, thus they are static in nature to most extent, which is seen as one of the limitations. But with proper analytic approach, the model provides best probable foresight. Long term energy scenario analysis is much more complex due to uncertainty but is crucial for for developing national policies.

From the literature review different analysis tools have been used insofar for the analysis and MAED and ANSWER MARKAL[4] (MARKet ALlocation) analysis tool has been widely used in developing and developed countries and thus is used in our energy system analysis.

For the analysis, base year 2010 data are collected. MAED[5] model is used to obtain sectoral energy demand till 2050. Useful energy obtained from MAED is assimilated to develop demand projection. Projected energy demand thus form basis for optimization in MARKAL.

Model for Analysis of Energy Demand(MAED)

MAED model evaluates future energy demand based on medium- to long-term scenarios of socio-economic, technological and demographic developments. Energy demand is disaggregated into a large number of end-use categories corresponding to different goods and services [12][13][14]. The influences of social, economic and technological driving factors are estimated and combined in each different category to present an overall picture of future energy demand growth under the assumptions of that scenario

MARKet ALlocation (MARKAL)

MARKAL is a generic model tailored by the input data to represent the evolution over a period of usually 40 to 50 years of a specific energy system at the national, regional, state or province, or community level. MARKAL is a

[4] MARKAL: (MARketALlocation) model was developed in the late 1970s at Brookhaven National Laboratory. In 1978, the International Energy Agency adopted MARKAL and created the Energy Technology and Systems Analysis Program (ETSAP).

[5] Model for Analysis of Energy Demand (MAED) is an energy planning tool developed by IAEA.

data-driven, energy systems economic-optimization model. The objective is a target-oriented integrated energy analysis and planning through a least cost approach. The energy demands are exogenously supplied in this model and the supply options are analyzed. Both linear as well as dynamic (non-linear) programming mathematical approaches can be utilized by this model. MARKAL solves a model run by minimizing the objective function. It uses LP methods to optimize the system. The present value of the total energy system costs throughout the planning horizon is the objective function, which is subject to specific constraints. The discount rate of 10% is used. MARKAL assumes perfect foresight in making the decisions, i.e. decisions are made with full knowledge of future events.

MARKAL is currently being in used in more than 60 countries and 200 institutions worldwide. It is a comprehensive model that well facilitates the scope in representing detail technologies and its characteristics. Throughout the system it takes into account the conversion processes, their efficiencies and losses as well as costs such as extraction costs, transportation and distribution costs, etc. Energy supply mix with optimum cost is given by the model. It can undertake number of user-defined constraints such as resource availability, cost, environmental emission threshold, etc. [15]

B. Methodological Framework

Figure 3 shows the modeling framework adopted during the scenario development. From the base year data, future energy demands were projected using MAED for designated sectors. The user inputs the structure of the energy system to be modelled, including resource supplies, energy conversion technologies, end use demands, and the technologies used to satisfy these demands. The user must also provide data to characterize each of the technologies and resources used, including fixed and variable costs, technology availability and performance, and pollutant emissions. MARKAL then calculates, using straightforward linear programming techniques, the least cost way to satisfy the specified demands, subject to any constraints the user wishes to impose. Outputs of the model include a determination of the technological mix at intervals into the future, estimates of total system cost, energy services (by type and quantity), estimates of criteria and greenhouse gas (GHG) emissions, and estimates of energy commodity prices.As seen in flowchart given in Figure 3, the modeling is an iterative method rather than a single upshot.

3. DATA DEVELOPMENT

The data development process for MARKAL model is a rigorous iterative progression. As mentioned earlier, the data projection from MAED and scenario development in MARKAL was done in a cyclic process with necessary calibrations in the model.

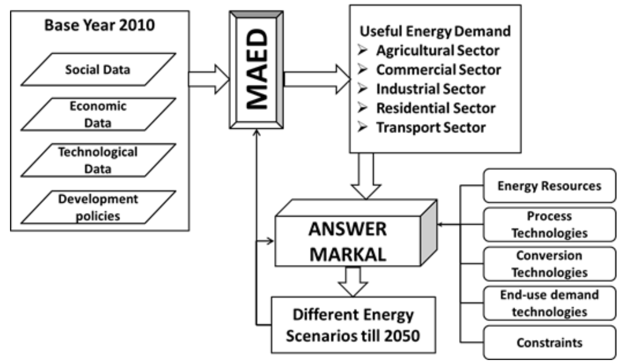

Figure 3: Methodological Framework

The general categories of data required for a MARKAL model are:

- System-wide global parameters
- Energy service demands
- Energy carriers
- Resource technologies
- Process and demand technology profiles
- Environmental emission factors

1. System-wide Parameters

System-wide, otherwise known as global, parameters are assumptions that apply to the entire model. Two important system-wide aspects of the model are:

- Cost discounting
- Subdivision of the year into load fractions

2. Energy Service Demand

Key demand related data include:

- Projections for useful energy demand services by sector.
- The load shape of the demand pattern by season/day-night

3. Energy Carriers

Energy carriers are the various forms of energy produced and consumed in the Reference Energy System [6]depicted in a MARKAL model.

- For all energy carriers-

[6] The Reference Energy System (RES) is a network representation of all of the technical activities required to supply various forms of energy to end-use activities. Analytical techniques are described to examine all operations involving specific fuels including their extraction, refinement, conversion, transport, distribution, and utilization.

- Overall transmission and distribution efficiency
- For electricity -
    - Investment and operation and maintenance cost for transmission and distribution systems.
    - Reserve margin, or amount of installed capacity above the highest average annual demand.

4. Resource Technologies

Resource technologies are the entry points for raw fuels into and out of the energy system, which include imports and exports, mining and extraction, and renewable energy

- Bounds indicating the size of each step on each resource supply curve.
- A corresponding resource supply cost for each supply step.

5. Process and demand technology profiles

Process technologies are those that change the form, characteristics, or location of energy carriers. Key process and demand technology data include:

- Technology costs-
    - The cost of investing in new capacity.
    - Fixed operating and maintenance (O&M) costs for installed capacity.
    - Variable O&M costs according to the operation of installed capacity.
- Energy carriers into and out of each technology.
- The model year in which the technology first becomes available for investment.
- Availability factors (for process technologies) and capacity utilization factors (for demand technologies) that describe the maximum percent annual (or season/day-night) availability for operation or a fixed percent annual (or season/day-night) capacity utilization per unit of installed capacity.
- The current existing installed capacity.
- Limits on capacity in the form of incremental new investment (absolute or growth rate) or total installed capacity.

6. Environmental Emission

MARKAL has the capacity to track the production of emissions according to the activity, installed capacity, or new investment in capacity of a resource or technology.

A. Software

All results referenced in this document were based on the following software versions:

- ANSWER v6
- GAMS 23.9.1
- MAED – 2

B. Developing National MARKAL Database

The goal for the development of the national model was to focus on five key sectors: agriculture, commercial, residential, industrial, and transportation

The current database runs from 2010 to 2050. After assimilating data characterization in each sectors and sub sectors, the model was created. The model was then calibrated against the national data available and expected results.

The goals of the calibration were: (i) to ensure that the model was producing reasonable results, given its input assumptions, (ii) to determine whether the model was providing a plausible, consistent representation of the key features of the national energy system, (iii) in cases where our results differ from expected results, to be able to identify why the differences exist, and (iv) to identify any significant errors in the construction or characterization of the Reference Energy System. It should be however noted that an exact calibration of MARKAL is not practically possible as the database and structure created are by far not same.[16]

Calendar year 2010 was chosen as the base year with modeling periods of 5 year intervals with short term (to year 2020) , medium term (to year 2030) and long term (to year 2050) time frames. Since the majority of the costs in the model based on international market values, particularly those for fuel supplies and power plant capital costs, the model was constructed in 2005 Nepali rupees.

1. Demand Side

The demand side was disaggregated into 5 sectors:

a) Agricultural sector
b) Commercial Sector
c) Industrial Sector
d) Residential Sector
e) Transportation sector

Each of the sectors has its end-uses purposes which are further classified by fuel types they use. This totals to 89 end-use with 292 end use devices. The data were developed from MAED and further apportioned to each end use with reference to base year for MARKAL model development.

2. Supply Side

Following supply side sources are included in the model:

- Traditional biomass resources – woody biomass, agricultural residue, animal residue
- Imported fossil fuels – coal, gasoline, diesel, kerosene, ATF, LPG, other petro products
- Hydropower – major, micro, mini
- Solar PV – isolated, grid connected

In this case, given the focus on the supply and power generation sectors, the data developed for the MARKAL model consisted of following components:

- Fossil fuel resource supplies and costs
- Electricity demand projections and load characteristics.
- Technical characterization of existing power plants
- Technical characterization of new power plant investment options, including renewable potentials.

4. Assumptions

Different assumptions were made before proceeding to the model.

A. Macroeconomic Assumption

GDP growth rate is assumed in three scenarios namely:

- Business as Usual Case Scenario(BAU)
  - GDP growth rate – 4.4%
- Reference Case Scenario (REF)
  - GDP growth rate – 5.6%
- Accelerated Growth Case scenario (AGC)
  - GDP growth rate – 6.5%

In GDP growth rate, the shares of each demand technology in the energy supply in future years were assumed to be same as in the base year.

B. Sectoral target

The study has been considerably influenced by the objectives of SE4ALL[7] with the chief targets of:

a) Access to modern energy,

b) Efficiency improvement, and

c) Increased renewable energy

C. Sectoral assumption in Combined Policy Scenario

Combined policy scenario is based on reference scenario – following the targeted GDP growth rate [17] with technology and policy interventions – electrification, efficiency improvement and introduction of modern clean technologies. The following are the brief assumptions taken in this scenario:

1. Agriculture:

The end use assumptions for the agricultural sectors consist of two sub sectors – water pumping and farm machinery. Electrification in agriculture is expected fully by 2050 in water pumping technology while it is only expected to be half in farm machinery which entirely at present is operated by diesel fuel.

2. Commercial sector:

The commercial sector is sub-divided into 3 subsectors namely commercial and tourism, commercial and service sector, financial and real estate and 7 basic end-uses namely cooking, space cooling, space heating, water heating, lighting, electric appliances and others. This sector makes use of mix energy at present but unlike other sector shift from traditional to modern electricity is plausible in commercial sectors. This fact is due for complete electrification assumption in this sector by 2030.

3. Industry:

There are 9 major industrial subsectors with 5 end-use technologies each. Following sub-sectors are considered: Industrial Food Beverage and Tobacco, Industrial Textile and Leather Goods, Industrial Chemical Rubber and Plastic, Industrial Mechanical Engineering and Manufacturing, Industrial Electrical Engineering Products, Industrial Wood Products and Paper, Industrial Bricks & Structural Clay Products, Industrial Cement & Non-metallic Products, Industrial Other Manufacturing.

Of the 5 end-uses, the major energy consuming end uses are Process heat, Motive power and Boiler. So, the policy is basically focused towards these three end-uses. As an energy saving policy, in process heat, the efficiency of the technology is aimed to have increased, and in boiler technology, it is aimed to electrify entirely by 2050 in all industries which include the introduction of new electric boilers. This process includes subsequent phasing out of older non electric boilers. The end-uses - Motive power and others are targeted to be electrified totally by 2030

4. Residential sector:

[7] Sustainable Energy for All (SE4ALL)is a global initiative led by the Secretary-General of the United Nations to achieve universal energy access, improve energy efficiency, and increase the use of renewable energy, as per decision by the UN General Assembly in December 2010. (http://www.sustainableenergyforall.org/)

There are 67 demand technologies in the residential sector, broken down into 8 sub-categories. Within each sub-category are different technologies powered by a variety of energy carriers with different efficiency levels. The sub-categories are: cooking, lighting, space heating, space cooling, water heating, refrigeration, miscellaneous and others. Each sub-category is analyzed physiologically in rural and urban area. Urban end use technologies are assumed to be electrified entirely by the end of analysis period while in rural area too large share is anticipated from electricity in energy fuel mix but in rural cooking where fuel wood share is still expected to cover 50% of total rural fuel mix. Introduction of solar thermal and solar PV for water heating and lighting is envisaged. Efficiency is improved in case of traditional technologies and most of them are phased out only to be replaced by modern energy technologies.

5. Transportation

There are 3 sub sectors and 23 end-use technologies in this sector. In this sector, mass transport is emphasized over private vehicles to reduce fuel consumption ratio and also to provide public service at low cost. Introduction of electric train in freight and intercity is assumed to be technology intervention for transportation. Introduction of bio-fuel – ethanol and biodiesel, in transport since 2020 to reach the target of total its fuel share to 5% and 10% of total fuel share of gasoline and diesel respectively is also assumed to promote renewable energy.

6. Supply side technologies and commodities:

With emphasis on electric appliances and technologies in the demand side, hydropower has been given major preference as a supply conversion technology. The hydro potential is assigned its utmost feasible capacity of 42,000MW for major hydropower, 80MW for Micro-hydropower [18] [19]. A reserve capacity of 25% is allocated for the hydropower plants. Along with this, grid connected solar PV is introduced as renewable source of electricity with target of 100MW by 2020, 500MW by 2030 and upmost 2100MW, i.e. the maximum estimated potential [20] by 2050.Along with these, biogas, solar thermal, SHS technologies are also included in the model.

5. RESULTS

A. Energy Mix

The comparative study of all scenarios reveals the changing energy consumption pattern. Energy consumption is increased with increase in GDP which correspond to increased economic activities and also signify improving living standard of people. However, combined policy scenario at reference GDP case brings in light the reduced energy consumption due mainly to shift in efficient and modern from traditional technologies. Energy saving is another benefits of the combined policy scenario.

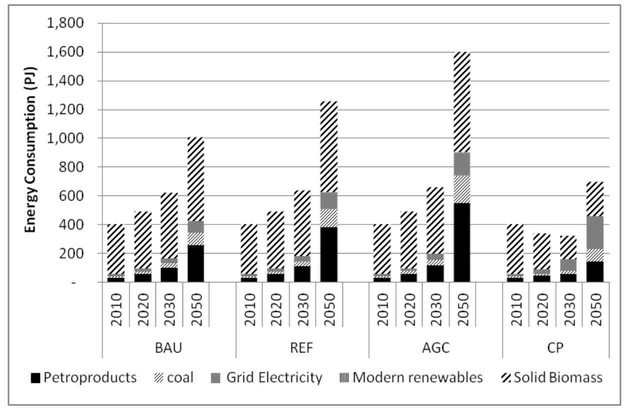

Figure 4: Energy Mix of four scenarios

Business as Usual Case Scenario

Energy consumption in base year amounts to 410 PJ which will increase to 490 PJ, 625 PJ, and 1010 PJ by 2020, 2030 and 2050 respectively. Energy mix by fuel in low growth rate shows large share of fuel wood that amounts to 312 PJ which is 77% of total fuel mix in 2010. With increasing energy demand with time, consumer shifts from traditional to modern energy which can be observed from reducing fuelwood consumption with time in BAU scenario and will have the share of 49% by 2050. Further the result shows that the fuel wood consumption commensurate with sustainable wood supply. Other biomass includes animal dung and agri-residue, the share of which remains constant at 9%. By 2050, 88 PJ of energy will be obtained from other biomass. With increasing dependence on imported petroleum products, there is no sign of reducing the share. It is noteworthy that 8% of current energy share of petro-products will increase linearly to 12%, 17% and 26% by 2020, 2030 and 2050 respectively. Remaining energy fuel mix comes from coal, grid electricity, and biogas and their share is nominal in base year and will be 8%, 7% and1% by 2020, 2030 and 2050 respectively.

Reference Case Scenario

Energy consumption in base year in reference case is same as 410 PJ, which will increase to 500 PJ, 640 PJ, and 1259 PJ by 2020, 2030 and 2050 respectively. Energy mix by fuel in this scenario shows decreasing share of fuel wood consumption from 77% in 2010 to 41% by 2050.With growth in GDP, economic activity is sure to increase that indubitably increase imported fuel consumption. This fact complies with the increasing trend of petro products consumption from 8% in 2010 to 18% by 2030 and 31% by 2050. Coal share will be 10% by 2050 while electricity share will be 9% unless no policy intervention is done.

Accelerated growth Case Scenario

Energy consumption in accelerated growth case will increase from base year 410 PJ to 500 PJ, 663 PJ, and 1600 PJ by 2020, 2030 and 2050 respectively. Energy mix by fuel in scenario shows share of fuel wood reduced to 35% from 77%. It is accounted primarily due to economic growth that shifts fuel mix from traditional to commercial and renewable energy sources. From the result it can be aforementioned that fuel wood share and petro products approximate same share by 2050. In absence of the adequate supply of indigenous sustainable source, imported petro-products replaces fuel wood which certainly is perilous to national economy. Coal and grid electricity consumption share will be 12% and 10% by 2050.

Combine Policy scenario

In combined policy scenario the total energy consumption in 2030 is expected 330 PJ and 710 PJ by 2050. Fuel wood consumption will be well below sustainable limits by 2020. With the policy intervention to promote commercial and renewable energy, traditional fuel wood share will be 22% of total energy mix by 2050. To reduce dependence on imported fuel and promote indigenous energy source, electrification in possible sector is incorporated that will substantially reduce import of petro products. The final energy mix henceforth shows 145 PJ which is 21% of total energy mix from petro products. As a result, electricity consumption grows rapidly after 2020. Electricity share will increase from 2% in 2010 to 8%, 24% and 32% by 2020, 2030 and 2050 respectively. The cumulative growth rate of electricity consumption in this scenario is 14 percent. Petroleum consumption will grow at an average rate of 9 percent. The comparative energy share in year 2050 in reference case and combined policy scenario are shown in Figure 5. It is clear from the fig. 5 that quantitatively, the total primary energy demand would be as much as halved. The demand for electricity would nearly double while demand for petroleum and coal would be nearly halved as well.

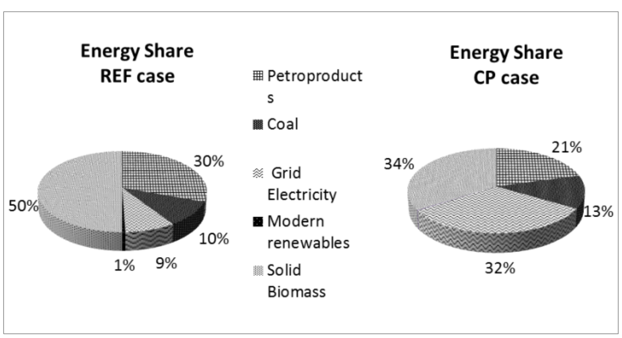

Figure 5: Energy Share in year 2050

The sectoral pattern of energy consumption shows residential sector consuming 87% of total energy in 2010 and 54 % in 2030 which further reduces to 29% by 2050. The shares of commercial, industrial, and transport sectors in 2030 will be 8%, 18% and 17% respectively and this share changed to 13%, 34% and 20% respectively by 2050. Remaining share is consumed by agriculture.

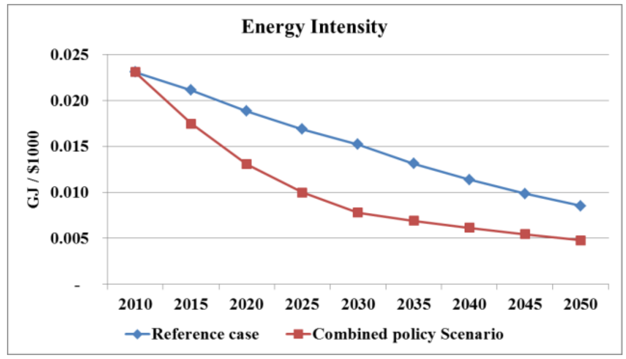

Figure 6: Comparison of energy intensities

B. Comparative analysis between REF and CP

i. Energy intensities

Energy intensity is a measure of energy efficiency of national economy. It is indicative of unit energy per unit of GDP. High energy intensity refers to high cost of converting energy into GDP [21]. It implies mix of energy services in economics.Efficient and improved technology reduces energy intensity. In combined policy scenario, efficiency as well as new and improved technologies is considered as a result of which substantial amount of reduction in energy intensities is observed eventually saving useful energy (Figure 6). Decrease in intensities in energy in combined policy is higher than reference case. The reason behind this is the penetration of competent technologies and phasing out of outdated technologies.

ii. Per capita energy consumption

Comparison between per capita final energy consumption in reference case and combined policy case is as shown in Figure 7. The result shows that in base year 2010 per capita final energy consumption which is 15GJ [22] is likely to increase to 27GJ in reference case but in combined policy it is expected to be16GJ. The disparity in figure owes chiefly the availability of efficient energy eventually leading to improved economic status.

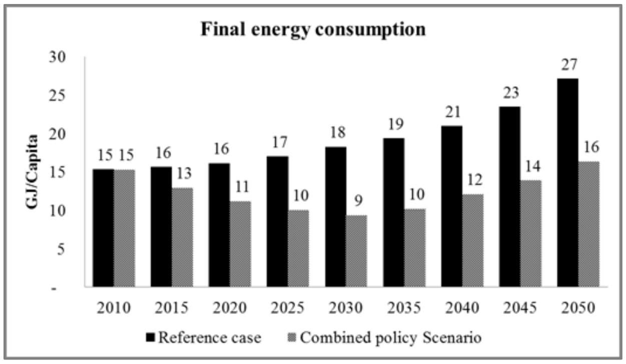

Figure 7: Energy consumption per capita

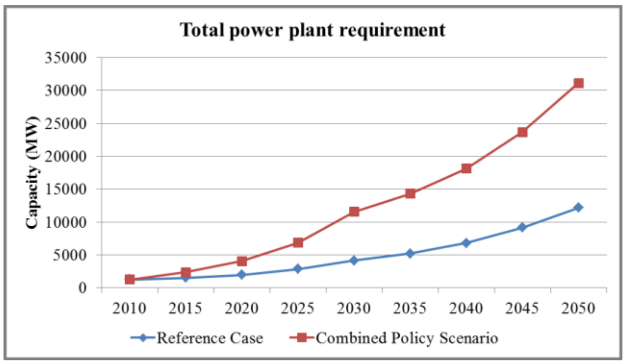

Figure 8: Power plant capacity requirement

iii. Power Plant Requirement

The electric power will be supplied mainly by – grid and off-grid – hydropower and rest by solar PV. The peak power plant capacity requirement in base year 2010 stands at 1272MW with 25% reserved margin. The power plant requirement for 2030 will be 11,536 MW (with 2,100 MW grid connected Solar PV 2030 onwards) and 31,133MW by 2050. This is almost 2.5 times the requirement in the reference case (Figure 8). To meet this requirement, an annual investment of 181 billion NRs (2005 constant prices) will be required for installation of power plants in the last period of 2025 - 2030. Such hefty requirement of power plant is mainly because of penetration of electricity in all plausible sectors.

iv. Emission

Emission calculation from the MARKAL shows reduction in GHG emission while shifting the scenario from reference to combined policy. Reduced GHG emission can be henceforth used for trading through Clean Development Mechanism (CDM) which eventually reduces the burden of cost constraint while making policy intervention [23]. There is reduction in approximately 448kg per capita in 2050 when technology intervention is preferred (Figure 9).

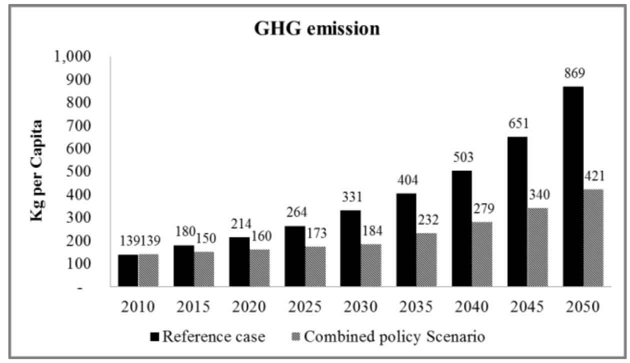

Figure 9: GHG emission per capita

6. Implications for Technology Intervention

Prospective development of country is only possible with the boost in economic activities. Energy is crucial indicator of economic development. But Nepal currently being fossil fuel importing country, larger the use of such energy can have adverse effect on economy. Thus introducing efficient and advance technology along with modern energy resources fundamentally drives nation into a way ahead.

From the result, it can be inferred that electric end use devicesif penetratedin all sectors, it will lower the fuel dependency. Moreover, efficient end use devices and fuel switching to modern form of energy in other end uses such as cooking and others will ultimately reduce the burden on national biomass resources as well as reduce environmental effects.Mass transport can be most viable source of intercity transport in terms of service and cost. Electric vehicle in freight and intracity transport supplements electricity demand but nevertheless reduce petroleum import. The use of indigenously produced biofuels also serves the same purpose as well as help increase in national economy to some extent. These can ultimately reduce national burden on export commodity.Thus, new and efficient technologies,which are readily available, can substantially reduce energy consumption as well as save expenditures on it. Such saved energy, if are residual, can be utilized in productive sectors and even has prospect for energy export.

Hydropower and Solar PV electricity are indigenous resources and most sustainable source of energy for all sectors. The total power plant requirement is under the nation’s potential and is thus viable [7][18][19][20]. However, solar thermal and isolated solar PV can be an emerging alternative source for water heating and lighting. The average received daily solar radiation on a flat surface various in the Nepal between 4.5–5.5 kWh/m2 [20][24].Unit cost of solar in international market is precipitously lowering. Therefore, promotion of solar powered technology will add national benefits as Nepal is also considered to have colossal source of solar energy.Furthermore, the reduction in GHG emissions due to clean energy usage is not only beneficial for health and environment, there is also possibility of carbon trading through CDM.

For the technology intervention thus analyzed so far, there is a dire need of effective policy implementation and strong commitment from government. Legal and institutional frameworkalong with national vision is also crucial to attain desired targets. Moreover, national plans for investment and financial securities plays vital role in implementing the targets.

7. CONCLUSION

There have been numbers of analysis performed in different sectors of energy in disaggregated form using various analysis tools. However the integrated energy system analysis projecting optimal future energy resources with policy intervention is limited. Following economic, social, environmental and technical constraints, data have been analyzed in MARKAL in different scenarios. In BAU scenario, energy fuel mix in future is less likely to change besides increased share of petro-products. Reference scenario is obtainable as per recent economic development of country according to macro-economist. However without technology intervention ample deviation from BAU energy fuel mix is implausible in both reference and accelerated growth scenario. We can thus conclude that without tangible amendment in policy, energy consumption scenario is less prone to shift from traditional to commercial and renewable sources. Combine policy scenario is thus assumed to envisage conceivable energy scenario of Nepal. Electricity is the most sought after technology in all sectors as per the scenario. Within 40 years, Nepal will need most of its feasible domestic hydro resources for its domestic purpose. Traditional resources will be phased out and will be replaced by renewable and commercial resources. Enormous investment will be required for achieving aforementioned economic swing. Financial analysis is not covered in this paper. Penetration of electricity to meet the national demand in all the commercial sectors so as to completely substitute the imported fuel and hence contribute national economy through the export of surplus energy is inferred. Energy intensities and per capita energy consumption seems to deviate positively that eventually improved energy statistics. GHG emission calculation also shows discernible reduction in emission in policy scenario.

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Activated Carbons Synthesized from Lapsi (Chorespondias axillaries) Seed Stone for the Removal of Arsenic from Water

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***Abstract*: The adsorption of arsenic (III) from aqueous solution by iron impregnated activated carbon synthesized from Lapsi (Choerospondias axillaries) seed stone were studied by batch adsorption method. Experiments were carried out to investigate the effect of pH on arsenic removal. The adsorption increases with increase in pH and after pH 6 it became almost independent of pH. The adsorption data were fitted with Freundlich and Langmuir isotherm. The results indicated that Langmuir isotherm is better fitted than Freundlich isotherm. The Maximum adsorption capacities were found to be 2 mg/g. The kinetic study on the adsorption of As(III) fit with the pseudo-second order model. Thus the iron impregnated activated carbon derived from Lapsi seed stone is a potential adsorbent for adsorption of arsenic from ground water.**

Keywords: Lapsi (Choerospondias axillaris) Seed, Activated Carbon, Zinc Chloride Activation, adsorption isotherms, kinetic.

1. INTRODUCTION

Arsenic is a naturally occurring element and usually occurs as arsenate (As(V)) or arsenite (As(III)). The occurrence, distribution and speciation of arsenic depend on the pH and Eh (oxidation-reduction potential). Arsenic exists in four oxidation states as +5, +3, 0 and -3. Figure 1 illustrates that arsenic occurs as arsenous acid species (H_3AsO_3, $H_2AsO_3^{-1}$ and $HAsO_3^{-2)}$ in a low Eh condition or in mildly reducing anaerobic condition such as in ground water whereas the arsenic acid species (H_3AsO_4, $H_2AsO_4^{-1}$, $HAsO_4^{-2}$ or AsO_4^{-3}) predominate in oxygenated surface water and presents in anionic form at high Eh condition.

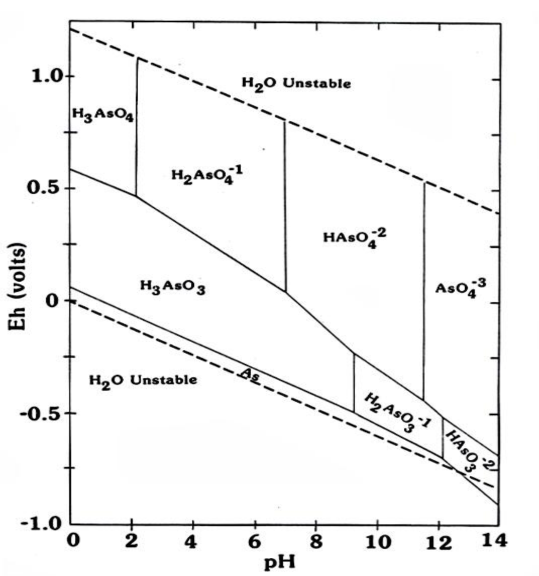

Figure1: The Eh-pH diagram for arsenic at 25^{o}C

WHO in 1993 and USEPA in 2001 lowered the arsenic standard from 50 µg/L to 10 µg/L. However, Nepal interim guideline value of arsenic is 50 µg/L. Long term exposures to arsenic can cause cancer of the bladder, skin, lungs and kidney.

Arsenic in natural waters is a worldwide problem. Arsenic pollution has been reported in Argentina, Bangladesh, Canada, Chile, China, Hungary, India Japan, Mexico, Nepal, New Zealand, Poland ,Taiwan, USA, etc and the largest population at risk among the 21 countries with known groundwater arsenic is in Bangladesh, followed by West Bengal in India as well as in the lowland of Nepal. In Terai (low land) and other parts of Nepal, as the surface water sources are getting scarce, groundwater is being extensively used for drinking purpose, 90% people in the Terai region of Nepal are using ground water for drinking purpose. The presence of Arsenic above WHO guideline in ground drinking water of Terai region of Nepal has become a major health concern [1].

The conventional techniques like coagulation, co-precipitation, carbon adsorption, synthetic ion exchange resins have been widely used for water treatment throughout the world. Adsorption is more efficient and effective technology for arsenic removal from ground water for drinking purpose but the cost of effective adsorbent is exuberantly high. The development of low cost and effective adsorbent for removal of arsenic from readily available local resources is a new challenge. The most widely studied adsorbents for arsenic removal include iron oxides coated sand [2, 3] cement [4] activated alumina [5] silica [6] zeolite [7] and activated carbon [8-10]. Among many types of adsorbent materials activated carbon are the most widely used for water treatment owing to their versatile adsorption capacity and low cost. Although activated carbon can be produced from almost any raw material, but in the recent years, attention has been paid in the preparation of low-cost activated carbon (AC) from the locally available lignocellulosic materials or agricultural by-products due to its wide ranges of practical applications and versatile adsorption capacity.

Recently we have reported preparation of series of nanoporous activated carbon derived from Choerospondias axillaries, locally know as Lapsi, an indigenous plant of Nepal [11]. The activated carbon impregnated with iron was successfully used for adsorption of arsenic from water [12]. The paper in hand reports the effect of pH, adsorption isotherms and adsorption kinetics for adsorption of arsenic (III) from water.

2. Materials and Methods

Lapsi seed stone powder and zinc chloride in the ratio of 1:1 is carbonized in nitrogen atmosphere at 400^o C for 4 hour and the resultant activated carbon was washed with 0.1 N HCl and distilled water. Then this activated carbon was impregnated with iron by precipitation method the details which is given elsewhere [12]. The distribution of iron onto the activated carbon from Lapsi seed stone was also investigated.

Stock solution containing 1000 mg/L of As (III) was prepared from AR grade As_2O_3. 1.320 g of arsenic (III) oxide dried for 1 h at 110^o C was taken in a volumetric flask of capacity 1000 ml. Then 2 g of sodium hydroxide was added and dissolved in a small quantity of deionized water and then diluted to a predetermined volume. Arsenic working solutions were freshly made by diluting stock solution with deionized water.

To study adsorption kinetics, 0.05g of iron-impregnated carbon was added to each of 8 bottles containing 25 ml of arsenic (III) solution of concentration of 100 µg/L The pH were maintained at 7 by using 0.1 M HCl and 0.1 M NaOH. The test bottles were shaken in a shaker at 200 rpm for 3 hours. The samples were taken out at fixed interval, filtered and determined the As concentration by Atomic Absorption Spectroscopy method.

Adsorption isotherms were studied by adding 0.05 g of iron impregnated carbon into each of 25 ml of arsenic solution of concentration 100 ppb to 900 ppb. After equilibrium was attained, the solution was filtered and arsenic concentration was determined by AAS.

3. Results and Discussion

Effect of pH

The effect of pH on arsenic (III) adsorption by iron impregnated activated carbon was studies from pH 2 to 10. Figure 2, shows the plot of amount of arsenic adsorbed per gram of activated carbon (q_e) against pH of the solution. The q_e increases with pH up to pH 6 then after it becomes almost constant. This clearly means that for effective removal of arsenic (III), pH should be above 6. The pH of majority of ground water ranges from pH 6 to 8.2 [14], hence for effective removal of arsenic from ground water adjustment of pH is not required. The wide pH range for the adsorption of arsenic (III) could be attributed to ferric hydro/oxide existed on the surface of the adsorbent.

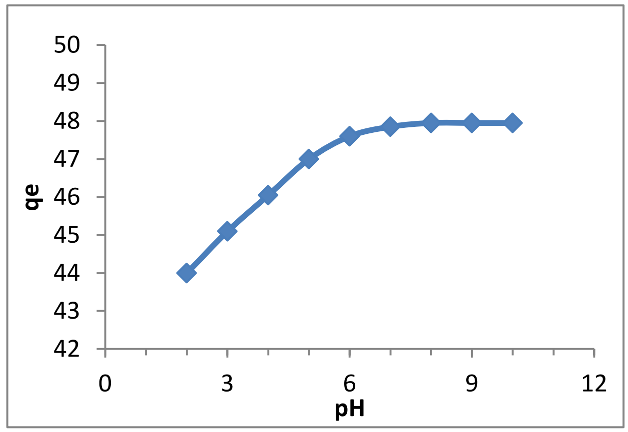

Figure 2: Effect of pH of the adsorption of As (III) onto iron impregnated activated carbon from Lapsi seed stone

Effect of contact time

Figure 3, is a plot of percentage of arsenic removal as a function of time at pH 7. The results showed that arsenic removal increased sharply upto 30 minutes and equilibrium was attained in about 180 minutes.

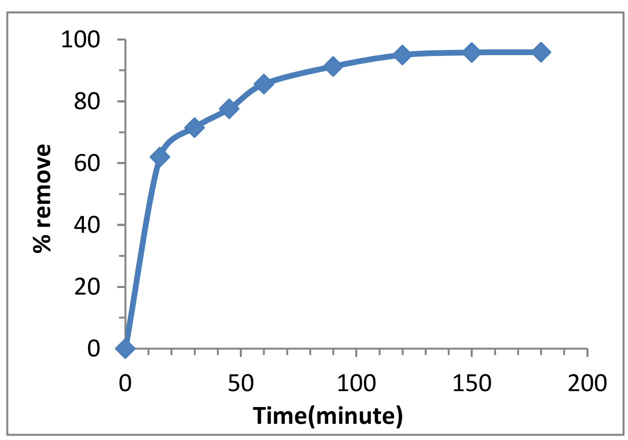

Figure 3: Arsenic removal by iron impregnated carbon as a function of contact time.

Adsorption Isotherm

The arsenic adsorption data were analysed with both Langmuir and Freundlich isotherm models. Langmuir adsorption is based on the maximum adsorption corresponds to a saturated monolayer of solute molecules on the surface of the adsorption. The linear form of the Langmuir equation can be represented as:

$$\frac{1}{qe} = \frac{1}{\mathrm{Bqm}} \times \frac{1}{\mathrm{Ce}} + \frac{1}{\mathrm{qm}} \qquad (1)$$

Where qe is the amount of arsenic adsorbed (mg/g) and Ce is the equilibrium concentration of arsenic in the bulk solution (mg /L) and b constant [15] is the Langmuir constant.

The Langmuir plot is shown in figure 4(a).The adsorption capacity (q_{max}) obtained from the Langmuir isotherm plot was 2 mg/g, which was much higher than that of the other adsorbents given in table 1.

Table 1: Adsorption capacity of various adsorbents of As (III)

Adsorbents	**Adsorption capacity qm mg/g**	**References**
Pine wood char	0.0012	Mohan et al 2007
Granular activated carbon	0.09	Reed et al,2000
Modified iron oxide coated sand	0.14	Vaishya and Gupta 2002
Iron oxided coated cement	0.67	Kundu and Gupta 2006
Activated carbon from olive pulp and seed	1.39	Budinova et al, 2006

Freundlich Isotherm is proposed by Freundlich in the year 1906. For adsorption from solution, the Freundlich isotherm is expressed by:

$$q_e = K_f Ce^{1/n} \qquad (2)$$

The linerized form of the Freundlich adsorption isotherm is obtained by taking logarithm of the equation 2,

$$\log qe = \log K_f + 1/n \log Ce \qquad (3)$$

where, K_f is the Freundlich constant, which indicates the relative adsorption capacity of the adsorbent related to the bonding energy, and n is the heterogeneity factor representing the deviation from the linearity of adsorption and is known as Freundlich coefficient.

The Freundlich plot is shown in figure 4(b). The values of K_f and n are found to be 12.36 and 1.05, respectively.

The R^2 values obtained from the Langmuir and Freundlich isotherm were 0.9794 and 0.9536, respectively indicating that the Langmuir isotherm fit better than the Freundlich isotherm for the adsorption of arsenic (III) onto the iron impregnated activated carbon. The adsorption of arsenic (III) was due to monolayer coverage of arsenic (III) onto homogeneous surface of iron impregnated activated carbon without interaction between adsorbed molecules. The distribution of iron in the activated carbon was quite homogeneous as indicated by mapping image of iron as obtained by EDS (figure 6).

Adsorption Kinetics

A pseudo second order rate expression based on adsorption equilibrium capacity may be expressed as

$$\frac{dqt}{dt} = k[qe - qt]^2 \qquad (4)$$

Where k is the rate constant of adsorption (g/mg min), qe the amount of solute adsorbate adsorbed at equilibrium (mg/g) and q_t the amount of solute adsorbed on the surface of the adsorbent at any time t (mg/g).

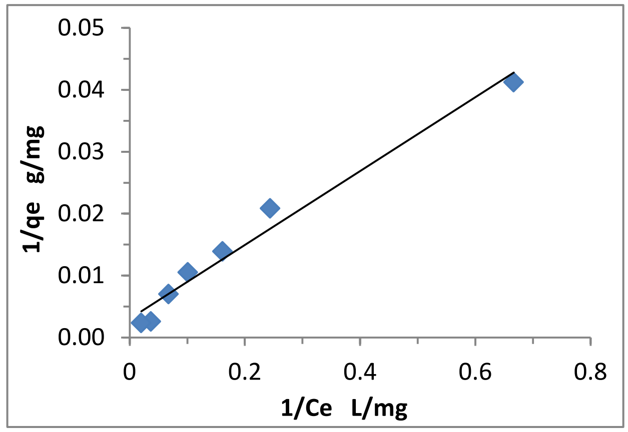

Figure 4 (a): Langmuir isotherm for adsorption of As (III) on iron impregnated activated carbon

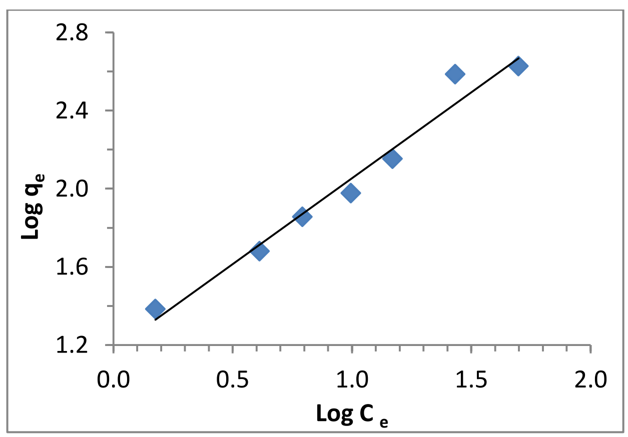

Figure 4 (b): Freundlich isotherm for adsorption of As (III) on iron impregnated activated carbon

The integrated rate law for a pseudo- second order reaction is

$$\frac{t}{qt} = \frac{1}{h} + \frac{1}{qe} t \qquad (5)$$

Where h is the initial adsorption rate (mg/g min).The plot of t/q_t vs. t at various initial concentrations is shown in fig.5. The points are the experimental data and the line is the line of best fit as obtained by the linear regression analysis. The high value of linear regression coefficient (R^2 > 0.999) obtained indicates that the adsorption kinetics follow the pseudo- second order mechanism.

4. CONCLUSION

The adsorption of arsenic (III) from the aqueous solution was optimum from pH 6 onward. It is observed that the equilibrium data obtained for the adsorption of As (III) can be well described by Langmuir isotherm model and yielded a maximum adsorption capacity of 2 mg/g. The isotherms study for iron impregnated carbon from Lapsi seed stone is quite favourable when compared with other materials in its maximum adsorption capacity. Study on the kinetic of adsorption onto the adsorption indicated that the experimental data followed the pseudo-second order kinetics within the equilibrium time of 3 hour.

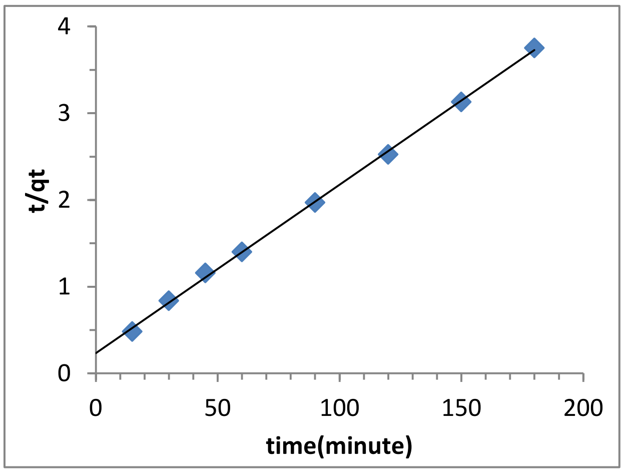

Figure 5: Pseudo second order kinetics of As (III) adsorption on iron impregnated activated carbon from Lapsi seed stone.

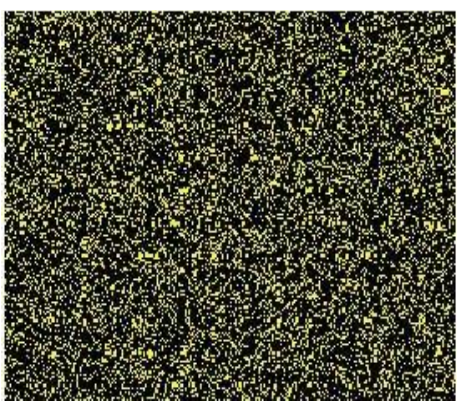

Figure 6: EDS-Iron impregnated activated carbon

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Design of Wireless Power Transfer System via Magnetic Resonant Coupling at 13.56MHz

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***Abstract*: Power is a must to modern systems. Power transmission through wires is common. But not in every field can wires be used because of certain limitations. The implantable biomedical devices like pacemakers, cardiac defibrillators, and artificial hearts require power supply for long term operation. The required power is supplied by driveline cable or by battery. WPT greatly reduces the risk of infection by eliminating the driveline cable which otherwise needs to puncture the skin to provide power and also saves the valuable space inside a person's body in case of battery powered. In such fields, what we need is wireless transmission. Wireless transmission is useful in cases where instantaneous or continuous energy transfer is needed, but interconnecting wires are inconvenient, hazardous, or impossible. In this paper, a simple design method of a wireless power transfer system using 13.56 MHz ISM band is proposed. The proposed wireless power transfer system consists of rectifier, oscillator, power amplifier, power coil, load coil and two intermediate coils as transmitter antenna and receiver antenna inserted between power coil and load coil.**

Keywords: Wireless Power Transfer, Resonant coupling, Oscillator, Intermediate coils, Power transfer efficiency.

1. INTRODUCTION

Power is very important to modern systems. From the smallest sensors, bionic implants, laptops, consumer products to satellites and oil platforms, it is important to be able to deliver power means other than classical wires or transmission lines. Wireless transmission is useful in cases where instantaneous or continuous energy transfer is needed, but interconnecting wires are inconvenient, hazardous, or impossible sometimes. In case of biological implants, there must be a battery or an energy storage element present that can receive and hold energy. This element takes up valuable space inside a person's body. In case of satellites, UAVs and oil platforms, solar panels, fuel cells or combustion engines are currently used to supply power [1].

The history of wireless power transmission dates back to the late 19th century with the prediction that power could be transmitted from one point to another in free space by Maxwell in his "Treatise on Electricity and Magnetism". Heinrich Rudolf Hertz performed experimental validation of Maxwell's equation which was a monumental step in the direction. However, Nikola Tesla's experiments are often considered as being some of the most serious demonstrations of the capability of transferring power wirelessly even with his failed attempts to send power to space [2].

There are three types of Wireless Power Transfer (WPT): radiative transfer, inductive transfer, and resonant coupling. Radiative transfer, although suitable for exchanging information, can transfer only small power (several millwatts), because a majority of energy is wasted into free space. Directive radiative transfer using highly directional antennas can be efficiently used for power transfer, even for long distances, but requires existence of an uninterruptible line-of-sight and has harmful influences on human body. On the other hand, inductive coupling can transfer power with very high efficiency but in a very short range (just in several centimetres) [2].

The last type of WPT, resonant coupling, can transfer high power at the medium range (several meters). Recently, MIT proposed a new scheme based on strongly coupled magnetic resonances, thus presenting a potential breakthrough for a midrange wireless energy transfer. The fundamental principle is that resonant objects exchange energy efficiently, while non-resonant objects do not. The scheme is carried with a power transfer of 60 W and has RF-to-RF coupling efficiency of 40% for a distance of 2 m, which is more than three times the coil's diameter. We expect that coupled magnetic resonances will make possible the commercialization of a midrange wireless power transfer [3]-[5].

2. RELATED THEORY

A. Resonant frequency

Resonance is a phenomenon that causes an object to vibrate when energy of a certain frequency is applied. In physics, resonance is the tendency of a system (usually a linear system) to oscillate with larger amplitude at some frequencies than at others. These are known as the system's resonant frequencies. In these particular frequencies, small periodic driving forces can even produce oscillations having large amplitude. The resonant frequency is calculated from (1).

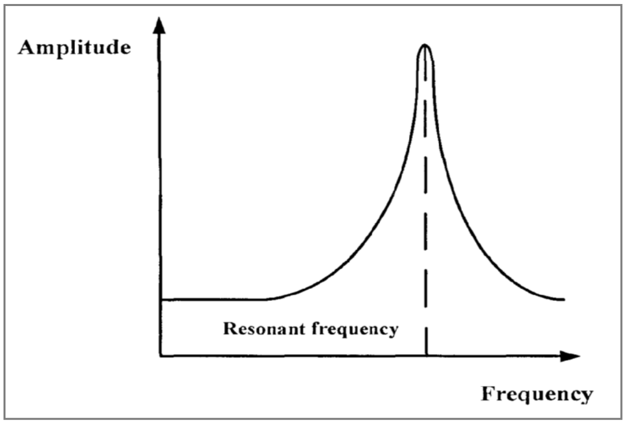

Figure 1: Resonant frequency

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

Where, L and C are respectively the inductance and capacitance of the tuned circuit.

B. Quality Factor (Q)

In physics and engineering the Quality factor (Q-factor) is a dimensionless parameter that describes the characteristics of an oscillator or a resonator, or equivalently, characterizes a resonator's bandwidth relative to its centre frequency [1]. Higher Q indicates the stored energy of the oscillator is relative of a lower rate of energy loss and the oscillations die out more slowly. So it can be stated that, oscillators with high quality factors have low damping so that a pendulum rings longer, in case of a pendulum example.

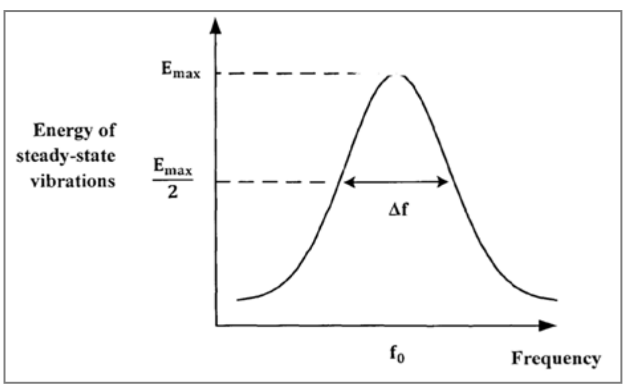

Figure 2: Bandwidth versus frequency

The above graph is the representation of the bandwidth, Δf, of a damped oscillator energy versus frequency. The higher the Q, the narrower and 'sharper' the peak is foΔf. Sinusoidal signal driven resonators having higher Q factors resonate with greater amplitudes (at the resonant frequency) but have a smaller range of frequencies around that frequency for which they resonate; the range of frequencies for which the oscillator resonates is called the bandwidth. Thus, a high Q tuned circuit in a radio receiver would be more difficult to tune, but would have more selectivity.

In an ideal series RLC circuit and in a tuned radio frequency receiver (TRF) the Q factor can be written as shown in (2).

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} \quad (2)$$

Where, R, L and C are respectively the resistance, inductance and capacitance of the tuned circuit.

C. Necessity of Impedance Matching

The resonance frequency changes as the coupling factor changes, and the maximum efficiency power transfer occurs at the resonance frequency. However, when this wireless power transfer system is applied in the MHz range (which allows smaller antennas), the usable frequency range is bounded by the Industrial-Scientific-Medical(ISM) band as shown in Figure 3. According to the ISM band, the usable frequency ranges are extremely narrow. For example, at 13.56MHz, the usable frequency range is 13.56MHz±7kHz [6].

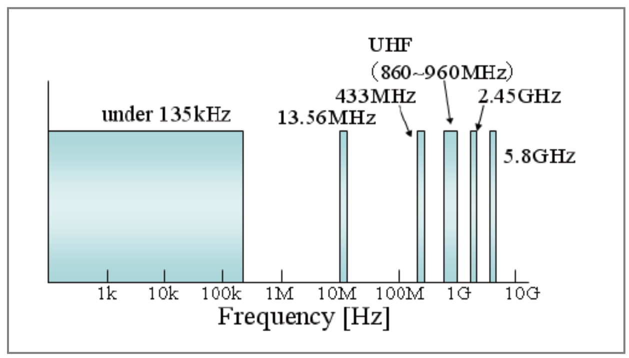

Figure 3: ISM Band

As a result, to apply this technology in restricted frequency ranges such as the MHz range, the frequency of the power source must be fixed at a usable range, and the system has to be tuned so that its resonance frequency matches the frequency of the power source.

D. Basic Theory of Impedance Matching

Impedance Matching is a technique commonly used in power transfer systems and communication systems to improve the efficiency of the system. It usually involves inserting a matching network (such as an LC circuit) to minimize the power reflection ratio to the power source of the system. In Figure 4, the power transferred to the load is written as (3) when the impedance of the power source is defined as Zsource and that of the load is defined as Zload. The power transferred to the load reaches its maximum when Zsource=Z*load, as in (4). Therefore, the circuit is considered matched and the maximum efficiency achieved when the impedance of the load from the source's point of view matches Zsource, and vice versa [1].

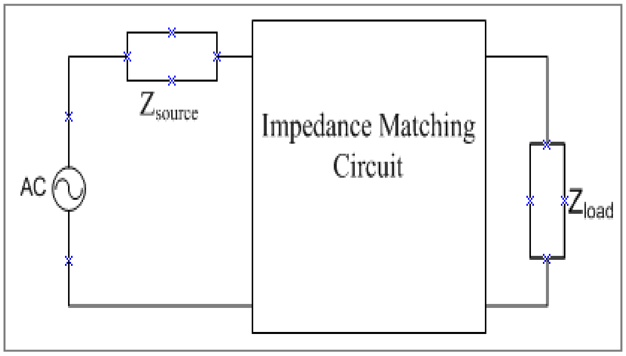

Figure 4: Theory of impedance matching

$$P = I^2 Z = \frac{V^2}{Z_{Source}}\left(\frac{1}{\frac{Z_{Source}}{Z_{Load}}+2+\frac{Z_{Load}}{Z_{Source}}}\right) \tag{3}$$

$$P_{max} = \frac{V^2}{4Z_{Source}} \tag{4}$$

The Impedance matching circuit can be considered as a two-port network that can be described with (5). The matching conditions are satisfied when the parameters satisfy (6) & (7).

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix}\begin{pmatrix} V_2 \\ I_2 \end{pmatrix} \tag{5}$$

$$Z_{Source} = \sqrt{\frac{AB}{CD}} \tag{6}$$

$$Z_{Load} = \sqrt{\frac{DB}{CA}} \tag{7}$$

E. Equivalent Circuit diagram of the WPT System

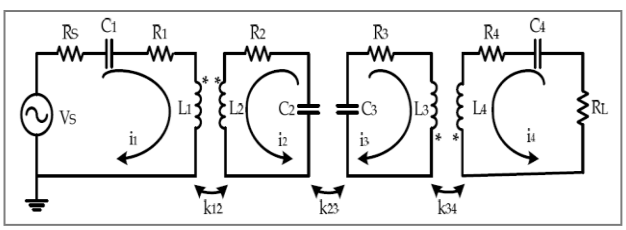

Figure 5: Equivalent circuit of WPT system

Figure 5 shows the circuit representation of the WPT system as modelled above. The schematic is composed of four resonant circuits corresponding to the four coils. These coils are connected together via a magnetic field, characterized by coupling coefficients k12, k23, and k34. Because the strengths of cross couplings between the power & Rx coils and the load & Tx coils are very weak, they can be neglected in the following analysis. Theoretically, the coupling coefficient (also called coupling factor) has a range from 0 to 1. If all magnetic flux generated from a transmitting coil is able to reach a receiving coil, the coupling coefficient would be "1". On the contrary, the coefficient would be represented as "0" when there is no interaction between them. Actually, there are some factors identifying the coupling coefficient. It is effectively determined by the distance between the coils and their relative sizes. It is additionally determined by shapes of the coils and orientation (angle) between them. The coupling coefficient can be calculated by using a given formula

$$k_{12} = \frac{M_{12}}{\sqrt{L_1 L_2}} \tag{8}$$

Where M12 is mutual inductance between coil "1" and coil "2" and note that $0 \leq k12 \leq 1$. Referring to the circuit schematic, an AC power source with output impedance of Rs provides energy for the system via the power coil. Normally, the AC power supply can be a power amplifier which is useful to measure a transmission and reflection ratio of the system. Hence, a typical value of Rs, known as the output impedance of the power amplifier is 50 Ω. The power coil can be modelled as an inductor L1 with a parasitic resistor R1. A capacitor C1 is added to make the power coil resonate at the desirable frequency. The Tx coil is a helical coil with many turns represented as an inductor L2 with parasitic resistance R2. Geometry of the Tx coil determines its parasitic capacitance such as stray capacitance, which is represented as C2. Since this kind of capacitance is difficult to be accurately predicted, for fixed size of the coil, a physical length, which impacts the self inductance and the parasitic capacitance, has been manually adjusted in order to fit the resonant frequency as desired. In the receiver side, the Rx coil is modelled respectively by L3, R3 and C3. The load coil and the connected load are also performed by L4, R4 and RL. A capacitor C4 also has the same role as C1, so that the resonant frequency of the load coil is defined. When the frequency of sinusoidal voltage source VS is equal to the self-resonant frequency of the resonators, their impedances are at least. In other words, currents of the coils would be at their most and energy can be delivered mostly to the receiving coil. Otherwise, energy of the transmitting power source would be dissipated in the power coil circuit itself, resulting in the very low efficiency. In general, setting the frequency of AC supply source same as the natural resonant frequency of the transceiver coils is one of the key points to achieve a higher performance of the system.

The circuit model offers a convenient way to systematically analyze the characteristic of the system. By applying circuit theory Kirchhoff's Voltage Law (KVL) to this system, with the currents in each resonant circuit chosen as illustrated in Figure 5, a relationship between currents through each coil and the voltage applied to the power coil can be captured.

The system model can be considered as a two-port network. To analyze this kind of system, S – parameter is a suitable candidate. Actually, S21 is a vector referring to a ratio of signal exiting at an output port to a signal incident at an input port. This parameter is really important because a power gain, the critical factor determining of power transfer efficiency, is given by [|S21|*|S21|], the squared magnitude of S21. The parameter of S21 is calculated by (9) [7].

$$S_{21} = 2\frac{V_L}{V_s}\left(\frac{R_S}{R_L}\right)^{\frac{1}{2}} \tag{9}$$

Thus, combining with $k\_12 = M\_12/\sqrt{}(L\_1\ L\_2\ )$ derived from (8), the S21 parameter is given as

$$S_{21} = \frac{j2\omega^3\ k_{12}k_{23}k_{34}L_2L_3\sqrt{L_1L_4R_SR_L}}{\begin{pmatrix} Z_1Z_2Z_3Z_4+k_{12}^2L_1L_2Z_3Z_4\omega^2+k_{23}^2L_2L_3Z_1Z_4\omega^2 \\ +k_{34}^2L_3L_4Z_1Z_2\omega^2+k_{12}^2k_{34}^2L_1L_2L_3L_4\omega^2 \end{pmatrix}} \tag{10}$$

The system equation indicated in (10) is expanded in terms of quality factor which appreciates how well the resonator can oscillate. The quality factor is presented in a formula as given below

$$Q_i = \frac{1}{R_i}\sqrt{\frac{L_i}{C_i}} = \frac{\omega_i L_i}{R_i} \Leftrightarrow \omega_i L_i = R_i Q_i, i = 1 \sim 4 \tag{11}$$

Where ωi and Ri are respectively the self-resonant frequency and equivalent resistance of each resonant circuit. In the power coil, for instance, Ri is a sum of RS and R1. Actually, ωi of each coil is defined to be the same. When the resonance takes place, the total impedance of each coil is presented as following

Z1 = RS + R1 ≈ RS, Z2 = R2, Z3 = R3,

Z1 = RL + R4 ≈ RL

For simplicity, it is common to set RS equal to RL. At the resonant frequency, ω0 = 1 / LiCi, from (10), the magnitude of S21 can be written as

$$|S_{21}| = \frac{2k_{12}k_{23}k_{34}Q_2Q_3\sqrt{Q_1Q_4}}{\begin{pmatrix} 1+k_{12}^2Q_1Q_2+k_{23}^2Q_2Q_3 \\ +k_{34}^2Q_3Q_4+k_{12}^2k_{34}^2Q_1Q_2Q_3Q_4 \end{pmatrix}} \tag{12}$$

The coupling coefficient k12 and k34 would be constant. There is only k23 varying with medium conditions. To find the range between the resonators at which |S21| or the efficiency is certainly at maximum, a derivative of S21 with respect to k23 is taken and then setting the result to zero, yielding

$$\frac{d|S_{21}|}{dk_{23}} = 0 \tag{13}$$

$$k_{23}^* = \sqrt{\frac{(1+k_{12}^2Q_1Q_2)(1+k_{34}^2Q_3Q_4)}{Q_2Q_3}} \tag{14}$$

This value of * *k*23 is equivalent to the maximum range that the transmitter is able to effectively transfer power to the receiver at the given resonant frequency (before the resonant frequency breaking in two peaks). Note that * *k*23 ≤ 1. With the purpose of finding out the maximum efficiency of the system in terms of |S21|, it is feasible to substitute k23, which is derived above, into (13)

$$|S_{21}|_{\max} = \frac{k_{12}k_{34}Q_1Q_4R_L}{k_{23}^*\sqrt{L_1\omega_1L_4\omega_4}} = \frac{k_{12}k_{34}Q_1Q_4R_L}{k_{23}^*\sqrt{L_1L_4}\,\omega_0} \tag{15}$$

It is clear that |S21|max un-proportionally depends on * *k*23. It means for the sake of a higher efficiency, the extent that the highest efficiency can be achievable is shortened. In order to get a greater value of |S21|max, * *k*23 is supposed to decrease. From (14), increasing Q2 and Q3 is able to reduce the * *k*23. In general, making the very high-Q transmitting and receiving coils is very crucial so as to achieve high transfer performance.

F. Wheeler's formula

The classic formula for single-layer inductance (air core) is called Wheeler's formula is given as:

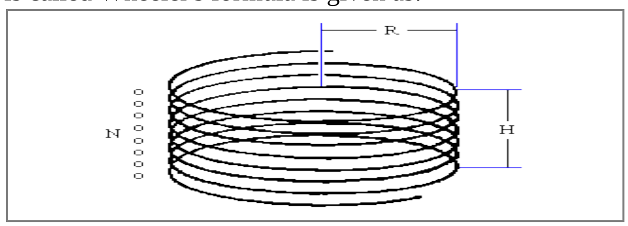

Figure 6 Coil antenna

$$L = \frac{N^2R^2}{2.54(9R+10H)} \tag{16}$$

Where,

L = inductance in micro-Henries

N = number of turns of wire

R = radius of coil in cm

H = height of coil in cm

3. WPT System Design Calculations

A. Block Diagram of Proposed System

The paper will be based on the principle of resonant inductive coupling. Magnetic coupling is an old and well understood method in the field of wireless power transfer. But as magnetic fields decay very quickly, it's effective only at a very short distance. By applying resonance within magnetic coupling, the power transfer at a greater distance can be obtained. For near field wireless power transfer, Magnetic resonant coupling can be more effective than any other methods available. The structure of the whole system is shown below.

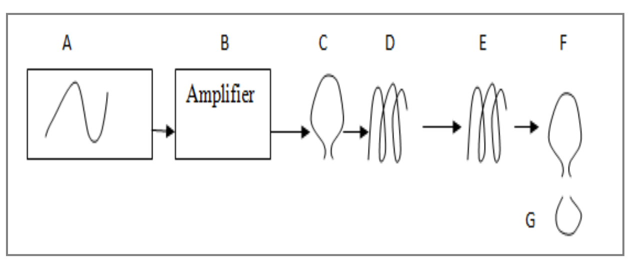

Figure 7: Structure of the WPT System

Here, I assume:

Object A represents high frequency oscillator.

Object B is representative of signal amplifier.

Object C is a source coil.

Object F is a load coil.

Object G is a resistive load.

Object D and E are transmitter and receiver antenna respectively.

By including a signal amplifier in the system, it will be able to amplify the amount of power that is transmitted. This is crucial for conduction tests at high power. From the amplifier the signal is then dumped into object C. This is located at the top of object D. This allows for the resonate frequency to pass from the object C to D. When the transmitting antenna begins to resonate it generates the evanescent resonate waves. Object E will pick up these waves. From the receiving antenna, the signal is then passed to object F. The load coil will then pass the signal on to the load G.

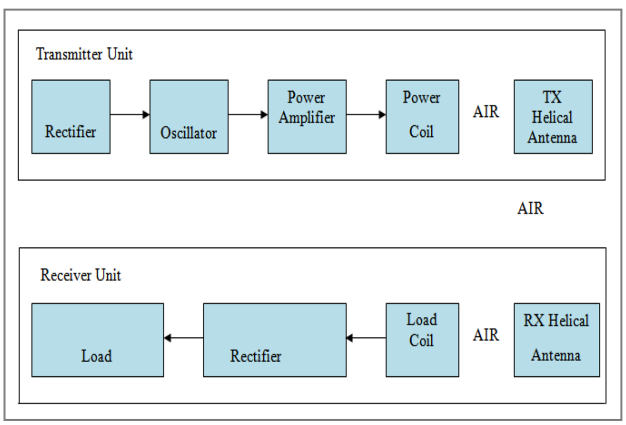

Figure 8: Block Diagram of the whole system

The intermediate coils D and E are placed between object C and F, which is tuned at the same frequency as C and F. The coil D, being in the area of the magnetic field generated by coil C, receives power. Similarly, coil E, being in the area of the magnetic field generated by coil D, receives power. Not having any resistive load, the coil in turn generates its own oscillating magnetic field. The advantage of using these intermediate coils is that these coils are completely separated from the source internal resistance. This increases the Q-factor, allowing greater power to be radiated.

The block diagram of the whole system is shown in figure 8. For the dc source, the simple full wave bridge model is used just for the simplicity of the project. At the same time the capacitor is used for smoothing the output curve. The PSPICE circuit diagram is given below.

The main advantages of a full-wave bridge rectifier is that it has a smaller AC ripple value for a given load and a smaller reservoir or smoothing capacitor than an equivalent half-wave rectifier. The full-wave bridge rectifier is designed on the Cadence, PSPICE Simulator as shown in Figure 9 and the result is shown in Figure 10.

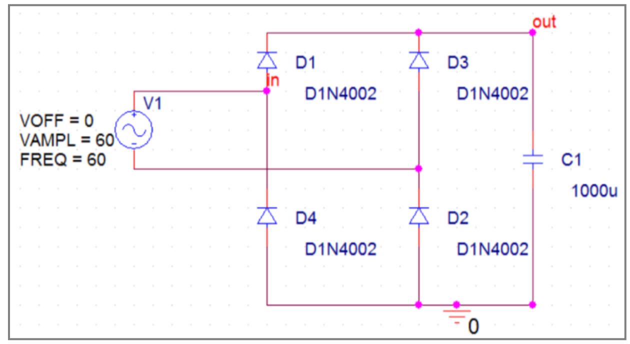

Figure 9: Rectifier

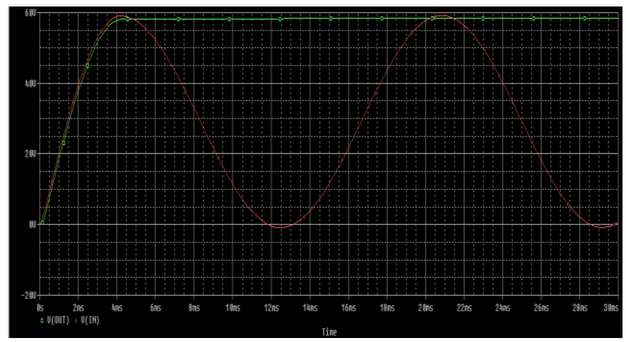

Figure 10: Input and Output curves of Rectifier

The following oscillator circuit is used. This oscillator uses PSPICE VPULSE that generates square wave in combination with H bridge amplifier.

When MOSFET M1 and M4 are turned on we have a positive voltage, when all 4 MOSFETs are off we have 0 voltage, and when MOSFETs M2 and M3 are turned on we get what appears to be a negative voltage because of the direction the current flows. For this reason, an h-bridge amplifier creates a more efficient amplifier because we get both positive and negative voltage from a single power supply. The designed h-bridge amplifier is shown in Figure 11.

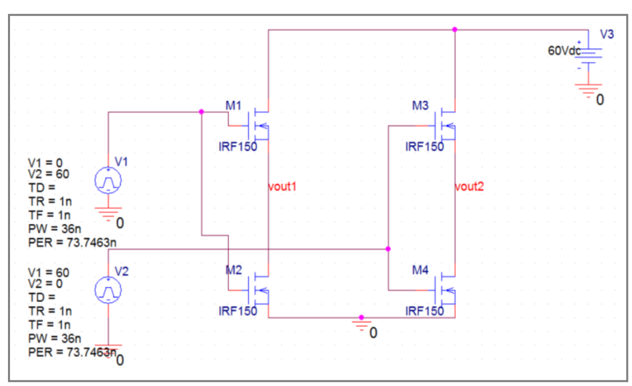

Figure 11: H-Bridge Amplifier

The transient analysis of the designed h-bridge amplifier through PSPICE simulation is done. The oscillator generates 13.56MHz frequency and can be verified with simulation result given below in Figure 12.

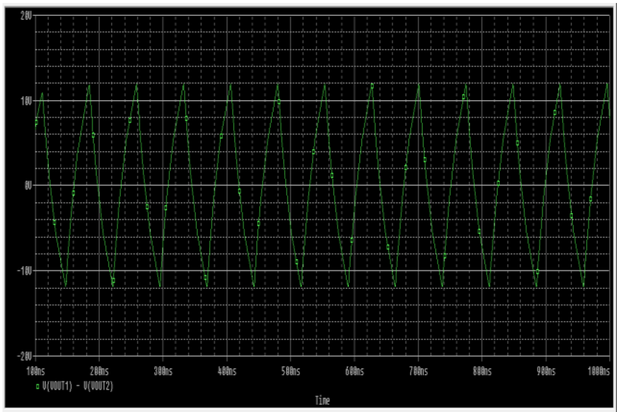

Figure 12: Output of H Bridge Amplifier

For the rectifying purpose at the receiver, the simple full wave bridge model is used.

B. Parameter Identification of Proposed System

We have from (16),

$$L = \frac{N^2R^2}{2.54(9R + 10H)}$$

Where,

L = inductance in micro-Henries

N = number of turns of wire

R = radius of coil in cm

H = height of coil in cm

For Power Coil,

N = 2, R = 5 cm, H = 3.3 cm, Then, L ≈ 0.5 uH

Also we have from (1),

$$f_r = \frac{1}{2\pi\sqrt{LC}} = 13.56 \text{ MHz}$$

C = 275.518 Pf

The design parameters for all the antennas are listed in the table below:

Table 1: Parameters of coil antennas

Coil (antenna)	N (turns)	R (cm)	H (cm)	L (uH)	F (MHz)	C (Pf)
Power	2	5	3.3	0.5	13.56	275.518
Transmitter	3	6	4.4	1.3	13.56	105.968
Receiver	1.67	6	4.4	0.4	13.56	344.398
Load	1	3.7	2	0.1	13.56	1.377nf

From (14) and (15), with the value given in Table I, quality factors, coupling coefficient and the maximum value of magnitude of S21 parameter are calculated as follows

From (1),

$$\omega_0 = \omega_1 = \frac{1}{\sqrt{L_1C_1}} \approx 85.2 \times 10^6 [\text{rad/ s}]$$

From (3), assuming RS=RL=50 Ohm and R1=R2=R3=R4 =0.015 Ohm,

$$Q_1 = \frac{\omega_0 L_1}{R_s + R_1} \approx 1.7$$

$$Q_2 = \frac{\omega_0 L_2}{R_2} = 7384$$

$$Q_3 = \frac{\omega_0 L_3}{R_3} = 2272$$

$$Q_4 = \frac{\omega_0 L_4}{R_L + R_4} \approx 0.17$$

It is assumed that the distance between power coil and transmitter coil antenna is fixed, so the coupling coefficient (k12) is fixed and assumed k12= 0.1. Also it is assumed that the distance between load coil and receiver antenna is fixed, so the coupling coefficient (k34) is also fixed and assumed k34= 0.01.The varying distance is between transmitter coil antenna and receiver coil antenna, so the coupling coefficient (k23) is a varying parameter. When the distance between Tx and Rx increases, the coupling between them decreases.

From (14), the coupling coefficient is calculated as,

$$k_{23}^* = \sqrt{\frac{(1 + k_{12}^2 Q_1 Q_2)(1 + k_{34}^2 Q_3 Q_4)}{Q_2 Q_3}} = 4.29 \times 10^{-3}$$

From (15), the maximum value of magnitude of S21 parameter is calculated as follows

$$|S_{21}|_{max} = \frac{k_{12}k_{34}Q_1Q_4R_L}{k_{23}^*\sqrt{L_1L_4}\,\omega_0} \approx 0.882$$

Power Transfer Efficiency of the WPT system is calculated as,

$$n_{21} = S_{21}^2 \times 100\,\% = 77.79\%$$

4. Design Verification Through Simulation

The equivalent circuit model of whole WPT system is simulated by using an advanced design system (ADS), a popular electric automation tool in RF engineering of Agilent Technologies with the circuit setup illustrated in Figure 13.

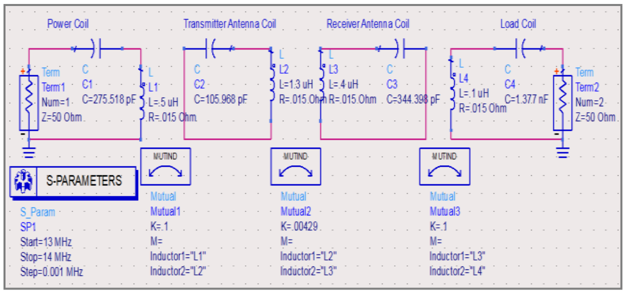

Figure 13: Equivalent circuit of WPT system on ADS

The parameters' values are taken from the Table I. The radius of power coil is 5 cm, the radius of load coil is 3.7 cm, radius of transmitter and receiver coil is 6cm. The power coil has two turns, load coil has one turn, transmitter coil has three turns and receiver coil has 1.67 turns.

The parameter S11 is the power reflection, which is the ratio of the receiving power at the transmitter divided by the transmitting power at the same transmitter and the S21 is the power transfer, which is the ratio of the receiving power at the receiver divided by the transmitting power at the transmitter. The result of the magnitude of S21 and S11 is obtained as shown in Figure 14.

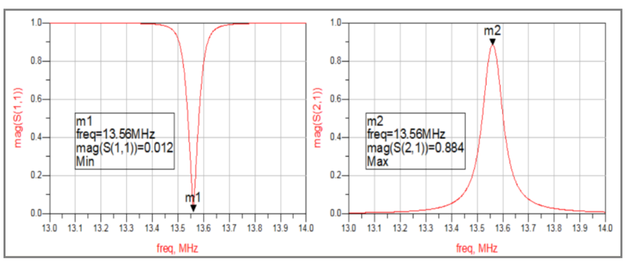

Figure 14: Simulation result showing │S11│ and │S21│

It can be seen from the above plot, the parameter │S21│ has maximum value 0.884 which is very much close to theoretically calculated value 0.882 at operating frequency of 13.56 MHz at a distance that corresponds to the coupling coefficient k23=0.00429.

The smith chart plot of Input Reflection Coefficient (S11) and Output Reflection Coefficient (S22) is shown in Figure 15.

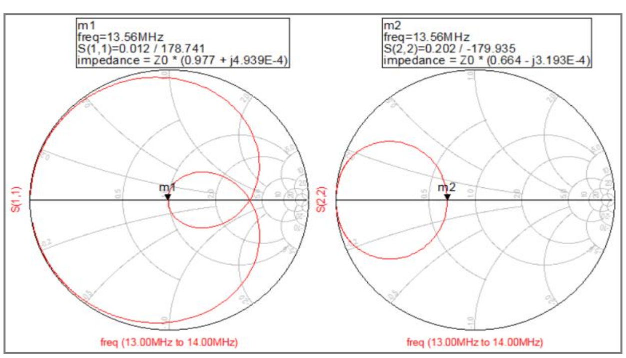

Figure 15: Input and Output Reflection Coefficient

It can be seen from the above plot that the S11 and S22 lie on the real axis at operating frequency 13.56 MHz. The value of input port source impedance is Zo*(0.977 – j 4.939E-4) ohms and the value of output port load impedance is Zo*(0.664 – j 3.193E-4) where Z0 =ZL=50 Ohm.

The equivalent circuit model to calculate the maximum power transfer efficiency ($n_{21} = S_{21}^2 \times 100\,\%$) is shown in Figure 16.

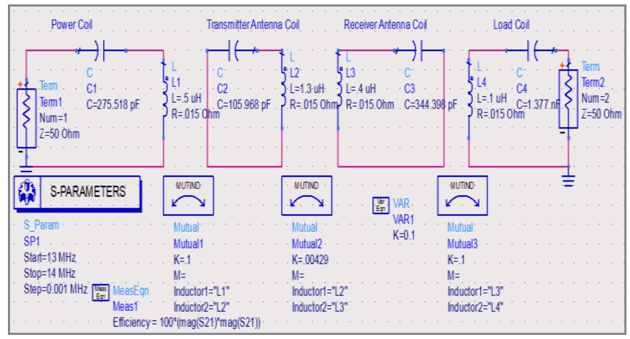

Figure 16: Simulation setup for Power transfer efficiency

The result of power transfer efficiency of the designed WPT system is shown in Figure 17.

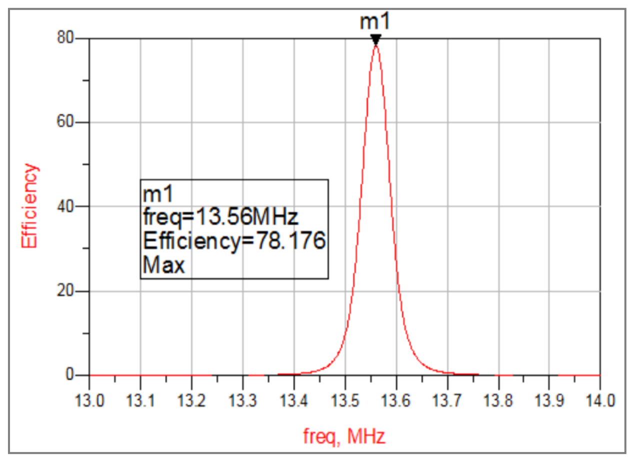

Figure 17: Power transfer efficiency of WPT system

The maximum power transfer efficiency of the WPT system as seen from the above result is equal to 78.176% which is very close to the theoretically calculated maximum power transfer efficiency 77.79%.The above results can be tabulated as shown in Table 2.

Table II: Theoretical and simulated efficiency of WPT system

Parameter	Theoretical	Simulation
Maximum Power Transfer	0.882	0.884
Power transfer efficiency	77.79%	78.18%

The value of magnitude of S21 of designed WPT System for three different coupling coefficients which is a function of distance between transmitter and receiver is shown in Figure 18. The coupling coefficient decreases as the distance increases or vice versa.

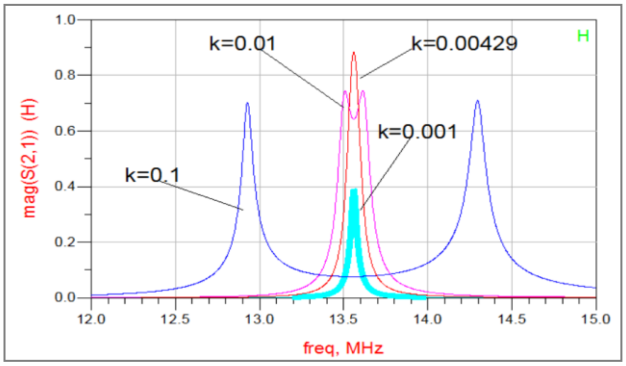

Figure 18: Simulation result showing │S21│ at different k23

5. Comparison with Other WPT Systems

The simulations in this section are based on the similar conditions as in Section IV. The parameters' values used here are taken from Table I.

A. Traditional Two Coil System

The circuit setup of traditional two coil (Power coil as transmitter antenna and load coil as receiver antenna) WPT system on ADS at a distance equivalent to coupling coefficient k=0.5 is shown in Figure 19.

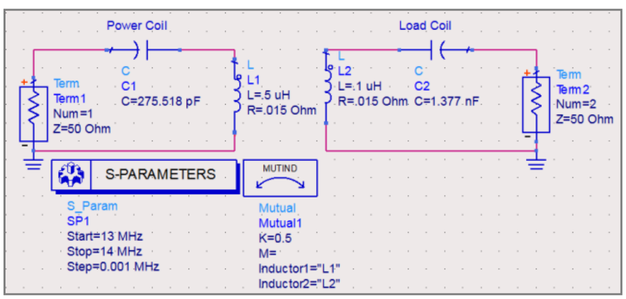

Figure 19: Simulation setup of two coil WPT System

The result of the magnitude of S21 and S11 can be obtained as shown in Figure 20.

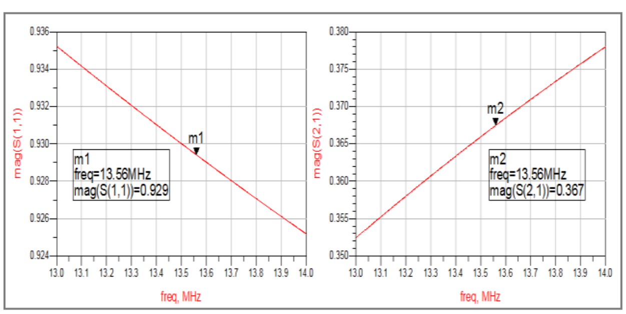

Figure 20: Simulation result showing │S11│ and │S21│

The value of magnitude of S11 and S21 of traditional 2 coil WPT System for coupling coefficient, k=0.5 which is a function of distance between transmitter and receiver is shown in Figure 20. The coupling coefficient decreases as the distance increases or vice versa.

B. Three Coil System

The circuit setup of three coil (Power coil as transmitter antenna and load coil as receiver antenna and intermediate coil as relay antenna at transmitter side) WPT system on ADS at a distance equivalent to coupling coefficient k=0.5 is shown in Figure 21.

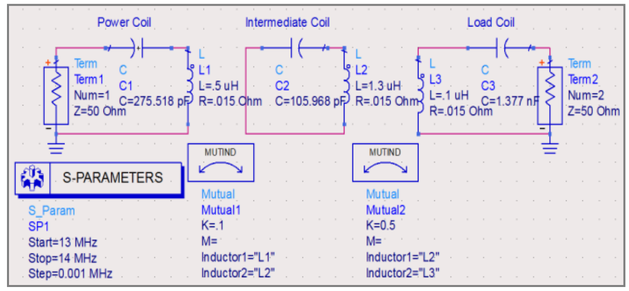

Figure 21: Simulation setup of three coil WPT System

The result of the magnitude of S21 and S11 can be obtained as shown in Figure 22.

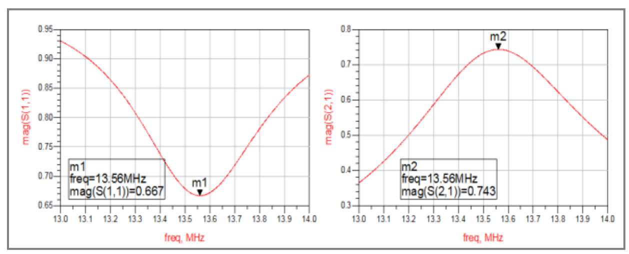

Figure 22: Simulation result showing │S11│ and │S21│

C. Designed Vs Two Coil Vs Three Coil WPT System

The Simulation results of│S11│ and │S21│ of designed WPT System, Traditional two coil system and three coil systems at operating frequency of 13.56 MHz are shown in Figure 23 in a single plot.

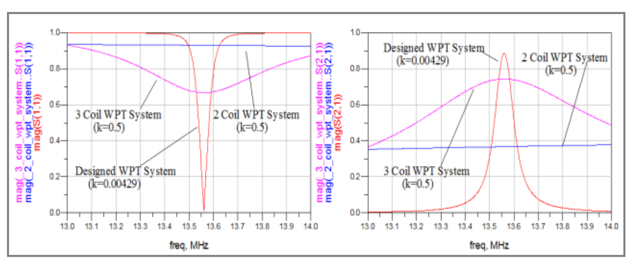

Figure 23: Simulation result showing │S11│ and │S21│ of designed WPT System, Two coil system and three coil system

The above results can be tabulated as shown in Table 3.

Table 3: Efficiency of two coil system, three coil system and designed WPT system

Systems	k	│S11│	│S21│	Efficiency
Two coil system	0.5	0.929	0.367	13.46%
Three coil system	0.5	0.667	0.743	55.20%
Designed system	0.00429	0.012	0.884	78.18%

It is very clear from the above results that the advantage of the four coil system over the two coil and three coil system is a high efficiency at a greater distance (k=0.00429).

6. Conclusion and Future Enhancement

The goal of this paper was to design a wireless power transfer system via magnetic resonant coupling at 13.56MHz. After analyzing the whole system step by step for optimization, a WPT system was designed. The designed WPT system has power transfer efficiency 78.18% at a coupling coefficient 0.00429. Simulation results showed that significant improvements in terms of power-transfer efficiency have been achieved. Simulated results are in good agreement with the theoretical models. It is described that magnetic resonant coupling can be used to deliver power wirelessly from a source coil to a load coil with two intermediate coils placed between the power (source) and load coil and with capacitors at the coil terminals providing a simple means to match resonant frequencies for the coils. This mechanism is a potentially robust means for delivering wireless power to a receiver from a power (source) coil at a fixed distance.

From the Figure 18, it is clear that the magnitude of S21 is highest at operating frequency 13.56 MHz at a distance corresponding to coupling coefficient 0.00429. As the distance between transmitter and receiver increases or decreases, the value of S21 decreases. In fact, the transfer efficiency significantly decreases with distance variations between the transmitter and the receiver. So, the designed WPT System is very efficient at a fixed distance corresponding to k=0.00429 but deteriorates its efficiency at other distance that does not correspond to designed coupling coefficient.

The distance at which the system has coupling coefficient 0.00429 and maximum efficiency of 78.18% can be found by designing the prototype of the system and using Vector Network Analyzer (VNA).

Figure 18 clarifies that when the coupling coefficient k23 decreases, there is the frequency splitting issue which substantially reduces the system efficiency. Moreover, as k23 increases, the resonant frequency also changes from the operating frequency of 13.56 MHz. Therefore, an optimal control mechanism is needed to maintain the optimal resonant condition and to realize the maximum wireless power transfer efficiency as well.

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Planning Approach for Earthquake Resilience in a Traditional Settlement: A Case of Urbanizing VDC, Khokana

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***Abstract*: In today's context of urbanization where cities are growing fast and even faster in the developing world such as in Nepal, this growth will definitely threaten to make the cities unsustainable and more vulnerable to disasters. Earthquake is a major disaster threat in case of Nepal. Particularly, in traditional settlements such as Khokana, the badly managed urbanization process resulting in spatial, social and cultural transformations is the cause for 'increasing vulnerability to earthquake disasters'. In this aspect, the research tries to explore the current dynamics of urbanization and identifies the factors responsible for causing seismic vulnerability of the settlement. Khokana as a traditional settlement has various aspects, which contribute towards mitigating, preparing and recovering from the impact of earthquakes. Therefore, the research makes an attempt to understand these disaster preventive aspects that are firmly rooted in the physical, social and cultural milieu.**

In the context where there is weak local governance, where disasters like earthquake are not given a priority in planning and development and where there is no participation of people for a safety living initiative, the research suggests a planning approach i.e. an approach for creating resilience, focusing on physical, socio-cultural and institutional aspects. So, overall this research helps in integrating Disaster Risk Reduction in Urban development that would contribute in creating 'Earthquake resilient city' and initiates a paradigm for disaster prevention and mitigation.

Keywords: Disaster, Urbanization, Earthquake, Disaster Risk Management, Vulnerability, Resilience

1. INTRODUCTION

"Disaster risk" a critical dimension in city planning. A disaster is a function of the risk process which results from the combination of hazards, conditions of vulnerability and insufficient measures to reduce the potential negative consequences of risk. It won't be wrong to say that disaster risk and badly managed urban growth are somehow related. Environmental degradation, settlement patterns, lack of access to infrastructure and services, encroachment of unsuitable terrain prone to natural hazards are a few that contribute to disaster risk. And this disaster in turn poses a serious challenge to human development.

Earthquakes have been a cause of major destruction and fatalities and as the process of urbanization is speeding up, the consequences of strong earthquake ground shaking are becoming more and more threatening to both life and properties. While earthquake prediction may be of some help, disaster prevention in terms of resilient physical structures, also incorporating socio-cultural and institution dimensions could be the main focus of attention of the civil society.

Why disaster risk reduction in Khokana?

Traditional settlements such as Khokana which are in the process of urbanization are under a major threat. In this process itself the place is losing its identity with increasing number of haphazard modern structures, lack of effective implication of bye laws and design standard resulting in towering effect and many traditional buildings being in a dilapidated condition.

Figure 1: Location map of Khokana with surrounding areas (Source: Google map)

Kathmandu valley's urban cultural heritage of building and urban spaces, water supply system, festivals, and street spaces, conservation practice and its institution of Guthi deserve to be researched specifically to further inform the mitigation measures and ways of incorporating into the modern building, town planning and social institutions. (Tiwari, 2012)

Khokana is a compact medieval Newari settlement situated on the south west part of Patan Sub-metropolitan city almost on the south-west edge of Kathmandu Valley. It is a culturally and historically important settlement which is also denoted from the very fact that it has been proposed as an additional Monument zone to Kathmandu Valley World Heritage Site. Thus the traditional setting of Khokana, which is getting vulnerable because of urbanization, should be preserved. Considering its potential value, the incorporation of disaster risk management in Khokana and making it a disaster resilient city seems contextual and appropriate.

Figure 2: Satellite (Google) image of Khokana, 2013

2. RESEARCH QUESTIONS

Global disaster risk is highly concentrated in poorer countries with weaker governance. Particularly in low and low-middle income countries with rapid economic growth, the exposure of people and assets to natural hazards is growing at a faster rate than risk-reducing capacities are being strengthened, leading to increasing disaster risk.(UNISDR, 2009)

Addressing such context of increasing disaster risk and vulnerabilities the research questions are:

Primary Research Question

How can traditional settlements such as Khokana be made earthquake disaster resilient in light of increasing urbanization and what are the factors that need to be addressed to characterize and measure resilience?

Sub Research Questions

In order to answer the above question, sub questions are:

1. What are the factors that contribute to vulnerabilities (physical and socio-cultural) in the study area against seismic risk?
2. How do the physical and socio-cultural frameworks influence disaster prevention and preparedness for coping with earthquake disasters?
3. How to mainstream Disaster Risk Reduction in urban planning work?

3. RESEARCH DESIGN

Methodology

The research is carried out using "Case Study Method" as a research strategy. Researcher Robert K. Yin defines the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used. (Yin, 1984)

For my research, Case study method seems appropriate as it not only involves understanding the local context but also helps in contextual analysis of events or conditions and their relationships. Further in this research, integration of qualitative and quantitative approaches are undertaken to have a clear understanding of the condition of the study area. Primary data was collected by conducting household surveys which included field visits for analyzing the existing situation of the area (visual assessment), questionnaire survey, sampling and interviews with locals as well as key informants. Interviews were also taken with the officials of concerned authorities to uncover their views on disasters, mitigation, preparedness, and multisectoral collaboration and participation. A simple random sampling method was used for this research. The sample size was determined by using Yamane's formula based on the total number of households as follows:

$$n= N/ (1+ NE^2),$$

Where n= sample size, N=Population size, E= margin of error (7%)

Total no. of households in Khokana=1056

Therefore, Sample size =170 households

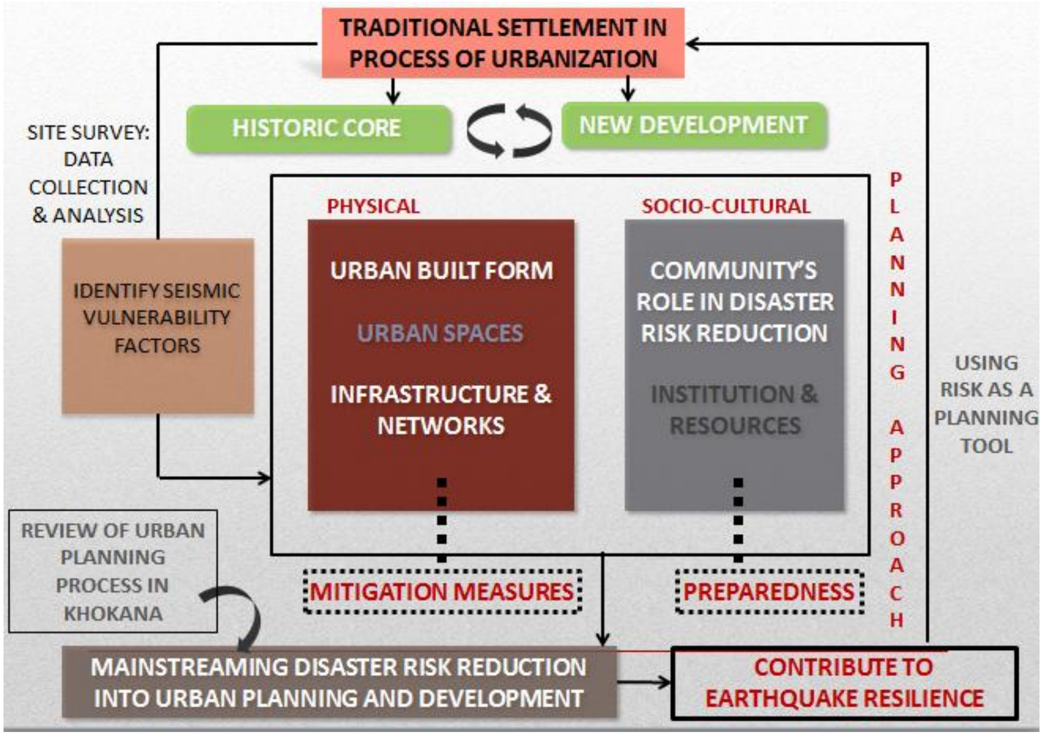

Figure 3: Conceptual Framework

4. Consequences of Urbanization - An Increasing Dynamics of Vulnerability

Vulnerability is determined by a combination of several factors, including awareness of hazards, the condition of human settlements and infrastructure, existing policies and organized abilities in all fields of disaster and risk management. Particularly in Khokana there are many transformations seen due to unplanned urbanization. At the physical level, many factors that are responsible for causing physical vulnerability are identified such as vertical subdivision of houses, incompatible addition of floors, replacement of traditional houses by modern constructions in the core, modern constructions of low quality in fringes, encroachment of open spaces, conversion of agricultural land to building parcels, dense settlement and dilapidated houses in the core and the presence of vulnerable emergency or critical facilities.

Similarly in Khokana, loss of traditional oil mill heritage, lack of financial resources, lack of earthquake preparedness, influence of modern culture, decline in economic potential, decline in mutual support systems such as Guthis and negligence of cultural properties lead to weak socio-cultural fabric that in turn causes the Socio-cultural vulnerability. Further there is lack of power given to local bodies and lack of technical and financial resources which all lead to weak local governance causing Institutional vulnerability.

5. Physical and Socio-Cultural Frameworks – Role in Disaster Prevention and Mitigation

Khokana as a traditional settlement has different potentials which are important from the view of mitigating, preparing and recovering from the impact of earthquakes. Physical frameworks such as the traditional built forms and spatial structure have knowledge embodied in the construction systems, use of materials, building design and organization, regarding disaster prevention and mitigation. The public and semipublic open spaces which form important part of traditional morphology are crucial for emergency escape in the event of an earthquake and can act as public-escape places in the historic fabric. Moreover ritual paths have defined village boundaries which have helped in preserving agricultural land, thereby protecting land as a sustainable livelihood resource.

At the socio-cultural level, there are the mutual support systems, traditionally defined through systems of guthis, which are binding the community together. Apart from guthis there are the newly emerging contemporary organizations which can promote community solidarity. These mutual support mechanisms may enable local community to cope with earthquakes and recover through collective initiatives. And there are the cultural resources which have immense potential and can be utilized in case of emergencies.

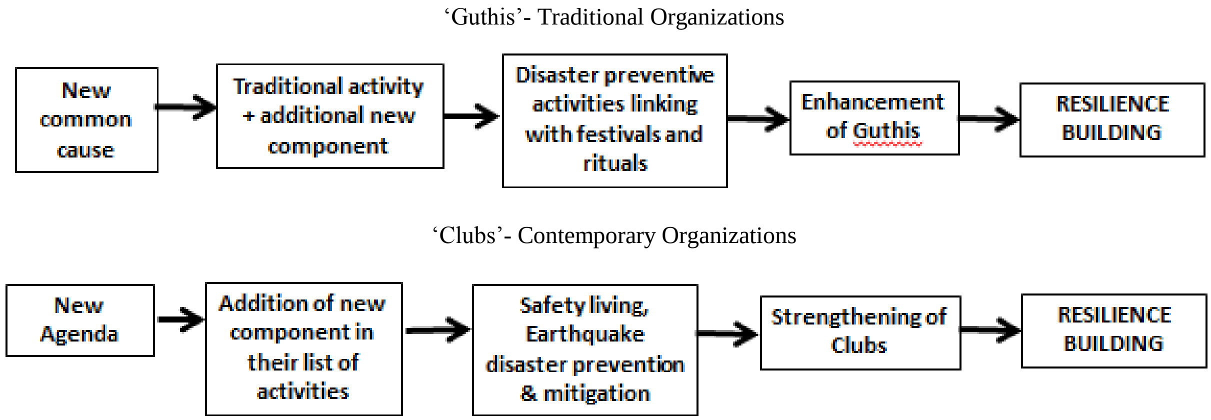

Figure 4: Guthis Vs Clubs

So, be it the physical frameworks or the socio-cultural frameworks, all have potential for increasing the resilience of the settlement. But it is sad to witness that with increasing urbanization; these potentials are often overlooked and not given a priority as such.

6. Mainstreaming Disaster Risk Reduction in Urban Planning Work

From the research it is realized that "Mainstreaming disaster risk reduction in urban planning and development" is very important and this is what forms the core of the study. Indeed with increasing disaster risks, particularly in cities, there is no doubt that the key to sustained risk reduction lies in 'mainstreaming' the reduction of risks into development. Mainstreaming risk in development is a crosscutting issue that needs to be owned by all government agencies and other organizations as well. The national government plays an important role in providing an enabling environment for mainstreaming disaster risk by various ways such as strengthening the legal and regulatory instruments, determining broad disaster risk management policies and strategies, advocating for the inclusion of DR concerns in broader development policies, defining responsibilities at different levels of government towards a coordinated, multi-sector, multi-tiered risk management process, providing resources to support DRM mainstreaming, including funds and training opportunities, incorporating in design and implementation of projects and monitoring and evaluating progress towards Disaster reduction.

Therefore, the consequences of mainstreaming is that it results in disaster risk reduction being embedded in the day to day operations of national and local organizations, in various sectors, with sufficient resources such as human, financial, technical and material being allocated for managing the risks.

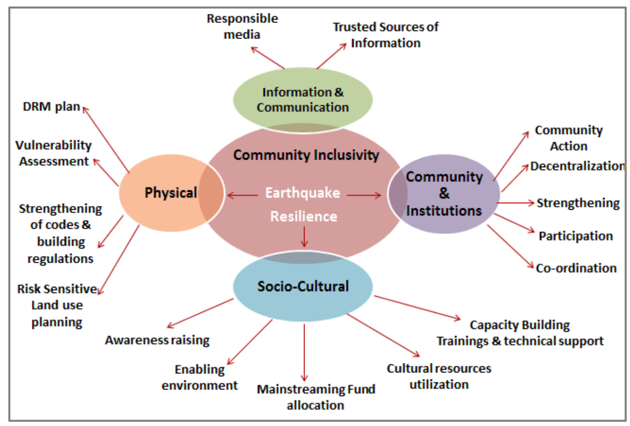

Figure 5: Important Elements for Mainstreaming DRR into Development planning

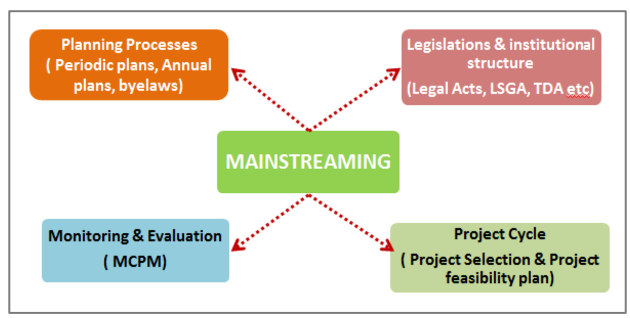

Figure 6: Mainstreaming DRR into Development planning

7. Final Reflections

In conclusion, traditional settlements in process of urbanization such as Khokana can be made earthquake disaster resilient by 'Mainstreaming & integrating Disaster Risk Reduction in Urban planning and development' that would contribute in resilience building. The more effective integration of disaster risk considerations into development policies, planning and programming at all levels, the more empowered are the community and the local government and the more resilient becomes the settlement.

For this, various factors that characterize resilience such as physical, socio-cultural and institutional components need to be strengthened and incorporated in development planning. It is important to improve built environment, improve existing and new dwellings, urban spaces, and cultural properties and raise awareness and preparedness level of community and institutions, incorporating co-ordination between different stakeholders, all working to create a more resilient environment, an environment which can minimize the effects of disasters and has the ability to recover speedily by reinstating physical, socio-economic and cultural vitality of the community.

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Mitigation of Inter Cell Interference in Multi Cell Orthogonal Frequency Division Multiple Access Systems

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Abstract*: Orthogonal Frequency Division Multiple Access (OFDMA) is the multi-user version of Orthogonal Frequency Division Multiplexing (OFDM). Due to the orthogonality of the sub-carriers, the interference between the sub-carriers is eliminated. However in multi-cell OFDMA system, if same sub-carriers are assigned to different users in neighboring cells, then inter-cell interference (ICI) occurs. ICI is more prominent for the users at cell boundaries due to which the cell edge users experience lower data rates compared to the users close to the base stations. In this paper, a dynamic radio resource allocation algorithm has been proposed for mitigation of ICI. This algorithm assigns sub channels to the users and their transmission power based on the user location and sub channel assignment information from neighboring cells. The performance of Reuse 1, Reuse 3, Partial Frequency Reuse (PFR), Soft Frequency Reuse (SFR) and the dynamic resource allocation algorithm have been analyzed on the basis of change in SINR values and channel capacity with increase in distance of User Equipment (UE) from the center of cell. The dynamic resource allocation algorithm provides satisfactory levels of Signal to Interference and Noise Ratio (SINR) values throughout the cell region and also maintains higher system capacity for users as compared to other resource allocation techniques.

***Keywords:* OFDMA, ICI, ICI mitigation, ICI coordination, resource allocation.**

1. Introduction

In Orthogonal Frequency Division Multiple Access (OFDMA) systems, the orthogonal sub-carriers are grouped over some time into blocks called resource blocks or physical resource blocks (PRBs). The PRBs are allocated to individual users based on their bandwidth requirements [1]. OFDMA technique provides high spectral efficiency due to the overlapping of the sub-carriers. OFDMA signals are also robust to frequency selective fading as they provide frequency diversity to the users [2]. The intra cell interference within a cell in an OFDMA system is negligibly small as the adjacent sub-carriers are orthogonal to each other. However in multi cellular OFDMA wireless systems, the inter cell interference (ICI) from neighbouring cells is a major problem.

In a multi-cell OFDMA system, ICI occurs if the same sub-carriers are assigned to different users in the neighbouring cells. The signal transmission in one cell may interfere with the signal transmission in same sub-carrier frequency in the neighbouring cells. ICI is particularly detrimental to cell edge users (CEUs) and causes serious degradation of the users' throughput. In order to mitigate ICI, various resource allocation and management schemes as well as inter cell interference coordination (ICIC) techniques have been designed [3].

Hard Frequency Reuse (HFR) is the basic method for resource block allocation over multi-cell network. It allocates different sub-bands to neighbouring cells in order to avoid ICI [4]. The total available wideband spectrum is divided into different groups, each consisting of a disjoint subset of total available sub-channels. Each of these disjoint groups is assigned to different neighbouring cells. Since the neighbouring cells are using sub-channels with different frequency bands, it is impossible for transmission in one cell to interfere with the transmission in a neighbouring cell. However, with HFR, the capacity of the system is highly degraded as the total available wideband spectrum is divided into groups and only a portion of the total spectrum is assigned to each cell.

The performance of the OFDMA system was improved with Fractional Frequency Reuse (FFR) scheme in comparison to HFR scheme. In FFR, the bandwidth allocation over the cells depends on the proximity of the mobile station to the base station [5]. The bandwidth allocation for cell centre users (CCUs) and CEUs are treated separately in FFR scheme.

Partial Frequency Reuse (PFR) and Soft Frequency Reuse (SFR) are the two major types of FFR. PFR allocates a sub-band of total available bandwidths to CCUs in all cells and a sub-band for CEUs, different from sub-bands used in adjacent cells [6]. Basically, the overall system bandwidth is divided into two groups; one for CCUs and remaining for CEUs. The bandwidth allocated for CEUs is further divided into sub-bands as in HFR scheme and each sub-band is allocated to different neighbouring cells.

SFR utilizes the entire available wideband spectrum with low power transmission so as not to interfere with the neighbouring cells. Only a portion of the available bandwidth is transmitted with high power for coverage towards the edge of the cells. The portion of the bandwidth which is transmitted in high power is different in different neighbouring cells so as to avoid interferences among the neighbouring cells. Thus in SFR, the CCUs can use all the bandwidth with low power transmission whereas CEUs are given a part of bandwidth with high power transmission [7]. The above static mitigation schemes are considered as conventional schemes for ICI mitigation.

A different class of ICI mitigation schemes is the dynamic interference coordination scheme. Dynamic interference coordination mechanisms achieve ICI mitigation by applying channel reuse avoidance techniques. A semi-distributed resource allocation algorithm for interference mitigation in downlink of a multi-cell OFDMA system is presented in [8]. This algorithm is based on predetermined knowledge of all users' Signal to Interference and Noise Ratio (SINR). In [9], the authors investigated a dynamic interference avoidance scheme that used inter cell coordination through X2 interface facilitated by LTE systems. In [10], an adaptive algorithm for ICI mitigation is proposed that decomposed a multi-cell problem into a distributed optimization problem. The proposed algorithm assigned a minimum number of sub-channels to cell-edge users arbitrarily and guaranteed a minimum service rate for them. In [11], the authors discussed the FFR scheme in large networks with irregular patterns. They concluded that two sub-bands always give better cell-edge performance. Finally, dynamic ICI schemes using interference graph approach are investigated in [12].

The remainder of the paper is outlined as follows. Section II describes the system model for analysis of resource allocation techniques. In Section III, the basic resource allocation techniques are described. The proposed dynamic resource allocation algorithm is described in Section IV. The simulation results are presented in Section V. Finally, the conclusions are given in Section VI.

2. SYSTEM MODELING

A. System Model Description

We consider a three-cell OFDMA based wireless communication system model as shown in Figure 1. The system model consists of three adjacent hexagonal cells in a two-dimensional coordinate system, each with equal radius R. Although ICI is prominent in both uplink (UE to eNB) as well as downlink (eNB to UE) transmissions, this paper considers the study of the downlink transmission only. The study is performed in cell A while Cell B and cell C are interfering cells. Each cell in the considered system consists of an Evolved Node B (eNB) at the centre of the cell and each eNB consists of a single omni-directional transmit and receive (TRx) antenna covering the entire cell region. The signal transmitted from eNB of cell A is the desired signal for the receiver UE located in cell A whereas the signal transmitted in same frequency channels from eNBs of cell B and cell C are interference signals for the receiver UE.

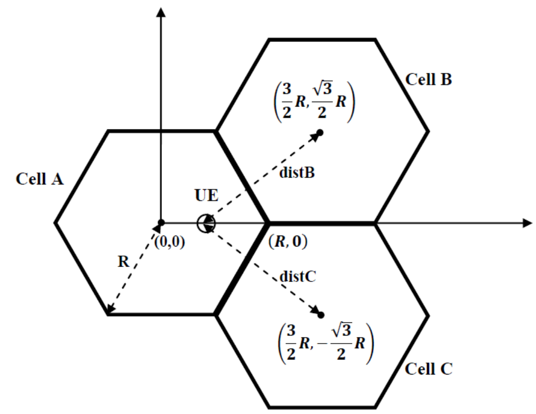

Figure 1: Three cell OFDMA system model

Cell A is centred at the origin of the coordinate system. Then, according to the hexagonal geometry, cell B and cell C would be centred at coordinates $\left(\frac{3}{2}R, \frac{\sqrt{3}}{2}R\right)$ and $\left(\frac{3}{2}R, -\frac{\sqrt{3}}{2}R\right)$ respectively. The User Equipments (UEs) are randomly distributed over the cells. For simplicity and uniformity, the receiver UE position in cell A is varied in equal steps along the x-axis from $(0,0)$ to $(R, 0)$ i.e. from the cell centre to the cell boundary. The distance of the UE from centres of cell A, cell B and cell C are obtained using the corresponding coordinates. The UEs are classified as CCUs and CEUs according to their distances from the centre of the cell.

B. Related Formulations

Signal to Interference and Noise Ratio (SINR) is a key parameter that can describe the performance of a resource block allocation technique. As a general rule, the received signal power level at a UE decreases as it moves away from the centre of the serving cell. Thus, the SINR level of received signal decreases as the distance from the cell centre increases. Furthermore, as a UE moves towards the cell edge from the centre of the cell, the strength of the interference signals from the adjacent cells rises. Since, ICI levels are stronger at the edge of the cell, the SINR values of the actual transmitted signal is further reduced as the distance from the cell centre increases.

The SINR at any point in a cell can be calculated by taking the ratio of actual signal strength and the strength of interferences from neighbouring cells and noise (thermal noise) at that point.

The SINR in the l^{th} cell of a wireless communication system is given by [13],

$$SINR = \frac{G_l P_l}{\sum_{i,i \neq l} G_i P_i + \sigma^2} \qquad (1)$$

where, P_l is the transmission power of the signal from l^{th} cell, which is the actual signal power and P_i is the transmission power of the signal transmitted from the i^{th} interfering cell. G_i is the transmission gain between the i^{th} cell and the UE location. The transmission gain is mainly depends on the parameters such as propagation path loss, shadow fading, fast fading, etc. during the propagation from respective eNB to the UE location. σ^2 is the additive white noise power given by,

$$\sigma^2 = N_o B \tag{2}$$

where, N_o is the noise power spectral density and B is the bandwidth of signal transmission.

The SINR values at different locations in cell A for the model described in Section II.A can be calculated by modifying equation (1) as,

$$SINR = \frac{G_A P_A}{G_B P_B + G_C P_C + \sigma^2} \tag{3}$$

where, P_A, P_B and P_C are the signal transmission power from cell A, cell B and cell C respectively. G_A, G_B and G_C are the transmission gains between cell A and UE location, cell B and UE location and cell C and UE location respectively.

To model the propagation path loss, an empirical formula for LTE simulations suggested in [14] is used, which is given as,

$$L_P = 128.1 + 37.6\ log_{10}(d) \tag{4}$$

where, L_P is the path loss from transmitter to receiver in dB and d is the distance between transmitter and the receiver in Km. Equation (4) is the distance dependent path loss equation defined for LTE system simulations with operating frequency of 2 GHz. The path losses for signal transmitted by cell A, cell B and cell C for the given model are obtained by calculating the distance between the respective eNB and the UE location as indicated in Figure 1 and then using equation (4).

Finally, the transmission gains G_A, G_B and G_C required for equation (3) is obtained from the calculated path loses, using the formula given as,

$$G_P = 10^{-\frac{L_P}{10}} \tag{5}$$

If all cells in the system have constant and equal signal transmission power level i.e. $P_A = P_B = P_C = P$, then equation (3) is reduced to,

$$SINR = \frac{G_A P}{G_B P + G_C P + \sigma^2} \tag{6}$$

Furthermore, for UE locations with high ICI levels, the thermal noise can be neglected and the calculation of SINR value can be simplified as,

$$SINR = \frac{G_A}{G_B + G_C} \tag{7}$$

The effect of varying SINR can be used to estimate the maximum capacity of the channel. This can be done by using the Shannon's channel capacity theorem, which gives [13],

$$C = B\ log_2(1 + SINR) \tag{8}$$

where, C is the maximum capacity of the channel in bits/sec for the given SINR value. B is the total bandwidth of the channel in Hz.

Similarly, the maximum achievable bandwidth efficiency (γ) in bits/sec/Hz can be obtained using the following equation,

$$\gamma = \frac{C}{B} = log_2(1 + SINR) \tag{9}$$

Using equations (8) and (9), the effect of change in SINR values in channel capacity or channel bandwidth efficiency can be obtained. Also, the relation between channel capacity and channel bandwidth efficiency with distance from the cell centre can be achieved using the relations between the distance of UE from the cell centre and SINR values.

3. Basic Resource Allocation Methods

The inter cell interference in OFDMA systems causes degradation in Quality of Service (QoS) especially for the CEUs near the boundary between the adjacent cells. Due to ICI from neighbouring cells, the CEUs experience lower SINR values as compared to that of the CCUs in the same cell. The decrease in SINR values due to higher interference results in poorer throughput rates. In order to maintain comparable QoS between both CEUs and CCUs, either the inter cell interference must be avoided or its effect must be minimized.

Several approaches are available in order to mitigate ICI and to increase service quality (increase data rates) to CEUs [3]. One of the major ICI mitigation scheme is ICI coordination (ICIC) technique. It is one of the Radio Resource Management (RRM) functions. Its task is to manage the allocation of physical resource blocks (frequency and time) in a coordinated way between the adjacent cells such that ICI is kept under control. ICI coordination techniques manage the allocation of frequency of sub-bands and time of allocation to different users in each cell by considering the sub-bands allocated in the neighbouring cells. Applications of ICIC techniques in multi-cell system minimize the probability of interfering with the transmission in nearby cells and the probability of getting interfered from the neighbouring cells.

A very basic resource block allocation method is to reuse the overall available wideband spectrum in each of the cells in the system. This method provides the highest spectral efficiency among all other resource allocation schemes. However, this method is severely affected by inter cell interference. Since every sub-channel is utilized in all adjacent cells, the signal transmission in one cell interferes with the ongoing transmission in all neighbouring cells. Thus this resource allocation scheme can't prevent ICI.

A simple method for resource block allocation over the cells with ICI mitigation capabilities is the Hard Frequency Reuse (HFR) method. In this method, the total bandwidth is divided into a disjoint sub-bands and each sub-band is assigned to different cells with dissimilar sub-bands in the adjacent cells. Since the adjacent cells use different frequency bands, the chances of interference from adjacent cells are completely removed. However, the interference may still occur from co-channel cells located in second and higher tier of cells. Also due to the allocation of only a portion of total available spectrum to each cell, the capacity of the system decreases drastically.

Another method of resource management that includes ICI mitigation capabilities is the Fractional Frequency Reuse (FFR). In FFR, the bandwidth distribution over the cells depends on the proximity of the mobile users to the base station. It means, the users in a particular cell are first classified as CCUs and Cell Edge Users CEUs. Then, CCUs and CEUs are allocated different frequency bands or same frequency bands with different power levels, such that the effect of interference from or to other neighbouring cells is minimized. Partial Frequency Reuse (PFR) and Soft Frequency Reuse (SFR) are the two major types of FFR.

Partial Frequency Reuse scheme divides the overall system bandwidth into two groups; one for CCUs and remaining for CEUs. The bandwidth separated for CEUs is further divided into sub-bands and each of the sub-bands is allocated to different neighbouring cells as in HFR scheme discussed above. The adjacent cells are allocated different sub-bands for CEUs in order to avoid the interferences from one cell to another [3].

Soft Frequency Reuse scheme allows the transmission of overall available wideband spectrum with low power so as not to interfere with the neighbouring cells i.e. only for CCUs. Only a portion of the available bandwidth is transmitted with high power for coverage towards the edge of the cells i.e. for CEUs. The portion of the bandwidth which is transmitted in high power is different in different neighbouring cells so as to avoid interferences among the neighbouring cells [3].

Some of the basic resource blocks allocation techniques are described below.

A. Reuse 1 Technique

Reuse 1 technique or Frequency Reuse of One technique is the most basic form of resource block allocation. In this method, the overall sub-channels available in the wideband system spectrum are assigned to each of the cells in the network. Figure 2 shows the illustration of Frequency Reuse 1 technique in a 3-cell network. Here, each of the cells A, B and C utilize the overall available system bandwidth.

The major advantage of using Reuse 1 technique of resource block allocation is that each cell is allocated the maximum possible number of channels. This results in high spectral efficiency of the entire system which is one of the requirements of broadband networking systems. However, Reuse 1 technique assigns all frequency channels to each of the cells. This means that each of the sub-channels in a particular cell has its co-channels in all of its adjacent cells as shown in Figure 2. The result is that when particular sub-channel(s) are being used in the adjacent cells, the transmission in one cell will create interference in another cell and vice-versa. Due to the nearness of the co-channel cells, the level of interference is high from all neighbouring cells, which cause SINR levels to drop to a low value resulting in degradation of service quality.

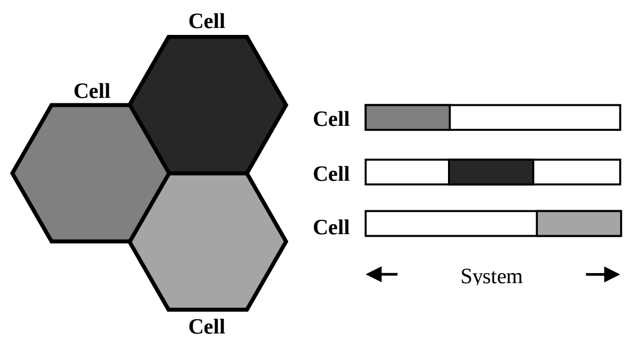

Figure 2 Illustration of Reuse 1 technique

Hence, although Reuse 1 technique provides high spectral efficiency, this method faces severe ICI problems. Thus, the use of Reuse 1 method is undesirable.

B. Reuse 3 Technique

Reuse 3 Technique or Frequency Reuse of Three Technique is another simple resource block allocation technique which uses HFR concept for spectrum allocation.

In this method, the total bandwidth available to the system is divided into three disjoint sub-bands of equal bandwidth each. The three sub-bands are allocated to three adjacent cells in such a way that each cell is surrounded by other cells which are assigned different sub-bands. Figure 3 illustrates Frequency Reuse 3 technique in a 3-cell network. Here, three adjacent cells, cell A, cell B and cell C, are allocated different sub-bands from the total available system bandwidth.

Reuse 3 technique eradicates the ICI problem in Reuse 1 technique by increasing the distance between the co-channel cells to at least two cells. The adjacent cells of a particular cell uses different group of channels as shown in Figure 3. Thus, a cell does not experience any interference from its adjacent cells. The only interference is from the co-channel cells which are at greater distances as compared to Reuse 1 technique.

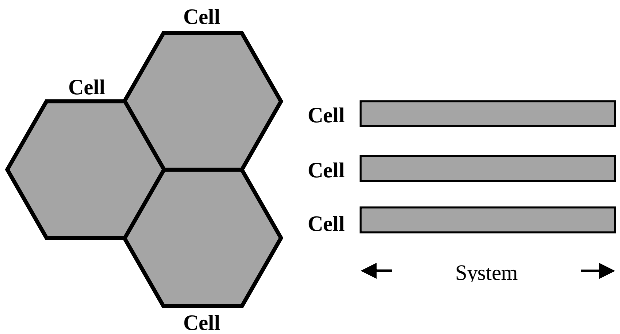

Figure 3 Illustration of Reuse 3 technique

The SINR levels are significantly improved in this technique. However, since each cell is allocated only one-third of the total system bandwidth, the capacity of individual cells and that of the entire system is highly degraded. Thus, although Reuse 3 technique is highly successful in minimizing the ICI from neighbouring cells, it is unable to maintain the high system capacity of Reuse 1 technique. Hence, the use of Reuse 3 method for resource block allocation and ICI mitigation is also undesirable.

C. Partial Frequency Reuse Technique

Partial Frequency Reuse (PFR) technique is a type of FFR scheme as described above. In FFR, the CCUs and CEUs are allocated different frequency bands or same frequency bands with different power levels, such that the effect of interference from or to other neighbouring cells is minimized.

PFR scheme divides the overall system bandwidth into two groups; one for CCUs towards the centre of the cell and remaining for CEUs towards the outer region of the cell. The bandwidth separated for CEUs is further divided into sub-bands and each of the sub-bands is allocated to different neighbouring cells in order to avoid the interferences from one cell to another.

PFR utilizes the advantages of both Reuse 1 and Reuse 3 techniques of resource allocation. A particular group of frequency channels allocated to the CCUs are reuse at reuse ratio of 1 i.e. all cells use the same frequency channels for CCUs. However, for CEUs, the remaining frequency channels are divided into sub-groups as in Reuse 3 technique. These sub-groups of frequency channels are allocated to adjacent cells in such a way that the chances of interference from one cell to a neighbouring cell is minimized, which is the same concept of Reuse 3 (or Reuse-n) technique.

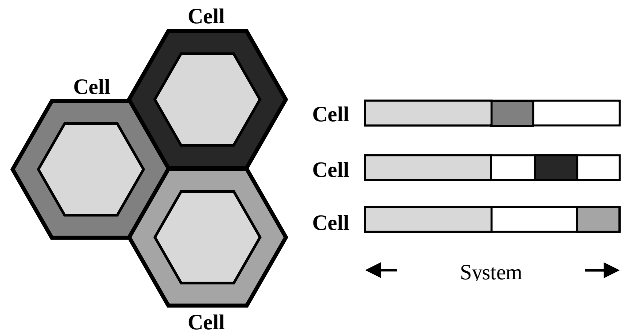

Figure 4: Illustration of PFR technique

Figure 4 shows an illustration of PFR resource allocation technique in a 3-cell system. The inner parts of each of the three cells are allocated the same group of frequencies. The remaining spectrum is divided into three groups with equal bandwidths. Each of the sub-bands is allocated to different adjacent cells as shown in Figure 4 with different shades of grey. This method reduces the interference level at the edges of each cell, which results in increased quality of service in the region.

D. Soft Frequency Reuse Technique

Soft Frequency Reuse (SFR) is another type of FFR scheme for resource block allocation. In SFR, the CCUs can utilize the entire system bandwidth as in Reuse 1 scheme and CEUs are allocated a portion of system bandwidth, which is different from the bandwidths allocated by adjacent cells for their edge users. This is achieved by first dividing the available spectrum to two groups; one for CCUs and remaining for CEUs. The bandwidth which is especially dedicated for CCUs is transmitted with low power such that the coverage area is limited to the inner region of the cell. The portion of the bandwidth allocated for the CEUs is transmitted with high power such that the coverage area includes the outer region of the cell as well. The portion of the bandwidth which is transmitted at high power is made different for adjacent cells in order to wipe out the problems of ICI.

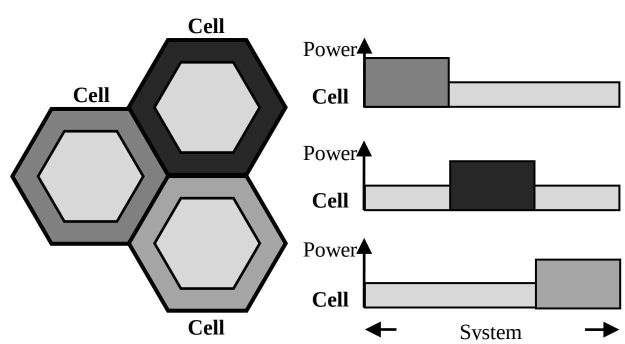

Figure 5 Illustration of SFR technique

Figure 5 illustrates the SFR technique for 3-cell system. It shows that the inner regions of each cell can utilize the frequency channels of the entire system bandwidth. The three cells in Figure 5 have allocated one-third of the total available bandwidth for CEUs, which will be transmitted at high power level. But each of the cells has allocated different portions of the bandwidth to avoid interferences.

Although CCUs have access to both bands (one dedicated to CCUs and another dedicated to CEUs), the bandwidths allocated for CEUs are firstly prioritized for CEUs. CCUs can use those bandwidths for higher data rates only if they are unassigned. The CEUs, however, can only use the portion of the bandwidth especially allocated for them.

4. PROPOSED DYNAMIC RADIO RESOURCE ALLOCATION ALGORITHM

The basic resource allocation methods described in Section III are static algorithms. In these algorithms, the resource allocation is performed by network designers which remain unchanged till further changes are made manually. Thus, these algorithms are unaffected by the changes in the traffic and interference patterns. Due to the inability of these static algorithms to cope with the changing traffic and interference patterns, these methods are not efficient.

In this section, a dynamic resource allocation algorithm is proposed that performs adaptive resource allocation as per the interference pattern in the adjacent cells. This algorithm requires each eNB to be provided with the information of resource allocation and power allocation in the neighbouring cells. The coordination between the adjacent cells for information interchange can be performed through the X2 interface between the adjacent eNBs. The algorithm provides the sub-carrier and the transmission power for the sub-carrier to particular users in the cell region in such a way that the interference from the adjacent cells for the particular sub-carrier is minimized.

The proposed algorithm assigns each user in a cell with a sub channel which experiences the lowest interference from the adjacent cells. During this process, preference is given to the cell edge users as CEUs are more prone to ICI than CCUs. The algorithm also features collision avoidance technique which assures that the sub channels which are already in use in the cell are not reallocated to other users in the same cell.

The steps involved in the proposed scheme are described below:

2. **Initialization**
    a. List all sub channels available in a cell and provide an identifier to each sub channel.
    b. Collect sub channel assignment and power allocation information from adjacent cells.
    c. Predict individual cell user location in the cell and calculate its distance from cell centre.
    d. Reset any sub channel assignments
    e. Clear all sub channel assignment flags to null.
3. **Exhaustive Search**
    a. For each cell, start with the user at farthest distance from the cell centre.
    b. Consider a sub channel from the list of all available sub channels. If the sub channel is already allocated i.e. if the corresponding channel assignment flag is marked, skip to step 2.c.

       Else,

        i. Calculate interference power to the particular sub channel from the adjacent channels based on neighbouring sub channel assignment and power allocation information.
        ii. Sum the interference levels from each of the adjacent cells to compute the total interference level.
        iii. If the considered sub channel is the first sub channel, select this sub channel as candidate sub channel for assignment and skip to step 2.b.v.
        iv. Compare the calculated total interference level with the stored minimum interference level. If the calculated value is greater than the stored value, skip to step 2.c.
        v. Else, the particular sub channel is the new candidate for assignment. Continue to step 2.b.v.
        vi. Store the sub-channel identifier and sum of total interference level as candidate sub channel identifier and minimum interference level.
    c. Update the new sub channel from the list of available sub channels and repeat step 2.b. until all sub channels are analysed.
    d. Finally, assign the sub channel to the user corresponding to the final candidate sub channel identifier.
    e. Repeat steps 2.b. to 2.d. for the next farthest user in the cell until each of the users in the cell has been assigned unique sub channels.
4. **Power Allocation:**

Assign transmission power levels to each sub channel according to the distance of the corresponding user from the cell centre.

$$P_{ch} = P_{max} \times \frac{D_{user}}{D_{max}} \qquad (10)$$

where, P_{ch} is the power allocated to particular sub channel, P_{max} is the maximum transmission power in the cell, D_{user} is the distance of the user from the centre of the cell and D_{max} is the maximum cell radius.

5. SIMULATION PARAMETERS AND PERFORMANCE ANALYSIS

The simulations are performed on three-cell OFDMA system described in Section II.A. The SINR values and system capacity at different locations in cell A for the system model shown in Figure 1 are calculated. The radius of each hexagonal cell is considered to be 500 m and the area inside the two-third of the cell radius is considered for CCUs and the region outside the two-third of the cell radius is considered for CEUs. The simulations are performed every 25 m, starting from 50 m up to 500 m from cell centre.

To calculate channel capacity, a maximum of six PRBs are considered to be allocated for each user when total available bandwidth is allocated to each cell. If a cell is allocated only a portion of available bandwidth, then the user will get lesser number of PRBs proportional to the allocated bandwidth. The system parameters are derived from WiMAX system specifications described in [15]. The main simulation parameters are listed in Table 1.

Table 1: Main Simulation Parameters

Parameters	Value
Cell Radius	500 m
Cell Center Users	< 333 m
Cell Edge Users	> 333 m
Max. Transmission Power	20 W
Thermal Noise Level	-174 dBm/Hz
Max. Number of PRBs per User	6
No. of sub-carriers per PRB	28
Sub-carrier Spacing	10 KHz
Max. Bandwidth per User	1.68 MHz

The performance of the proposed dynamic resource allocation algorithm is compared with the performances of the basic resource allocation techniques (Reuse 1, Reuse 3, PFR and SFR techniques). Figure 6 shows the SINR vs. UE location curves for the OFDMA system with Reuse 1, Reuse 3, PFR, SFR and proposed resource allocation techniques. Since the Reuse 1 technique cannot mitigate ICI, this system experiences the highest ICI values. Thus, SINR levels for the system with Reuse 1 technique are poorest. Reuse 3, PFR and SFR techniques have similar interference patterns. Hence, these techniques have same SINR vs. UE location curves. Due to the use of ICI mitigation techniques, these methods provide higher SINR levels in comparison to the Reuse 1 technique. The SINR vs. UE location curve for the proposed algorithm lies in between that of Reuse 1 technique and other techniques. The proposed algorithm provides much stable SINR values throughout the cell region with only a small difference in SINR values for users towards the centre and towards the boundary of the cell.

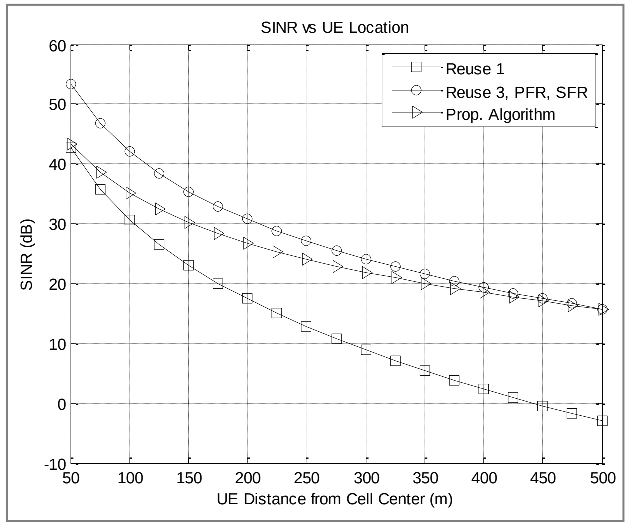

Figure 6: Comparative analysis of SINR vs. UE locations

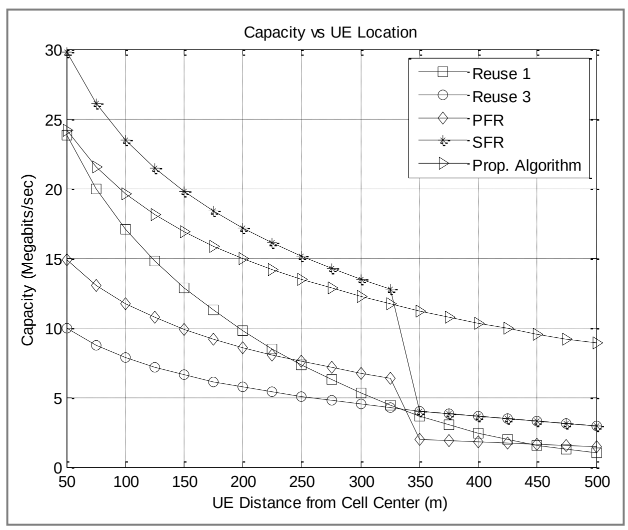

Figure 7: Comparative Analysis of Capacity vs. UE locations

Figure 7 provides the comparative analysis between Reuse 1, Reuse 3, PFR, SFR and the proposed resource allocation algorithms on the basis of maximum capacity per user. The result is based on the assumption that each user is provided a maximum of six PRBs containing 28 sub carriers each, which leads to the total of 1.68 MHz bandwidth. Figure 7 shows that, for Reuse 1 technique, the system capacity for CCUs is high but decreases rapidly as the users move towards the boundary of the cell. The Reuse 1 technique does not provide any ICI mitigation measures which results in highest levels of interference from the neighbouring cells. Hence, although the entire system bandwidth is reused in each cell, the capacity of the system decreases drastically towards the boundary of the cell. The Reuse 3 technique provides almost uniform system capacity for the users throughout the cell region. But the system capacity is very small due to the reduced bandwidth in each cell.

The system capacity vs. UE location curves for PFR and SFR techniques show that there is wide variation between the capacities for CEUs and CCUs. The PFR technique provides higher capacity for CCUs in comparison to the Reuse 3 technique but the capacity for CEUs is further degraded. SFR technique provides the highest system capacity for CCUs in comparison to other techniques. But the system capacity for CEUs is only as that for Reuse 3 technique. Thus, the CEUs experience highly diminished QoS in comparison to the CCUs in cases of PFR and SFR techniques.

The proposed algorithm provides the most efficient distribution of system capacity for all users throughout the cell region. The capacity for the proposed algorithm is higher than all other techniques except for the SFR technique in case of CCUs. In case of CEUs, the proposed algorithm provides the highest capacity compared to all other techniques. Also, the proposed algorithm causes only a narrow variation in system capacity for CEUs and CCUs, unlike in PFR and SFR techniques.

6. CONCLUSIONS

In this paper, a dynamic radio resource allocation algorithm has been proposed for a multi cell OFDMA system in order to mitigate the problems of ICI interferences from neighbouring cells. The dynamic resource allocation algorithm assigns the sub-carrier and its transmission power to particular users in the cell region in such a way that the interference from the adjacent cells for the particular sub-carrier is minimized. This algorithm utilizes the coordination between the adjacent cells for information on sub channel assignment and power allocation in neighbouring cells. The performance of the dynamic resource allocation algorithm has been compared with that of the basic resource allocation techniques that include Reuse 1, Reuse 3, PFR and SFR techniques. The simulation results show that the dynamic radio resource algorithm provides satisfactory levels of SINR values throughout the cell region. This algorithm also provides the most efficient distribution of system capacity for both CCUs and CEUs, compared to other resource allocation techniques. Also, this algorithm causes only a narrow variation in system capacity for CEUs and CCUs, unlike in PFR and SFR techniques.

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Urban Growth in the Northern Fringe of Kathmandu Valley Focusing on the Residential Development: The Case of Dhapasi and Surrounding VDCs

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***Abstract*: Urban fringes are the transition zone between urban areas and rural hinterland and are characterized by mixed land uses and ecologically fragile areas. In Kathmandu's context, the VDCs adjacent to the inner city serve as the fringe. The pattern of urban growth in the valley can be defined as the ongoing urbanization in terms of infill development in the inner city and rapid expansion taking place outside the city in the fringes. The study focuses on the urban growth of the northern fringe taking the case of 3 VDCs, Dhapasi, Gongabu, and Tokha Saraswoti; and its effects in the land use and environment. The urban growth in these VDCs is considered higher in comparison to the inner city in response to the inadequate housing and deteriorating environment in the inner city. Due to the availability of relatively inexpensive and huge expanses of barren land and ease created due to weak governance, the private developers have focused the recent development in these areas in the form of group housings and apartments. As the effort has been targeted to higher income group, the endeavor hasn't mitigated the haphazard or inevitable sprawl in the area in the form of inconsistency in the density, high land fragmentation, and inadequacy of basic infrastructure. Besides, the northern fringe is ecologically important area as it serves as a major recharge zone for the valley and was predominantly an agricultural area in the past. Due to the lack of regulatory framework to control the haphazard growth, the natural resources in the area are depleting causing an adverse impact in the land use and environment. The thesis is focused on the trend of urban growth in the area and its effects in the land use and environment. Besides, the study tries to focus on the probable interventions required to control the urban growth and preserve the northern fringe.**

Keywords: urban growth, urban fringe, sprawl

1. Introduction

The growth rate in the global context is seen to be lower in comparison to Kathmandu Valley due to managed urban growth in the fringes or planned decentralization through the creation of new towns or satellite towns outside the city with the initiatives to provide accommodation at cheaper prices. In contrast, the lack of properly planned satellite towns or sub cities in the valley has lead to haphazard expansion outside the inner city resulting unplanned urban growth or sprawl lacking basic infrastructure like road, water supply, drainage, and transportation. Hence, urbanization in the valley can be considered the rapid expansion towards the fringes, which represent the predominantly agricultural land of the past.

The study area Dhapasi and surrounding VDCs, Gongabu and Tokha Saraswoti represent the northern fringe and covers about 633 ha of land bounded by Ring Road in the south and the VDCs in other sides. The area was predominantly a Newar settlement and was considered a major cultivation area of the valley. The area lies within 3.5kms from the Ring Road and is connected to the inner city through Gongabu-Tokha Road functioning as the arterial road. With the construction of Ring Road in the mid 70s, the urban growth in the valley expanded from the inner city to the fringes as a response to inadequate housing conditions and low environmental condition in the inner city.

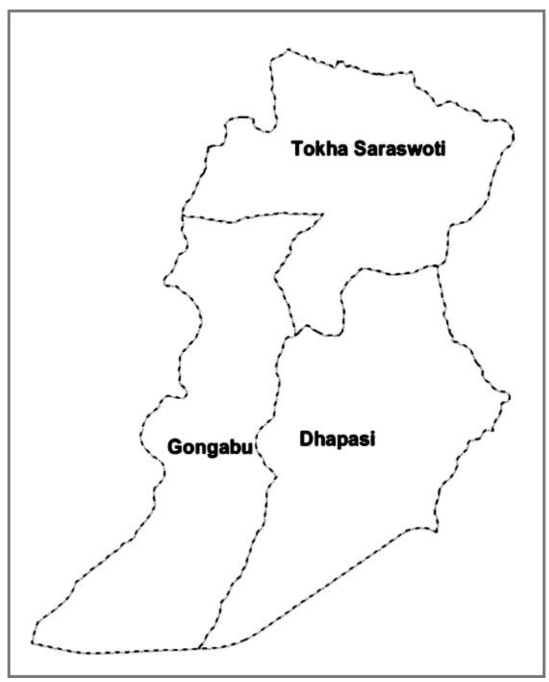

Figure 1: Map of the Study Area

The area is characterized by physical heterogeneity including plain and steep land with huge portions of land covered with forests, rivers, and agricultural fields making most of the areas uninhabitable. In terms of urban ecology, the area carries a lot of significance as it lies in the Bishnumati catchment area with two important rivers Bishnumati and Sangla flowing through it and is a major water recharge zone of the valley (Pandey et.al., 2012). Hence, the area is ecologically fragile and the urban growth in the area has an effect on the overall environment of the valley.

Despite the lack of plain and habitable areas, the urban growth in the area is taking place in a rapid pace in terms of owner built housings and formal housings from the private developers to fulfill the primary needs of housing. However, the formal housings comprise only a small portion of the residential development in the area and have targeted mainly the higher income group. Due to the lack of regulatory framework or policies regarding the urban growth in the fringes, the ongoing development has highly effected the land use and environment in the area in terms of depletion of natural resources like ground water, agricultural fields, contamination of river, increased pollution, and congestion.

2. METHODS

The research is exploratory as urban growth is a dynamic process and can't be generalized. The research follows the study of secondary data and interviews with the key stakeholders like the local government, private developers, and the residents to study the trend of urban growth in the area and its several aspects. In order to study the spatial transformation of the area, the aerial maps of the area in the year 1999, 2008, and 2013 were digitized and analyzed. As the study area covers a huge area and a population, purposive sampling was done to select the respondents. The semi structured interviews were taken from the residents of the formal housings and residents from the informal housings residing within the neighborhoods of the formal housings. Based on the collection of secondary data, mappings, and interviews with the key stakeholders, analysis of the urban growth as a result of residential development was done; and recommendations to manage the further urban growth, address the need of housing, and preserve the environment for the sustainability were given.

3. RESULTS

The three VDCs comprising the study area emanated different patterns of urban growth despite the close proximity due to different drivers of urban growth such as the physical settings, social and economic factors. The urbanizing VDCs (Gongabu and Dhapasi) adjacent the municipality showed higher growth in the last decade (2001 – 2011) with an annual growth rate above 9% and Tokha Saraswoti had 6.5% compared to 3.7% in the municipality. Similarly, Gongabu had the highest population density (257.28 p/ha) followed by Dhapasi (137p/ha). However, Tokha Saraswoti had low density (26p/ha) compared to 44p/ha in the municipality (based on the CBS Data, 2011).

Table 1: Population Growth in the Study Area (Source: CBS Data 2001/2011)

SN	Name of VDC	Area (in ha)	2001		2011		Inter Censal Changes (%)	Exponential Annual Growth Rate (%)	Pop. Density per ha
			Pop.	HH	Pop.	HH			
1	Dhapasi	224.5	11618	2563	31406	8202	170	9.9	139.90
2	Gongabu	211.5	20848	4837	54410	14456	161	9.6	257.28
3	Tokha Saraswoti	197.9	2681	470	5152	1189	91	6.5	26.04

The study of the spatial transformation of the land use pattern in the last 15 years revealed that the area was predominantly covered by agricultural land with above 70% of agricultural land in Dhapasi and Gongabu and 89.5% in Tokha Saraswoti in 1999. Besides, the area had a considerable amount of forests ranging 13-24 ha in each VDC. The residential area in 1999 occurred as sparse settlement near the Ring Road and dense old settlement towards the north. The new residential development occurred in smaller stretches, or as smaller scattered pockets surrounded by agricultural fields.

Figure 2: Aerial Map of the Area (1999)

The land use map in 2008 showed a considerable growth in residential areas in Dhapasi and Gongabu leading conversion of agricultural land above 36% in Dhapasi and 23% in Gongabu in 10 years. However, the growth in Tokha was low with 3.2% increase in the residential land cover.

The current land use map of the area shows an overall conversion of above 200 ha of agricultural land and 30 ha of forests for residential purposes in the last 15 years, with a total coverage of residential area of 65-75% in Dhapasi and Gongabu and 15% in Tokha Saraswoti. The urban growth pattern in the area varied from compact to dispersed development leading to sprawl. In Gongabu, the most densely grown VDC, dense settlement occurred near the river and in the southern area with flat land, whereas sparse development occurred in the north with steep topography and forests. In Dhapasi, dispersed development was seen due to the steep topography of the VDC. In Tokha, sparse development occurred in the agricultural fields. Overall, the urban growth pattern in the area followed the haphazard pattern with uncontrolled land fragmentation towards the south and dispersed development towards the north without a proper layout of road and basic infrastructure like water supply, drainage, or adequate public transportation. Higher urban growth in the urbanizing VDCs has lead to social heterogeneity in the caste, employment, and education level of the people.

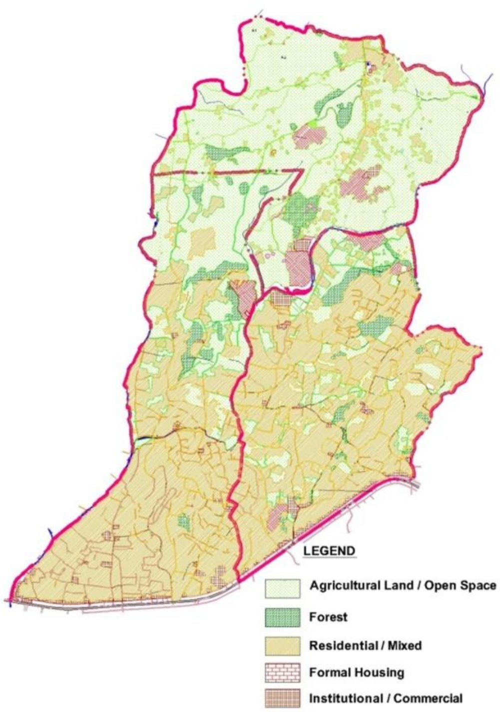

Figure 3: Land Use Map (2013)

The urban growth pattern and the changes in land use shows that much of the forests and agricultural fields have been encroached in the urbanizing VDCs due to high land fragmentation; but Tokha still has huge expanses of agricultural fields (nearly 3000 Ropani) which can be considered high yield fields with yield rate 176.6 kg per Ropani in comparison to 89.7 kg per Ropani in Dhapasi. Similarly, Dhapasi and Gongabu consist of land covers rich in sand. Mapping of the ground water resources reveal 93.5 ha of northern portion of Tokha Saraswoti lies within the water recharge zone of the valley. Hence, the area remains agriculturally productive and ecologically sensitive which needs to be preserved.

Table 2: Crop Yield per Year

VDC	Area of Cultivated land (Ha)	Area (Ropani)	Paddy Cultivation per year (kg)	Paddy Yield per year per Ha	Paddy Yield per year per Ropani	Yield of milled Rice
Dhapasi	18.2	358.5	32150	1766.5	89.7	20897.5
Tokha Saraswoti	151	2976	525429.6	3479.7	176.6	341529
Gongabu*	32	629	56,528	1766.5	89.9	36743.2
Total	201.2	3963.5	614107.6			399,169.9

Formal or planned housings in the area include 5.6% of the total residential land use comprising six major housings including two apartments and four group housings. Subha Homes was the first formal housing to be developed in Dhapasi in 2003. Similarly, Park view Horizon in Dhapasi and Grande Towers in Tokha remains among the prominent apartments in the valley with 212 units and 371 units respectively. Subha Homes, Harmony Housing, Grande Villa, and Veenas Residency are the group housings with approximately 100 units of independent housings in each. Three private developers have been involved in the development of the formal housings in the area, with the highest stakes shared by CE, with four major housing projects forming a part of the Samakhushi Tokha Hybrid Corridor Program under which the company envisions to develop the 500 m wide corridor of the Gongabu – Tokha Road. The current occupancy of the housings shows 81% of the total units constructed with 14% occupancy in the apartments and 68% occupancy in the group housings out of the total constructed units.

Figure 4: Water Recharge Zone

The overview of the formal housings showed that they had the provision of well planned roads, water supply, drainage, security, and compact density ranging between

175p/ha – 450p/ha. In terms of land use, the formal housings have helped in suppressing the land fragmentation to certain extent through the consolidated uses of land. However, the market analysis makes it evident that the formal housings in the area have addressed only a small target group as they have been developed with a purpose of maximizing commercial benefits and remains highly unaffordable to the normal working class. The current market price of the housings was between 75 Lakh – 90 Lakh for apartments (1250-1500 sq.ft.) and 52 Lakh – 1.72 Crore for the group housings (1000 – 1750 sq.ft.). Considering the current income levels (approximately NRs. 30,000 – 35,000 per month) in reference to the existing government pay scale, acquiring the cheapest housing units of 52 – 60 Lakh for a family of 4 requires 40-50% of the total earning of two economically active members for accommodation with a repayment period of 15 years, which shows the high unaffordability of the current housings for the normal working class. Hence, they are opting for the incremental housing, where the owner has the control over the house costing through the land value, built up areas, and finishing cost.

Table 3: Land Prices in the Study Area

Location	Land Value		
	Present	**5 years Ago**	**10 years Ago**
Urbanizing VDCs (Gongabu/Dhapasi): Within 0.5 kms from Ring Road			
Trunk Roads	30-35 lakh per Anna	5-6 Lakh per Anna	2-3 Lakh per Anna
Inner Roads	20-25 Lakh per Anna	4-5 Lakh per Anna	1 lakh per Anna
0.5-2 kms from Ring Road			
Trunk Road	20-25 Lakh per Anna	5-6 Lakh per Anna	2-3 Lakh per Anna
Inner Roads	10-15 lakh per Anna	3-4 Lakh per Anna	1 Lakh per Anna
Rural VDC (Tokha Saraswoti) 2-2.5 kms from Ring Road			
Trunk Roads	10-15 Lakh per Anna	3-4 lakh per Anna	50-60 Thousand per Anna
Inner Roads	8-10 Lakh per Anna	2 Lakh per Anna	30-50 Thousand per Anna
2.5 – 3.5 kms from Ring Road			
Trunk Roads	9-10 Lakh per Anna	3-4 Lakh per Anna	30-50 Thousand per Anna
Inner Roads	7-8 Lakh per Anna	2 Lakh per Anna	30-50 Thousand per Anna

Land price has been the main criterion involved in the selection of site by the private developers. The assessment of land value in the last 10 years revealed that the land value has sharply increased in the last 5 years with the land value ranging 35 – 15 Lakh in the urbanizing VDCs (Gongabu and Dhapasi) and 15-7 Lakh in the rural VDC (Tokha Saraswoti) compared to the land value of 6 – 2 Lakh per Anna 5 years back depending on the accessibility of the land from road. Due to highly varying land prices, the private developers are often acquiring the uninhabitable areas like undeveloped barren land or agricultural land for the development of housings. As a result, the ecologically fragile areas like floodplains or agricultural fields and steep land have been converted impacting the land use and environment through decrease in forests and agricultural fields, excessive extraction of ground water, river pollution, and congestion. Deep boring with a depth of 100m – 200m was the only mean of water supply in the group housings and apartments which amounted an extracted of 0.12 MLD or 120 cu.m. per day with the present occupancy which amounts to 0.44% of the sustainable extraction of water for the whole valley which is 0.027 million cu.m. per day (Pandey et.al., 2012), and is calculated to increase to 0.55 MLD or 550 cu.m. per day under the full occupancy of the housings. Similarly, the housings lacked sewerage treatment plants for soil waste disposal and waste water was directly disposed to the river in most of the cases.

In order to minimize the adverse effects in the environment, environmental protection act (1996) mandates the necessity of conducting EIA in the development works including housing. In the study area, the current practice of conducting EIA prevails with threshold limits of 10,000 sq.m. built area for apartments and 4 ha land area for the group housings under which only Grande Towers was seen to conduct the EIA. Hence, the collective effects of the housings which exceed the threshold limits given by the act has gone un-accessed as most of the housings have been developed phase wise or in smaller areas. Besides, the EIA is often carried during the construction phase making it ineffective to make interventions for environmental protection.

4. Discussions and Conclusion

The northern fringe is ecologically important as it serves as a major recharge zone and has high productive agricultural fields. In order to meet the rapid urbanization and due to the lack of regulatory framework, haphazard growth is taking place in the area resulting sprawl in terms of inconsistency in the density, high land fragmentation, lack of essential infrastructure and higher dependency on automobiles for travel. The urban growth has densified in the southern portion and sparsely dispersed in the northern portion characterized by steep topography which still has huge expanses of highly productive agricultural fields. Due to inadequacy of monitoring and land use zoning, the growth is going in a haphazard pattern encroaching the agricultural fields and ecologically fragile areas and depleting the natural resources.

In order to manage the further urban growth and preserve the northern fringe, institutional involvement of government and certain interventions are necessary. Attention must be given to address the middle and low income groups in housings to prevent the further land fragmentation. For the purpose, the private developers should be required to set aside certain amount of new housing development for marginalized groups with schemes of financial assistance from the government in terms of loans and subsidies. Besides, the policies to preserve the northern fringe need to be brought in terms of strong enforcement of land use zoning showing the water recharge zone, floodplains, and agricultural fields where the urban growth should be discouraged by providing lucrative incentives for the agricultural activities. Similarly, larger lot sizes like 3 – 5 Ropani which are suitable for agricultural purpose should be introduced instead of existing minimum lot size of 80 sq. m which has lead to high land fragmentation in the highly productive agricultural fields. Hence, the policies to preserve the northern fringe and manage the urban growth should be brought to accommodate the further growth in the area.

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Satellite Estimated and Ground Based Comparison of Solar UV Index in Kathmandu

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***Abstract*: The study is based on the satellite estimation and ground measurements of solar UV index in Kathmandu for the year 2009 to 2011. Kathmandu (27.72^{0}N, 85.32^{0}E) is located at an elevation of 1350m from the sea level. The ground based measurement and satellite estimation was performed by NILU-UV irradiance meter and EOS Aura OMI spacecraft. The NILU-UV irradiance meter measures UV radiation in different spectral range. The Ozone Monitoring Instrument (OMI) is a spectrometer designed to monitor solar radiation in spectral range of (270-500) nm. This study shows that satellite overestimates the ground based (GB) UV Index (UVI) before monsoon by 103.6 % in 2009 and 98.3%in 2010 and in 2011. During the monsoon period overestimation decreased to 66.7% in 2009, 83.1% in 2010 and 90.5% in 2011. The correlation coefficient (r) between ozone from satellite and ground based measurement from January to May is also studied. It is observed that the correlation between satellite estimated ozone and ground based ozone was found to 0.86 in 2009, 0.74 in 2010 and 0.65 in 2011 in Kathmandu. The study showed that the estimation of OMI before monsoon is high than after monsoon. The mean UVI ratio between satellite estimated and ground based measurement ranged 1.4 – 2.2 for 2009 to 2011.**

Keywords: OMI, Aura, Ozone, Ultraviolet, UV Index

1. INTRODUCTION

The amount of solar ultraviolet (UV) radiation (200-400 nm) reaching the earth's surface is affected mainly by atmospheric ozone absorption, cloudiness and aerosols. Changes in UV radiation at surface may strongly affect the human health and the terrestrial and aquatic ecosystems [13].

Surface UV radiation estimates have been provided from the Ozone Monitoring Instrument (OMI), flying on the NASA EOS Aura spacecraft since 15 July 2004. OMI is a spectrometer designed to monitor ozone and other atmospheric species [10]. Two algorithms, OMI-TOMS and OMI-DOAS (Differential Optical Absorption Spectroscopy), are used to produce OMI daily total ozone datasets. OMI UV products are local solar noon irradiance at 305,310, 324, and 380 nm, as well as EDRs and Erythemal Daily Doses (EDDs). OMI continues the Total Ozone Monitoring System (TOMS) record of total ozone, aerosol, and UV measurements. Satellite ozone and UV data derived from TOMS were exhaustively validated by means of ground-based ozone and UV data ([2], [5], [1], [8]). Reference [2] found a reasonably good agreement between satellite ozone data and ground-based measurements retrieved in six European sites: generally the ground-based ozone seems to be slightly than TOMS ozone (less than 3%). Regarding UV data, [5] found that erythemal UV estimates from TOMS demonstrate better agreement with ground-based measurements in case of low level of pollution. Reference [1] compared TOMS overpass retrievals against Brewer measurements at Ispra (Italy) and Thessaloniki (Greece), obtaining large positive biases in both cases (on average about 19% for Ispra and 30% for Thessaloniki). They found that these discrepancies can be mainly explained by the aerosol effect. Reference [8] confirmed that TOMS UV data overestimate ground-based measurements by almost 20% under high aerosol load.

Kathmandu is the capital and largest metropolitan city of Nepal. The city is the urban core of Kathmandu valley which contains two sister cities namely Patan 5 km to its southeast and Bhaktapur 14 km to its east and is a touristic destination centre. Satellite estimation and ground based measurements of UV radiation has not been performed in Kathmandu. Being located at high altitude UV Index and UV dose in Kathmandu is expected to be higher. UV Index is an indicator that helps to measure the effect of solar ultraviolet radiation on human skin. It is an important indicator and is useful to raise public awareness for skin damage. The higher the Index, the greater the risk of skin damage due to UV radiation. UV index differs from place to place and depends upon different factors. Ozone, aerosols, clouds, solar elevation, altitude and albedo are the factors that affect solar UV radiation reaching the earth's surface. Thus the ground based measurement of UV radiation with satellite estimation at Kathmandu is an important part of the study. The main aim of this study is to present the ground based solar UV index with OMI estimation in Kathmandu. The paper emphasized to compare the UVI at Kathmandu during monsoon and before monsoon. The correlation between ground based UV Index (UVI) with OMI estimated UVI is also analyzed. The paper also focused to compare ground based total ozone with OMI.

Section 1 represents the introductory part of UV radiation. Methodology is given in section 2. Results and discussion of the UV measurement is presented in section 3. Conclusions of the measurement are included in section 4.

2. Instrumentation and Methodology

2.1. Ground based observation

The instrument used to measure solar UV irradiance at Kathmandu (27.72^{0}N, 85.32^{0}E) is NILU-UV irradiance meter. The various types of instruments all have their pros and cons depending on the manpower available for their operation, the location and accessibility of the measurement site, and the accuracy, stability, and the quality requirements of the measurements. The need for an accurate and reliable instrument that could operate independently in harsh environments with in-board storage of data and the possibility for the remote download of data through public telephone lines motivated development of the Norwegian Institute for Air Research UV radiometer (NILU-UV). The NILU-UV instrument is a multichannel, moderate-bandwidth filter instrument. It is a six-channel moderate-bandwidth filter instrument. Five of the channels are in the UV with centre wavelengths at 305, 312, 320, 340, and 380 nm and a bandwidth of 10 nm at FWHM. The sixth channel measures the so-called photo synthetically active radiation. It covers wavelengths between 400 and 700 nm with a bandwidth of 300 nm at FWHM. The front optics consists of a flat Teflon diffuser followed by custom-made interference filters from Barr Associates, Inc., Westford, Mass. To minimize stray-light problems the five UV channels in addition have UG-11 and read leak filters. For the same reason the 305, 312, and 320nm channels are equipped with individual specified short-pass filters. For all channels the radiation is recorded by S1226-8BQ silicium detectors from Hamamatsu. The instrument is the temperature stabilized at 50°C. It records data in a built in data logger at a 1-min time resolution. The data logger has the capacity to store 3 weeks of 1 min averages. By interfacing the instrument to a computer using a RS-232 port, data with 1-s tine resolution may b recorded. The total weight of the instrument ready for operation is 3 kg the instrument is weatherproof and designed to operate in harsh environments [6].

2.2. Satellite observation

OMI, the ozone monitoring instrument flying on Aura, is the latest of a series of ozone mapping instruments. In terms of the long-term ozone data record OMI can be considered an advanced version of the total ozone mapping spectrometer (TOMS). A series of TOM'S instruments flew on Nimbus 7 (November 1978 to May 1993), Meteor 3 (August 1991 to December 1994) and earth Probe (August 1996 to December 2005). OMI continues this time series of global total column ozone measurements.

OMI is the Dutch-Finnish contribution to EOS-Aura OMI is a nadir viewing, wide swath, ultraviolet-visible (UV-VIS) imaging spectrometer that provides daily global measurements of the solar radiation backscattered by the Earth's atmosphere and surface, along with measurements of the solar irradiance. Full instrument details of OMI have been given elsewhere [10], but details relevant to ozone retrieval are summarized here. Unlike the heritage TOMS instruments which measure ozone at six discrete wavelengths from 306 nm to 380 nm [11], OMI measures the complete spectrum from 270 nm to 500 nm at an average spectral resolution of 0.5 nm. OMI combines the advantages of GOME and SCIAMACHY [3], measurement of the complete spectrum in the ultraviolet/ visible wavelength range, with the advantages of TOMS, complete spatial coverage. The UV channel consists of two sub channels: the UV-1, ranging from 270 to 310 nm, and the UV-2, ranging from 310 to 365 nm. The total ozone retrieval is based on measurements from the UV-2 detector. The VIS-channel covers the range from 365 to 500 nm.

The nadir pointing telescope of OMI has a very large field of view of 114^o perpendicular to the flight direction of the satellite. This gives OMI a swath width of 2600 Km, consisting of 60 individual pixels along the swath. The instrument achieves complete daily global coverage of the sunlit earth. The state of the art CCD detectors render a very high spatial resolution of 13 km × 24 km at nadir. The small ground pixel size enables OMI to look 'in between' the clouds, giving better reach into the troposphere for retrieving tropospheric composition information than any other UV-VIS backscatter instrument flown to date.

3. Results and Discussion

The study analyzes the variation of the noon time ground based measurement and the satellite estimated solar UV index for the year 2009 to 2011. Alongside, the study also emphasizes on correlating the ground based daily total ozone with the satellite estimated ozone. Figure 1 shows the daily variation between the noon time ground based and the satellite estimated solar UV index. The figures clearly show that for a given day the satellite data are always estimated greater than the corresponding ground based data.

In fact the satellite overestimated by71.9% in 2009, 79.6% in 2010 and 2011 respectively in comparison to the ground based UVI. The overestimation of OMI with GB UV index could be mainly due to the variability between solar noon times and overpass times. Looking at a given time and location the SZA is the dominant factor that determines the spectral detail as well as absolute solar UV irradiance. As a consequence the UV spectrum depends on location, on the time of the day and on the day within a year [12].

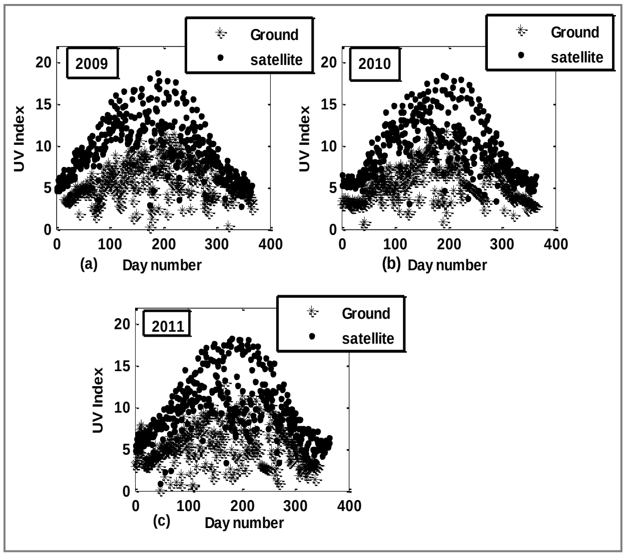

Figure 1: Daily variations of ground based and satellite estimated UV Index

The monthly mean UVI ratio between GB and OMI estimated UVI is shown in Figure 2. The highest and lowest value of OMI and GB UVI was found in June/July and in December/January in all years. This is because in high altitude side, sun is in southern hemisphere in winter and the angle made by the sun is large, whereas in summer UVI is high because sun is in northern hemisphere and the angle made by the sun is small. The ratio of OMI and GB UVI ranged 1.4 – 2.2 in 2009 and 2010 while in 2011 it ranged 1.4 – 1.8.

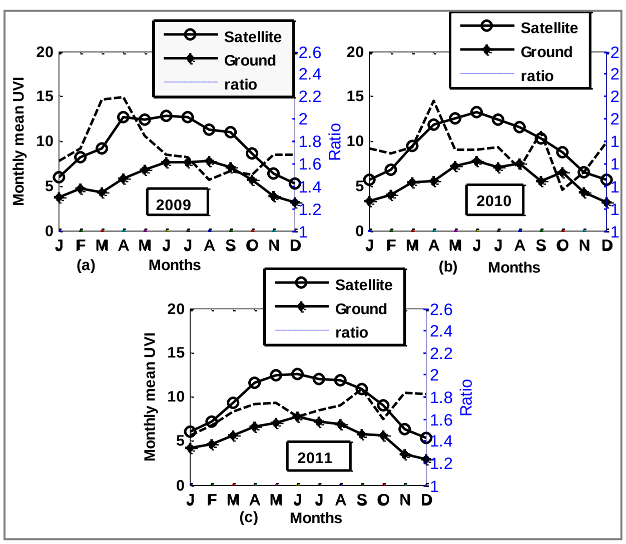

Figure 2: Monthly mean ratio of satellite estimated and ground based UVI

The analysis (Figure 3 and 4) shows that the satellite overestimates the ground based UVI by 103.6% in 2009, 98.3% in 2010 and in 2011. The fluctuation in UV data before monsoon is mainly due to the combined effect of clouds and aerosols. During monsoon satellite overestimation drops to 66.7% in 2009, 83.1% in 2010 and 90.5% in 2011. During monsoon the aerosols and pollutants are washed out and cloud plays a dominant role in attenuating solar UV radiation reaching the earth surface. The OMI overestimation of ground-based UV measurement may be partly explained with the fact that satellite instrument do not prove well the lower atmospheric layers of urban sites where aerosols play an important role ([9], [8]).

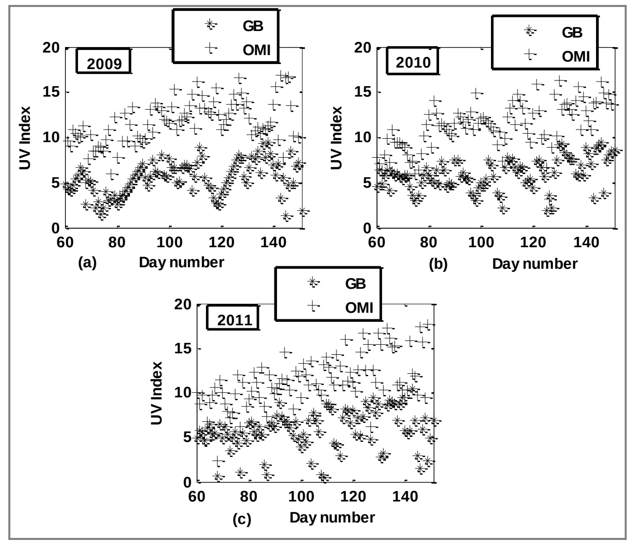

Figure 3: Scatter plots of ground based and satellite estimated UV Index before monsoon

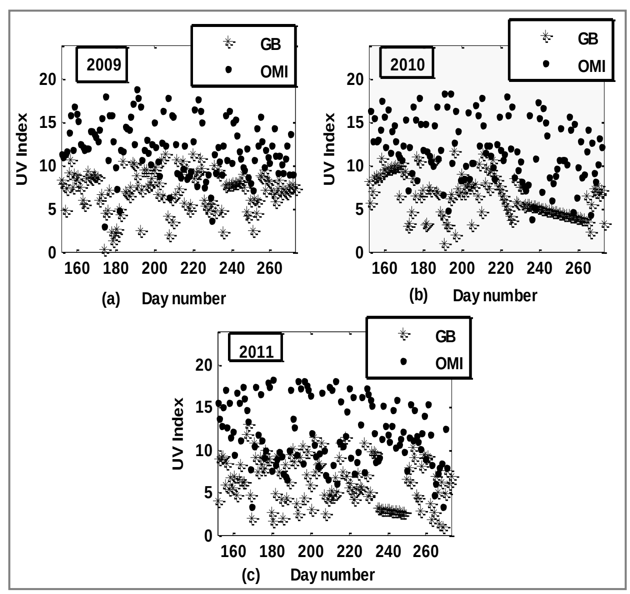

Figure 4: Scatter plots of ground based and satellite estimated UV Index during monsoon.

Daily variation of noon time ozone for 2009, 2010 and 2011 is shown in Figure5. It is observed the GB noon time daily mean total ozone is 1.3%, 2.5% and 2.0%

higher than the corresponding OMI value in 2009, 2010 and 2011 respectively. The reason behind this ground based overestimation might be due to clouds present in the OMI grid. The mean difference between daily total ozone column amounts derived from NILU-UV measurements and from Earth Probe TOMS data was -1.4% ±3.2% [4].

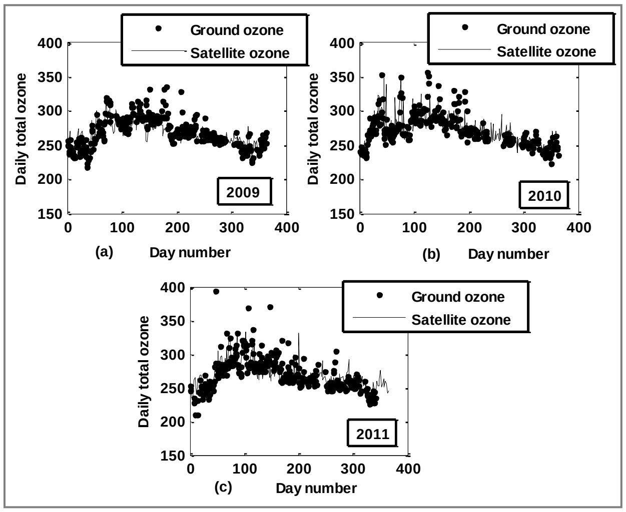

Figure 5: Daily variations of ground based and satellite estimated ozone

The correlation between satellite estimated and ground based ozone in 2009, 2010 and 2011 is shown in Figure6. Correlation between satellite and ground based ozone from January to May was found to be 0..86 in 2009, 0.74 in 2010 and 0.65 respectively in 2011 that agrees with the correlation given by [7].

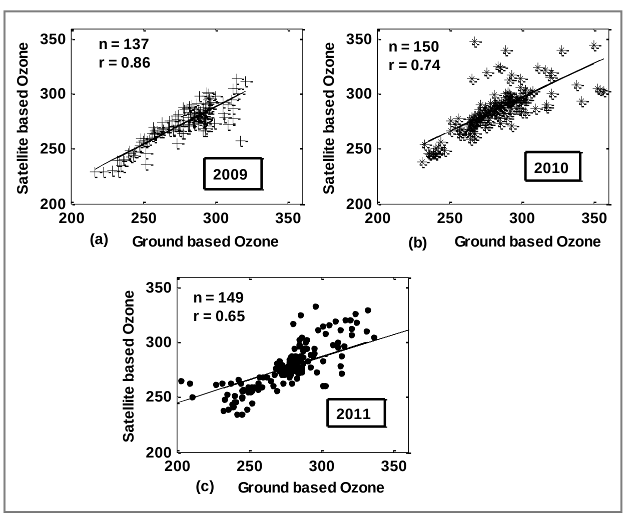

Figure 6: Correlations between ground based and satellite estimated ozone for January to May
(The solid black line represents the linear fit)

Satellite and ground based noon time mean UVI is shown in Figure7. The daily mean ground based UVI was found to be 5.5 in 2009, 5.4 in 2010 and 5.3 in 2011. Meanwhile for satellite it was 9.7, 9.5 and 9.5 in 2010, 2011 and 2012 respectively. In Kathmandu there was no dramatic change in UVI in all years. It was observed that the Ground based and satellite estimated UVI decreased slightly from 2009 to 2011. The main cause of this decrease might be the increased level of pollution in Kathmandu.

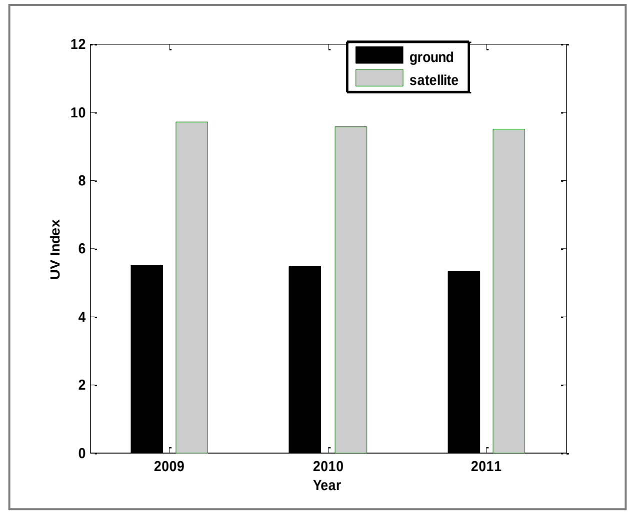

Figure 7: Yearly variations of satellite and ground based noon time mean UVI in Kathmandu

4. CONCLUSION

The satellite estimated and ground based measurements of solar UVI in Kathmandu, Nepal using Ozone Monitoring Instrument and high quality ground-based measurements were analyzed and reported. The comparison between GB noon time UVI and OMI noon time UVI showed that, on an average OMI exceeds the ground based measurements by 103.6 % in 2009, 98.3% in 2010 and 2011 respectively before monsoon. During monsoon overestimation of UVI decreased to 66.7% in 2009, 83.1% in 2010 and 90.5% respectively in 2011. On further analysis it was found that the overestimation of UVI before monsoon was greater than that after monsoon. The main cause of this overestimation is that the ground based instrument measures the UV irradiance at a single point while OMI measures the UV irradiance over a large area. Apart from this the dusty events of Kathmandu are also the cause of overestimation. The analysis also showed that the correlation coefficient(r) between ground based ozone and OMI based ozone from January to May was found to be 0.86, 0.74 and 0.65 respectively in 2009, 2010, and in 2011 for all sky condition. The study also showed that, the ratio between OMI and GB UVI ranged 1.4 – 2.2 in 2009, and 2010 and 1.4 – 1.8 in 2011. The decreasing trend of UVI was observed from 2009 to 2011.

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Black Carbon Aerosol Variation in the Industrial city Biratnagar, Nepal

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***Abstract*: Measurement of black carbon (BC) aerosols was carried out by using AE-31 7 channel aethalometer in the industrial city Biratnagar for five months January to May 2011.Monthly and diurnal variation of BC was distinct. Monthly BC concentration ranges from 3.3 -20.1 µg /m^3. It was found that BC was highest during January and it decreases gradually until May. Moreover, there was a significant diurnal variation of BC with two high peaks one at about 9:00 morning and another at late evening 20:00 local time with minimum concentration in the afternoon. Interestingly, evening peak was larger than morning peak; it infers that fuel consuming domestic and industrial activities in evening are dominating than morning. Moreover, daily and monthly concentration of elemental carbon (EC) was more than BC in Biratnagar reflecting consumption of more biomass fuel than fossil fuel for domestic, industrial and other urban activities. Analysis of winter month observation and wind rose suggests that highest concentration of BC is not only due to local effect but also a result of transboundary effect. A meaningful anticorrelation of BC and wind speed is observed with R square value 0.6 infers significant role of wind speed in the reduction of aerosol from the atmosphere.**

Keywords: Aethalometer, black carbon, elemental carbon

1. INTRODUCTION

Black carbon (BC) is defined as the carbonaceous material having intense black or dark color and it absorbs visible light efficiently (Cachier, 1995; Hansen et al, 1984). Often a smaller fraction of atmospheric BC is elemental carbon (EC) and most of it consists of highly polymerized organic material having rather low hydrogen to carbon and oxygen to carbon ratios (Cachier, 1995). The contribution of EC can be highly increased close to its source like traffic. BC and EC both are the major anthropogenic components of atmospheric aerosols. About one half of the global BC aerosol emission is estimated to rise from fossil fuel combustion (Cooke and Wilson, 1996). BC aerosols have been found to be contributing significantly to the atmospheric warming both globally and regionally (Ramanathan and Carmichael, 2008). China and India are large emission sources of BC from industry, residential, and transport sectors, including the incomplete fossil fuel combustion from sources such as open biomass burning and wood burning cooking stoves (Bond et al., 2004; Ramanathan et al., 2007; Ramanathan and Carmichael, 2008). BC represents the fraction of the carbonaceous material that absorbs visible light; EC is graphitic carbon that absorbs in the visible range and it is not reduced to CO_2 when heated to 800^{o}C in an inert atmosphere. In principle, all EC is BC, but all BC is not necessarily EC. BC aerosol particles have a detrimental impact on human health (Samet et al., 2000; Pope et al., 2002). BC acts as an indicator of air mass affected by anthropogenic pollution (Penner, 1995). Recent studies suggest that BC can alter the cloud lifetime (Acerman et al., 2000), precipitation pattern (Menon et al., 2002), reflectivity and melting of snow and ice (Hansen and Nazarenko, 2003). Since most of the BC particles are in the fine particle size mode (Ogren and Charlson, 1983; Penner et al., 1992), dry removal rate is small (Ogren et al., 1984). Bahrmann and Saxena (1998) showed BC concentration decreased abruptly after precipitation due to scavenging affects.

It is for the first time black carbon aerosol was monitored in Biratnagar for about five months .The industrial city is main business hub of Nepal because it is a transit area of Nepal India business. It is neighbored by high coal consuming industrial state of India, Bihar so; present study will provide a snap shot of black carbon variation with possible transboundary effect.

2. EXPERIMENTAL DETAILS

2.1. Study Area

Biratnagar is a sub-metropolitan city located 26 ^{o}28’60”N 87^{o}16’60”E. It is a flat land situated at the border with India and is, therefore, a major canter for trade and commerce with India. This site is linked with Indian state “Bihar” which is an industrial state full of coal mines and mine industries. According to 2011 CBS census data, the population of Biratnagar is about 0.2million and is, therefore, fourth largest city of Nepal after Kathmandu, Pokhara and Lalitpur. Number of industries registered in this area are 295(CBS 2006). The study site is shown in figure 1. This site is neighbored with industrial state of India, Bihar.

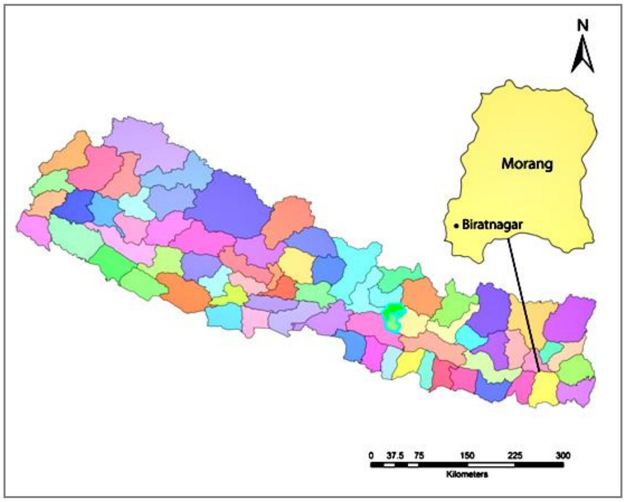

Figure 1: Map of Nepal showing the study site Biratnagar

2.2. Instruments Used

Black carbon concentration was continuously measured using an aethalometer AE 31 manufactured by Magee Scientific USA. The aethalometer is an instrument that provides a real time read out of the EC or EC aerosol particles in air stream. The instrument aspirates ambient air using its inlet tube. Black carbon mass concentration is estimated by measuring the change in the transmittance of a quartz filter tape, on to which particles impinge. The instrument was placed in operation at the time interval of 5 minutes, round the clock with a flow rate of 2 liters per-minutes (LPM). These data are automatically recorded in the flash card of the instrument and displayed on the screen. Five minute's data obtained were used for making hourly, daily, monthly and seasonal average calculation for the interpretation.

3. Result and Discussion

BC (along with EC) was measured from January to May2011 in Biratnagar using aethalometer. Five minutes data obtained by the instrument were converted into hourly and monthly for diurnal and monthly interpretation and is presented in this paper.

3.1. Monthly Variation

The monthly variation of BC in the observed months from January to May is distinct with highest concentration in January and lowest on May. The monthly average of BC varies from 3.3 -19.5 µg /m3.The EC value of Biratnagar is higher than BC value indicating consumption of more biomass fuel(agriculture wastes, cow dung and burning wood) than fossil fuel(cooking gas, kerosene, petrol and diesel) .

Monthly box and whisker plot for the study period January to May for the concentrations of BC is given in figures 2. The square sign (▫) denotes the monthly mean, the horizontal bar represents the monthly median and the hatched boxes contain 25^{th} to 75^{th} percentile range of values for that month. Outliers are shown as asterisk (*) for the month. It can be seen that the concentration BC is higher in the first two months (January February) in Biratnagar which are winter months while in rest premonsoon (March, April and May) it is comparatively lower. Further it can seen that the variability in the concentrations of d BC is higher in those months when monthly values are higher and low when the values are less. Moreover the high concentration of BC in winter months is attributed to consumption of high amount of biofuel and fossil fuel for the internal heating and other activities.

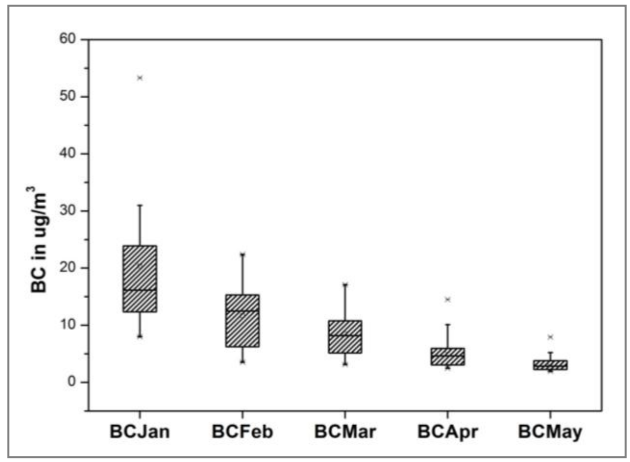

Figure 2: Monthly distribution of BC concentration as displayed in box and whisker plot

From the wind rose plot of Biratnagar Figure-3(a-e) , it is clear that percent of calm wind (less than 0.5m/s) is comparatively higher in January and February than the rest of the months. In addition, wind is blowing SW, WSW during January and February while it is ENE and E in March, April and May. The neighboring state Bihar in India is also a flat land and consumes huge amount of coal for industries and thermal power. Transboundary effect is dominating in addition to consumption of high amount fuel for winter heating. Hence, high concentration of carbonaceous aerosols is found in Biratnagar. In the case of remaining three preceding months in premonsoon, comparatively less amount of fuel is consumed for domestic activity than winter. In addition wind is blowing from ENE and E, of the rural hilly area of Nepal. This is one of the causes of flushing of BC from the study site towards boundary Indian area so the concentration of carbonaceous aerosols is less in these months.

The daily average of BC in Biratnagar is shown in figure 4. It also shows error bar for each day. Variation of BC is very significant in January and February and become almost homogenous in the rest of the months. Low values of BC in few days of May and April are attributed to significant rain recorded in those days.

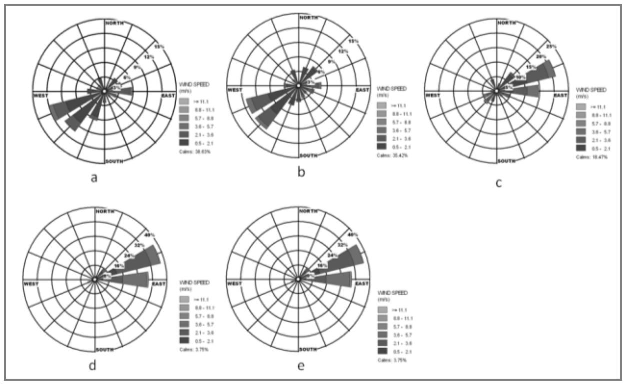

Figure 3: Wind rose diagrams for Biratnagar from January-May 2011(a-e)

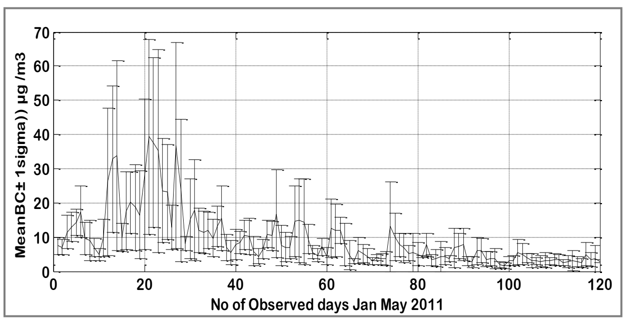

Figure 4: Daily average BC concentration from January to May 2011 in Biratnagar

3.2. Diurnal variation

Five minute interval data of aethalometer was used for making hourly. The average hourly EC and BC value for each month was plotted and is shown in Figure 5 for Biratnagar site. A distinct diurnal variation of BC at Biratnagar was observed .Two high concentration peaks of carbonaceous aerosols are observed one at about 8:00 morning and another at about 20:00 late evening local time (local time 5:45 ahead of UTC).At Biratnagar, evening peaks are greater than the morning peak. The amplitude is largest in January and gradually decreases until May. These values of carbonaceous aerosol and higher peak in the evening than in the morning shows that more domestic, industrial and on road activities are there in the evening.

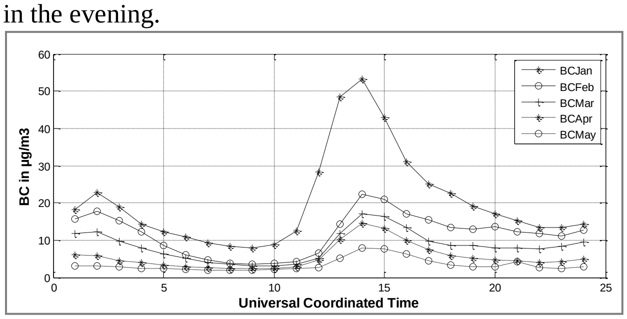

Figure 5: Diurnal Variations of BC in Biratnagar from January to May

3.3. Correlation of BC and wind speed

Diurnal variation of wind speed is very significant in Biratnagar as shown in figure 6.It shows maximum peak value of wind speed as 2.6m/s around 11:00-14:00 local time and it gradually decreases onwards. Comparison of diurnal pattern of BC and wind speed (Fig 5 and 6) shows maximum value of BC when wind speed is minimum and vice versa. It infers a significant role of wind speed in the variation of BC.

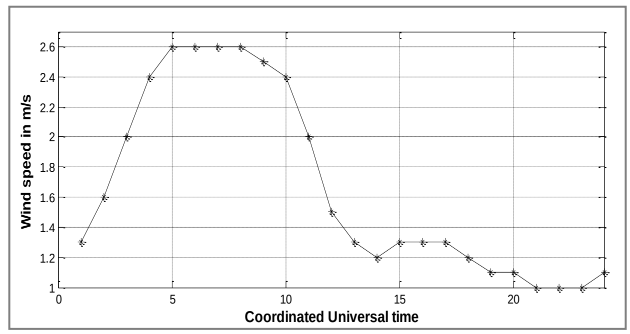

Figure 6: Diurnal variation of Wind speed in Biratnagar (January to May2011)

Wind speed is one of the important climatic factors to influence the variation of aerosols in the atmosphere. In this paper an attempt has been done to know the relation of wind speed and BC in the flat land Biratnagar. There is a meaningful anticorrelation between BC and wind speed with R square value 0.6 which suggests important role of wind speed in the variation of BC aerosol in this site. Figure 7represents scatter plot of BC and wind speed which shows low concentration of BC when wind speed is high and high concentration of BC when wind speed is low.

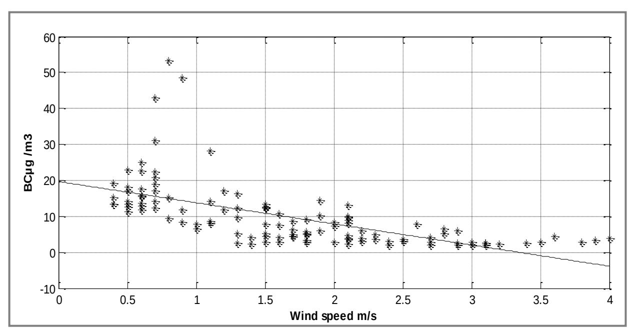

Figure 7: Scatter plot of BC and Wind speed in Biratnagar

4. CONCLUSIONS

The monthly average concentration of BC represents distinct variation in Biratnagar; it gradually decreases from January to May. Highest concentration of BC was observed on January showing transboundary effect of aerosol in winter with addition to local effect. Monthly average value of EC is higher than BC in Biratnagar showing consumption of more biofuels than fossil fuel for domestic, industrial and other urban activities.

Diurnal variation of BC is apparent with two high peaks one in the morning at about 9:00 and another in the late evening 20:00 local time with minimum value in the afternoon. The evening peak was larger than morning inferring more on road and industrial activities at evening than morning.

There is distinct diurnal variation of wind speed with maximum peak at the time when BC aerosol remains the minimum. Further, it has been observed that there is a meaningful anticorrelation between BC and wind speed with R square value 0.6

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Intraregional Disparity – Cause and Effect of Urban Degradation of Historic Small Towns in Kathmandu Valley, (A Case Study of Sankhu)

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***Abstract*: Intra-regional disparity is the disparity between two or more sub-regions within the same region. In this study, Kathmandu valley has been considered as a region, and disparities between two or more towns as well as disparity between municipality and Village Development Committees within the valley are considered as Intra-regional disparity.**

Whoever read literatures, published regarding Kathmandu valley, make their thought that Kathmandu valley and its people are more developed than other parts of the nation, but they cannot know that most parts of the valley and their people are just in opposite to their thought because they do not get to read about such disparity within the valley.

"Whether the problems of the villages or small towns in the valley are problems of the valley or not" is the point of departure of this thesis.

We know the settlements in the Kathmandu valley were formed in walking era, and hence they were functioning as theory specifies about emergence of towns and urban rural linkages. But, as far today's context, it is little different that most of these historic towns in the valley are deteriorating and defunctness because major administration as well as other essential services have been concentrated within the ring road and surrounding historic towns became under the shadow.

Sankhu was formed especially due to being on historical route to Tibet. In the past, traders of Nepal and India would use this route for import export business with Tibet. Development of science and technology should be beneficiary for all; but in the case of Sankhu, it seems opposite effect of invention of vehicles.

It can be said that Sankhu was a prosperous town in the past mainly from the point of view of its economic activities, culture and fabulous urban fabric. Now, Sankhu is on the degraded condition. Its traditional economic activities have been declined to lowest level. Important urban fabric, and cultural elements and activities are deteriorating, as well as there are high level of socio-economic disparity between Sankhu and Kathmandu city.

However, Sankhu has great potential to develop as a satellite town of Kathmandu. If it would happen, Sankhu would be developed parallel to Kathmandu, but Government did not make any such policy. Moreover, it was left to divided position into three different administrative units rather than making as a unit.

On the basis of examples of Manchester city of London, and Bhaktapur and Bandipur in Nepal, it can be said that degenerated towns can be regenerated if they get proper support from government. Likewise, Sankhu has several potential to be regenerated. Sankhu is looking for an integrated action plan regarding its economic development. Therefore, it will be better to have an integrated economic development plan by integrating mainly three sectors, viz. Trade and Service, Agriculture, and Tourism.

Keywords: Intraregional Disparity, Urban Degradation, Urban Regeneration

1. Introduction

Background

"Being a capital city, Kathmandu Valley in comparison to the rest of Nepal, possesses basic amenities like water supplies, electricity, gas, telecommunications, roads, sanitation, education, security, and transportation."

"Between 2001 and 2011, Kathmandu valley experienced average annual population growth rate of 4.33%, which is more than 3 times that of national growth rate 1.35%."

The above two sentences have been taken from two different literatures viz. "Kathmandu Valley Profile"-Briefing Paper presented on the workshop Governance and Infrastructure Development Challenges in Kathmandu Valley took place 11-13 February 2009 in Kathmandu, Nepal; and CBS report.

These two sentences are only representatives of several statements of intellectuals regarding Kathmandu valley. Whoever read such literatures make their thought that Kathmandu valley and its people are more developed than other parts of the nation, but they cannot know that most parts of the valley and their people are just in opposite to their thought because they do not get to read about such disparity within the valley.

Should it be considered the only progress of few large cities as the progress of the entire valley?

Or,

Should it be considered the only problems of few large cities as the problems of the entire valley?

"Whether the problems of the villages or small towns in the valley are problems of the valley or not" is the point of departure of this research work.

Urban rural relation includes three major aspects, viz. a) urban centers and their structure, function and spatial distribution, b) resource-use system of the rural (hinterland) area, and c) services and institutions that facilitate relations between urban and rural areas (Pradhan, 2012). Central place theory which is a spatial theory in urban geography that attempts to explain the reasons behind the distribution patterns, size, and number of cities and towns around the world. It also attempts to provide a framework by which those areas can be studied both for historic reasons and for the location patterns of areas today (Briney, n.d.). In the definition of central place, settlements may be used to refer to hamlet, village, town or city. These are the hierarchical ranking of settlement, which can be distinguished according to functions, population size and associated hinterland areas, and transportation network (Pradhan, 2012). While looking Nepal's traditional pattern of urban centers, we can get almost same pattern in the Kathmandu valley.

As we know the settlements in the Kathmandu valley were formed in walking era, and hence they were functioning as theory specifies. But, as far today's context, it is little different that most of these historic towns in the valley are deteriorating and defunctness because major administration as well as other essential services have been concentrated within the ring road and surrounding historic towns became under the shadow.

Even the Bhaktapur, despite being one of the three old royal towns of the Kathmandu valley, was facing such disparity till decade of 70s that the image of Bhaktapur among the population of the valley was not very good. Bhaktapur was regarded as unhygienic, lacking in modern urban attractions and economically backward despite being an extraordinary example of an untouched, traditional Newar town with many fine buildings of architectural value and a style of life that is steeped in tradition (BDP, 1979).

This paper concentrates over the historic town Sankhu. Sankhu, the eastern most settlement in the Kathmandu valley and located at the end of a small valley, is one of the oldest settlements of the valley (Sakwa, 1997). It seems Sankhu was formed especially due to being on historical route to Tibet (China) through Kathmandu even from India. In the past, traders of Nepal and India would use this route, by walking and riding horses, for import export business with Tibet. Going through Melamchi and Sipaghat, the traders climbed over many hills and finally entered Tibet through Kodari. Hence, there was a huge commercial activity in Sankhu until few decades ago. With the development of science and technology, all should have achieved some benefits, but in the case of Sankhu, it seems opposite effect of invention of vehicles.

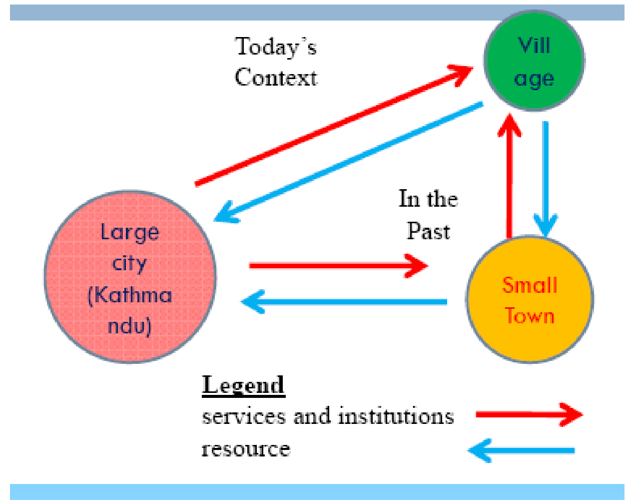

Figure 1: Urban Rural Linkage

Defining the Topic

Defining the topic is very important to move forward by making choices on gathering information and reading literature.

Intraregional Disparity

Inter-regional disparity represents the disparity between two or more regions, where as Intra-regional disparity is the disparity between two or more sub-regions within the same region. It might be disparity between two or more countries if a continent or sub-continent is considered as a single region. For instant, disparity between Japan and Nepal in the Asian continent, and disparity between Nepal and India in South Asian sub-continent are known as intra-regional disparity. In the case of within Nepal, if development region is considered as a region, disparities between zones as well as between districts are known as intra-regional disparity.

In this study, Kathmandu valley has been considered as a region; and disparities between two or more towns as well as disparity between municipality and Village Development Committees are known as Intra-regional disparity.

Urban Degradation

Urban Degradation specifies the run down condition of the physical, social and economic characteristics of urban areas. Urban areas face decline with the passage of time when the factors contributing to their rise become obsolete. We can take the case of the textile city of Manchester. Raw materials were imported from the colonies, processed in these cities and they were sent back to the colonies. But with the independence gained by such colonies, such cities experienced steep decline (Pokharel and Shrestha, 1998).

In the case of Kathmandu valley and surrounding areas, we can take the examples of Sankhu, Nala, Lubhu and others. Sankhu and Nala were emerged in early time mainly due to being strategic locations of traditional Indo-Nepal-Tibet trade routes. After opening the vehicular route, traders avoided those walking routes and thereafter these towns started to degrade. Similarly, Lubhu once was a textile city, but with the import of garments and other clothes from abroad in the following years, Lubhu underwent a process of decline.

Need of Research on topic

Due to geographical diversity, there are differences in resource endowments in various parts of the country. These are not well known and not well used. National economic structure is still fragmented with the presence of isolated pocket economies. The majority of the people remained alienated from the mainstream of development. Disparities between the Tarai and the Hills as well as between rural and urban areas continued to go (Joshi, 2006). Not only such inter-regional, but also there are several intraregional disparities between large Kathmandu city and surrounding small towns in the Kathmandu valley.

Surrounding historic small towns have not been getting proper support from the state and they are almost out from the mainstream of development works, and due to occurring such disparity, the historic towns have been deteriorating in one hand, and also people have been migrating to the larger city Kathmandu for better opportunity, although they are not so far from the capital city. It is clear that intraregional disparity has been adding more other social and economical disparities in intraregional like as money attract money.

In such aspect, the cause and effect both are the intraregional disparity with urban degradation as medium between them. There need some casual research to explain the theory in better way and this thesis will focus on that.

Objectives

Main objective of research is:

- To find out the inter-relation between Intra-regional disparity and the urban degradation of historic towns in Kathmandu valley.

To support the main objective, the research aims

- To measure disparity on input activities of towns, which includes disparity on budget allocation, infrastructure development, conservation works.
- To assess the relation between such input activities and urban degradation of historic towns.
- To assess the relation between urban degradation of historic small towns and increase on social disparity between those small towns and large cities.

2. METHODOLOGY

Research Paradigms

This research is based on combination of positivism as well as constructivism belief. Therefore, there has been used methodology within these two paradigms. As we know positivism is experimental/Quasi experimental, there will be tried to verify the hypothesis through quantitative methods, as well as under the constructivism paradigms, the hypothesis will be tested through phenomenological research method.

Research Design

A research design is the framework or plan for a study used as a guide in collecting and analyzing data. There are three basic types of research design: exploratory, descriptive, and causal. The goal of exploratory research is to discover ideas and insights. Descriptive research is usually concerned with describing a population with respect to important variables. Causal research is used to establish cause-and-effect relationships between variables (Brown and Suter, 2012).

Based on above research paradigms, this research is based on exploratory research and Causal research as well. Exploratory research was conducted to provide a better understanding of a situation. It is not designed to come up with final answers or decisions. Through exploratory research, it is hoped to strengthen hypotheses about what is going on in a situation. A hypothesis is a statement that describes how two or more variables are related. For example, if the historic town has been degraded during the last few decades, as a researcher we use exploratory research to provide insights about what caused the degradation of the town.

As hypothesis, *Intraregional Disparity is the main cause as well as effect of deterioration of historic small towns in Kathmandu valley*, the causal research has been applied to examine cause and effect relationship of some variables like as relation of state's budget allocation for infrastructure development, interest over the conservation etc. with the deterioration level as well as regeneration level, for instance Bhaktapur, of the historic towns.

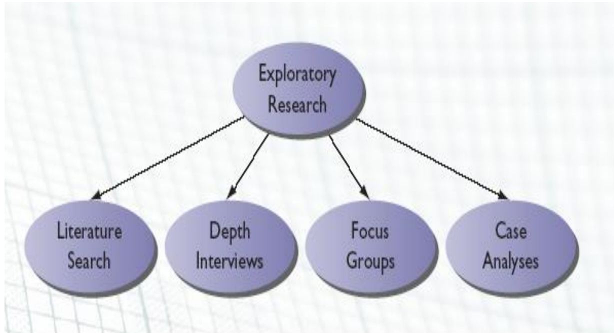

Figure 2: Diagram of Exploratory Research

In causal research, a field experiment is conducted in a realistic or natural situation. Just like lab experiments, one or more variables are manipulated to see their effect on an outcome variable.

Case study as Research strategy

For the verification of the hypothesis, there were conducted several case studies in general in different historic towns in Kathmandu valley, and among them the case study of the Sankhu has been done in detail. There is studied its importance in the past, cause of deterioration and its impact in local level and metro level in the whole valley.

Not only negative cases but also positive cases were studied for knowing their impact on the society. For instant, case of Bhaktapur was studied to compare the physical, social and economic conditions of Bhaktapur before and after the Bhaktapur Development Project.

3. CASE STUDY AREA- SANKHU

As already mentioned in Background, Sankhu, the eastern most settlement in the Kathmandu valley and located at the end of a small valley, is one of the oldest settlements of the valley. It is very difficult to say that how much it is old. There are several legends, which help to know about the formation of Sankhu, Bajrayogini sanctuary, Manichud Daha (pond), and their relations. By which it seems that these were formed with the formation of the Kathmandu valley in present stage from a lake (Shrestha, 2000). Moreover, it is also heard that lord Manjushree had come firstly to Bajrayogini to take permission of draining out the water from lake.

There are other several names of this historic town, likely Sanketu Nagar, Shankharapur, and Sakwa. It is said that Sankhu was derived from Newari name Sakwa. Sakwa means beneath the Tibet. Tibet was known as *San de* in Newari and *Kwa* means beneath.

Historical Background of Sankhu

Sankhu is an oldest settlement in Kathmandu valley. It is very difficult to say that how much it is old. It is said that Goddess Manjushree came from Tibet and visited firstly to the lord Bajrayogini at Gunbihar. She cut down Chobhar gorge by taking permission from goddess Bajrayogini. From this, it can be said that Bajrayogini has been existing in Sankhu region since then when valley was as a lake. There are several legends, viz. *Manishail Mahawdan, Swayambhu Purana, Himwatkhanda Mahapurana, Swasthani,* etc., which help to know about the formation of Sankhu, Bajrayogini sanctuary, Manichud *Daha* (pond), and their relations. By which it seems that these were formed with the formation of the Kathmandu valley in present stage from a lake.

Not only legends but also the historical documents, *bamshawalis*, viz. *Gopalraj Bamshawali*, *Shanti Swasti Ghatanawali* etc., and inscriptions tell about the history of these places.

The layout of Settlement

Sankhu town is located at about 17 Kms. North-East of Kathmandu city core on the traditional trade route to Tibet. It can be said that emergence of Sankhu, in early time, is mainly due to being on the entry point to Kathmandu valley for the peoples coming from eastern Nepal as well as from Lhasa (Tibet). Therefore, there was advantage of location for the town.

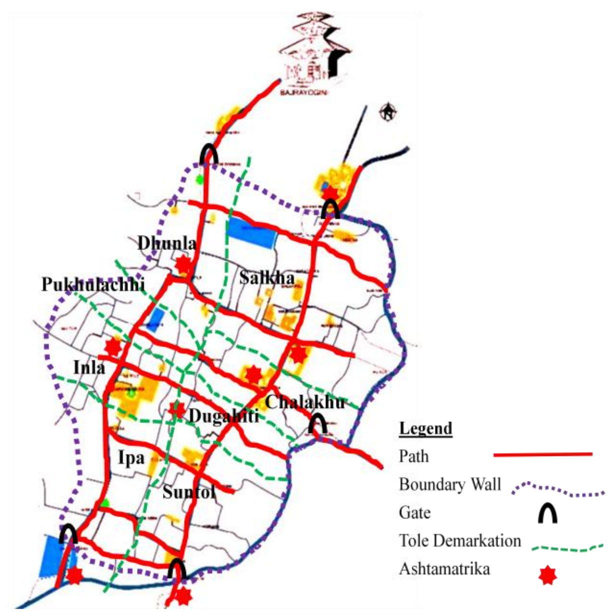

Figure 3: Layout of Sankhu Town

The old settlement has been planned in gridiron pattern, in the shape of Shankha (conch Shell). Being a historical and old town, still there exist lot of temples, statues, patis, hitis, Raj kulos, Inscriptions, as well as intangible cultures likely several guthis and festivals. Sankhu is said that it was planned mainly to celebrating Bajrayogini chariot festival.

Similar to the case of Patan, Bhaktapur and other towns of Kathmandu valley, the layout of the settlement is based upon the Vedic principles and cosmic laws. In the case of Sankhu, the Ashtamatrika Yantra has been used for both the outer settlement consisting of seven peripheral villages forming the ancient Sankhu kingdom as well as the inner settlement of Sankhu town itself.

The town was built with facilities of roads, sub roads, drain, patis, sattals, and gates with religious manner. Sankhu is believed to be once fortified town in the past and it had eight gates, eight toles. Presently five gates are in existence. In according to today's administrative division of Sankhu, among eight toles, four toles are in Pukhulachhi VDC whereas Bajrayogini and Suntol VDCs each have two/two toles.

4. Analysis and Findings

Sankhu as a Prosperous Town in the past

It can be said that Sankhu was a prosperous town in the past mainly from the point of view of its economic activities, culture and fabulous urban fabric.

Economic Activities in the past

Sankhu had great potential for trade business because it was on trade route to Tibet. Sankhu had a custom office on that traditional silk route. Therefore, Sankhu had location advantage being on the traditional silk route. Traders, from not only Kathmandu and Patan, but also from India used this route to go to Lhasa. Such traders would make their night stay at the Sankhu, and go to Lhasa on next day.

Trade with the Lhasa was one part; nevertheless, people from all the villages of Sindhupalchowk district and northern part of Kavre district would come here for shopping. People from all those villages would come here to sell their agricultural products and buy other goods from here.

In the walking era, beyond the traditional trade route, Sankhu had another location advantage that it has two main rivers of the valley viz. Salinadi and Gadgade River. There were several flourmills (*Panighatta*), which were run by water flow. Due to presence of those Flourmills, Sankhu was center for collecting the agricultural products brought from the villages. People from Sankhu would collect Corn, wheat and others and go to sell to Asan after making them flour by grinding in flourmills.

Most of the people in Sankhu would engage in such type of business throughout the year after farming season. Professional traders in Sankhu would do their job of selling goods to the people from the villages; in parallel, small traders could get job throughout the year. Hence, economy of Sankhu was on the higher position during walking era.

Cultural Activities and Elements

Sankhu had higher level of intangible cultural activities, and tangible elements as well. There were several tangible cultural elements likely, temples, chaityas, ponds, dyachhens, gates in one hand, in parallel, there had been conducted several festivals and guthis, likely Bajrayogini chariot festival, Salinadi mela etc.

Highest level of urban fabric

As per explained in previous chapter, the town had been planned in gridiron pattern, in the shape of Shankha (conch Shell). Similar to the case of Patan, Bhaktapur and other towns of Kathmandu valley, the layout of the settlement is based upon the Vedic principles and cosmic laws, and it had two layers of Ashtamatrikas. The town was built with facilities of roads, sub roads, drain, patis, sattals, and gates with religious manner. Sankhu is believed to be once fortified town in the past and it had eight gates, eight toles. It had fabulous residential buildings with sanjhyas and gajhyas.

Sankhu as a Degraded Town at now

Now, Sankhu is on the degraded condition. The degradation can be explained in better way through its effects. Its traditional economic activities have been declined to lowest level. Important urban fabric, and cultural elements and activities are deteriorating, as well as there are found high level of socio-economic disparity between Sankhu and Kathmandu city.

Effects of Degradation

Deterioration of Historic Urban fabric

Due to outmigration of educated and wealthy people, Sankhu could not achieve development works, nor any conservation works for a long. On the other hand, Government did not treat it as important place. It did not get any budget to conserve its historically important urban fabrics. As a result, its historic urban fabric totally damaged.

Deterioration on culture

There have occurred some changes in cultural activities. In the past, there was system of certain kind of musical performance during Bajrayogini festival as well as funeral activities in the Sankhu, but, from the last 20-25 years, such kind of system and musical instruments (e.g. *Kan Baja*) has been totally lost.

Now the festivals have been remained only for local and surrounding village people apart from relatives of the people of Sankhu, whereas, in the past, people would come to Sankhu from distant places likely Fatakshila, Bhotechaur during Bajrayogini festival. Although the number of relatives has been increasing, their time spending has been decreasing significantly than past years due to easy vehicle accessibility.

Increasing Socio- Economic Disparity

Disparity on Income

From the household surveys 2010 in Sankhu (VDCs profile), it is derived that per capita income of people in Sankhu was NRs. 31,183 at that time. On the other hand, Nepal's per capita income for Fiscal Year 2010-11 was NRs. 46,020.

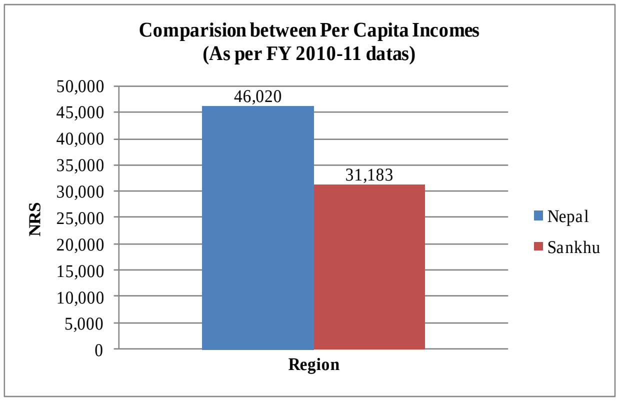

Figure 4: Per Capita Income

It shows that despite being in the district of Capital city, Sankhu could achieve only two third level of national percapita income. If it is compared to its own district level per capita income, i.e. per capita income of Kathmandu district, there will be different on more proportion. Furthermore, its comparison to the KMC is unimaginable. Therefore, there is huge income disparity between Sankhu and KMC.

Disparity on Population Density

Although being a compact settlement, Sankhu core town has less population density than overall Kathmandu district. The population density of Sankhu city core is 3,860 persons/Sq. Km., whereas, it is 4,416 person/Sq. Km. within whole district of Kathmandu.

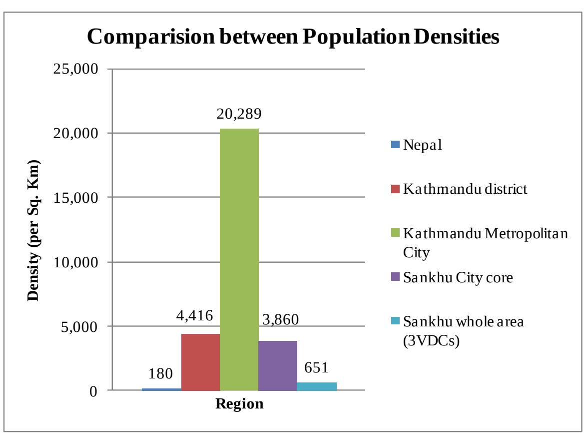

Figure 5: Population Densities

Moreover, it is too small while taking whole area of three VDCs of Sankhu region. It is counted only 651 person/Sq. Km. Hence; Sankhu is not being able to maintain its own district level of population density, KMC level is so far. Therefore, there is high level of disparity on population densities in Sankhu and KMC.

Disparity on Population Growth

Although Kathmandu valley is considered as having high growth rate of population, Sankhu is opposite to that. In last decade, data shows Kathmandu district as a whole has more growth rate than KMC. This is mainly due to lack of vacant land within the boundary of the KMC, and settlement increased in VDCs mostly peripheral area of KMC. The in-migrant people in the valley did not choose the Sankhu as their destination in one hand; on the other hand, people from the Sankhu also migrated to the KMC and near to KMC. Therefore, annual population growth rate of Sankhu city core became negative by 1.09%.

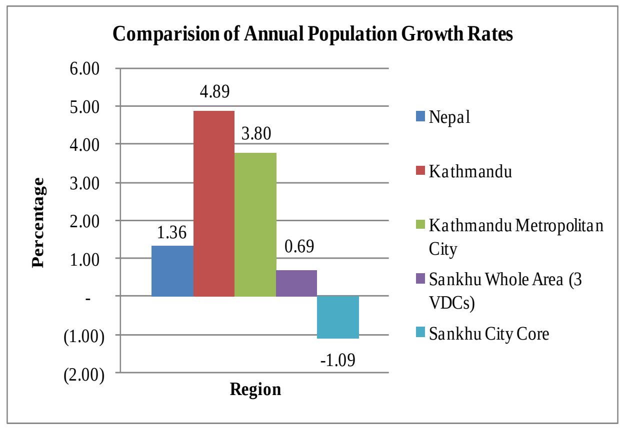

Figure 6: Population Growth Rate

Due to some population increment on village area, annual population growth rate of Sankhu appeared as positively 0.69%, which is very lesser than Kathmandu district as a whole (4.89%) and KMC (3.8%). Hence, there is significantly disparity on population growths in Sankhu and KMC, and Sankhu and peripheral VDCs of KMC.

Disparity on Literacy and Education Level of population

Data shows literacy rate of Sankhu is slightly more than national literacy rate. Among the total population of aged 5 years and above, Sankhu found to having 68.97% of literacy rate, which is slightly more than that of national (67.28%), but significantly lower than that of Kathmandu district as a whole. It is mainly due to having high literacy rate in the KMC and peripheral area of KMC. Therefore, it can be said that there is high level of disparity on literacy in Sankhu and KMC.

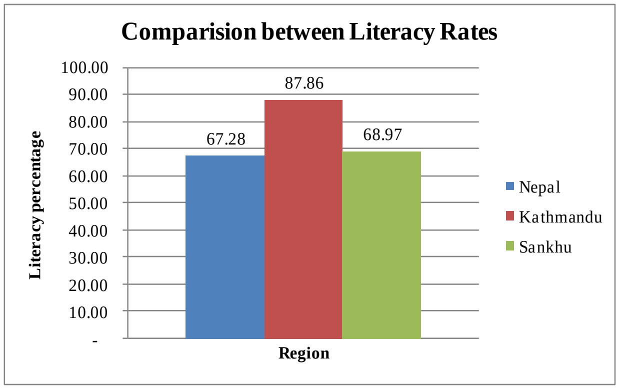

Figure 7: Literacy Rates

Similarly, among the literate peoples aged 5 years and above, percentage of the people who have achieved higher degrees are significantly lower in Sankhu in the comparison to the Kathmandu district as a whole. Proportion of the people having SLC and just Literate are more in Sankhu. In Sankhu, only 1.39% of literate people have achieved post Graduate and above degrees, whereas there are 4.48% of literate peoples in the whole Kathmandu district have achieved such degrees. Similarly, 10.69% have Bachelor's degrees and 10.69% have higher secondary degrees in Sankhu; and both of these percentages are lesser than percentages of population of same kind of degrees holders in the whole Kathmandu district. It has mainly happened due to having more proportion of population having higher degrees in the KMC and peripheral area of KMC. Therefore, there is disparity on people's education level in Sankhu and KMC.

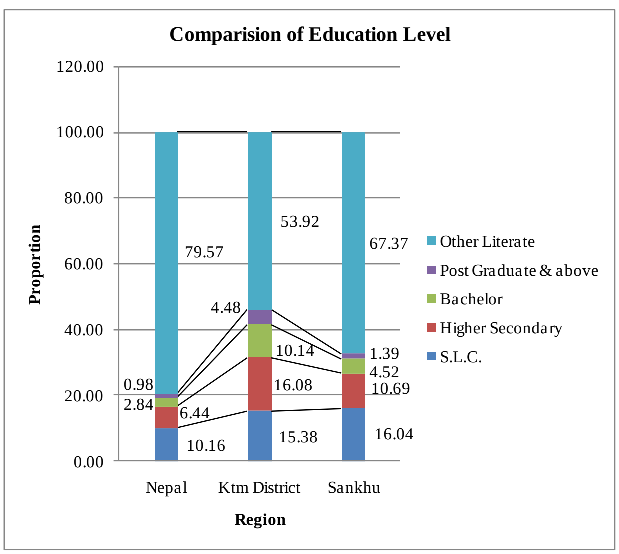

Figure 8: Education Level

Disparity on Living standard

It is found that people's living standard in Sankhu is very lower than that of people in KMC. Due to having low income, most of them are being far from utilizing modern inventories. Moreover, they are living on traditional way of life. To enforce the statement, data on below table will be helpful. Still 27.40% of total households in Sankhu area have no any toilets in their houses. Whereas, it was found only 1.16% of households without toilet are in the whole Kathmandu district. It proves that there is huge disparity on living standard of people in Sankhu and KMC.

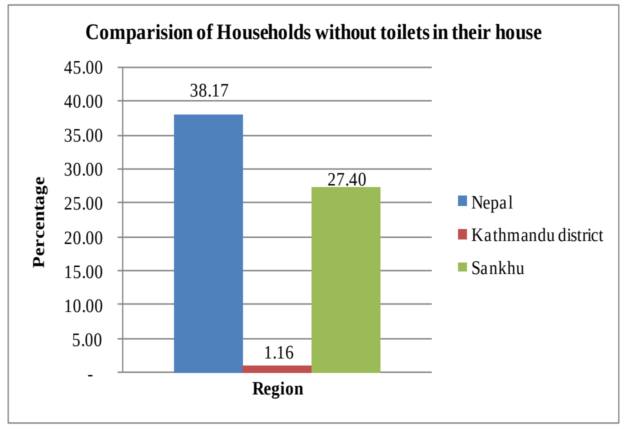

Figure 9: Households without Toilets

Causes of Degradation of Historic Town Sankhu

Main causes of the degradation of Sankhu are three inter-related factors namely lack of social infrastructure, outmigration of wealthy and educated people from Sankhu to large city, Kathmandu, and lack of economic activities.

Outmigration

Now, as per interviews with local people of Sankhu, about 25-30% of people of Sankhu have their houses in Kathmandu, and hence, many houses became vacant in Sankhu. Due to outmigration of educated and wealthy people, Sankhu did not take speed on development works.

Nepal Living Standards Survey (NLSS), 2011 shows that most of the immigrant population (28.5%) in urban area of Kathmandu valley has been migrated mainly due to following the family. The percentages of migrated population due to education purpose and looking for work are also in significant position in urban centers of Kathmandu valley.

However, in the case of Sankhu, there are higher percentages of population of out migrants due to start new job and start new business, including with education purpose. Nevertheless, percentage of out migrants due to following the family is on the top position also in the Sankhu.

This is mainly happened due to lacks of social infrastructure and economic activities in Sankhu.

Lack of Social Infrastructures

There is only Bhagyodaya campus for higher education, which was established in 2059 B.S. This campus is providing only faculty of B.B.S. In the case of health facilities, only a health post was serving from 2015-16 BS for preliminary health care to all the people of Sankhu and surrounding villages, and it is still providing same type of services.

Therefore, students as well as others need to go to Kathmandu city for better health care because these public health posts are not providing services through higher than HA level technicians and private clinics are more costly for general peoples of Sankhu.

Due to lack of such social infrastructures, it affected negatively on economic activities in Sankhu. It reflects that government did not show any interests on decentralization of such social infrastructures within the valley so that it could help to develop small towns like Sankhu, and minimize pressure over Kathmandu city.

Lack of economic activities

There is rare to see significant economic activities in Sankhu. Most of the people are involving in traditional agriculture. Main occupation of highest number of population having age more than 10 years old, i.e. 46.20% is seen as agriculture. Also the involvement in the agriculture of youths is significant, which account 39.96 % of youth having age 16-24 yrs. Although most of the people are involving in agriculture, they are not being able to get enough production from that. It is found that only 29.08% of households get enough food for full year.

On the other hand, number of population that is economically inactive is very high in the Sankhu. There is found 27.78% of total Population having age of more than 10 years are economically inactive.

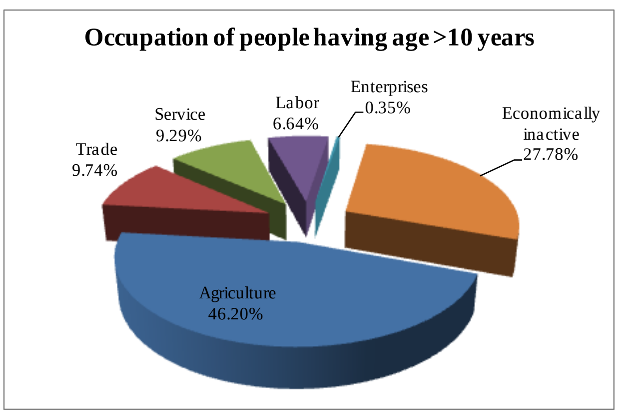

Figure 10: Occupation

Moreover, youth unemployment is a serious problem in Sankhu. Among population of 16-24 yrs age group, 40.06% are not involving in any kind of income generating activities.

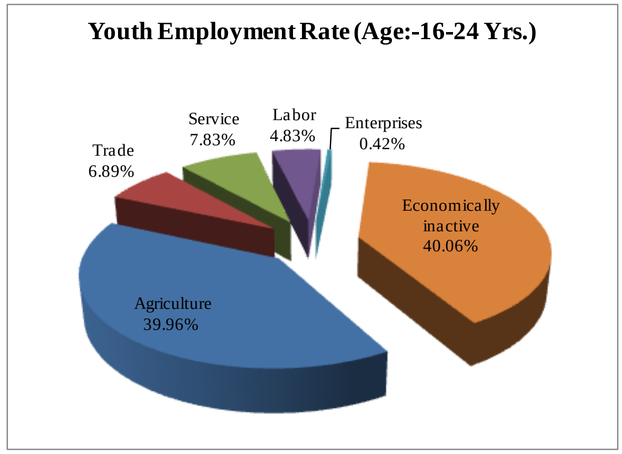

Figure 11: Youth Employment

It has well become to know from the literature review and depth interviews that Sankhu had higher level of economic activities in the past. It was a higher level of trade center on the silk route between India and Tibet. With the time, that trade route disappeared and trade business of Sankhu declined on one hand, on the other hand government did not recognize its other potentials and did not make any policies to develop this region and left to decline historically important town.

Despite having great potential of tourism, Sankhu is not being able to grab the profit from that. There is hard to see such significant industries in Sankhu. The traditional trade business has been squeezed only to local people, which was major economy of Sankhu in the past. Due to lack of such economic activities, employment became a major problem and people migrated to Kathmandu city for better opportunity.

Although these three interrelated activities are the in front causes of degradation of Sankhu, there are several other reasons behind them. Degeneration of Traditional Trade Activities of Sankhu is the main cause of lacking of economic activities. After degeneration of traditional trade activities, there could be developed other activities like as development of Sankhu as tourism center as well as service center, but Government could not show any interest towards that.

Degeneration of Traditional Trade Activities of Sankhu

It has already been explained about traditional trade activities of Sankhu that it was a higher level of trade center with some *paani ghattas* as agricultural products processing industries. With the time, that trade route disappeared and trade business of Sankhu declined. Firstly, when China made victory over Tibet, they banned to the traders from Nepal, and hence, it seems trade business was started to decrease from 2013 B.S. Before that, there was a linkage of Sankhu up to Lhasa and there was trend to go to Lhasa, but later on Nepali traders used only to return from there. Thereafter, trade was remaining only for national people.

Secondly, its trade business declined significantly after construction of Kodari (Araniko) highway at four decade ago. Before construction of that highway, Sankhu had linkages with almost all villages of Sindhupalchowk and northern villages of Kavrepalanchowk districts. After construction of this road, Trade Linkage of Sankhu remained only with some villages of western Sindhupalchowk and northwestern villages of Kavrepalanchowk district.

Thirdly, after the construction of Melamchi Lamidanda road during three decade ago, peoples from these remaining villages of Sindhupalchowk and Kavre districts used to go through Banepa on the bus, and trade business of Sankhu was remained only for locals and surrounding villages viz. Palubari, Bisambhara, Nanglebhare. Only few people from westernmost villages of Sindhupalchowk district, viz. Bhotechaur would come to Sankhu.

Fourthly, trade business in Sankhu further decreased after the conduction of buses from Melamchi to Narayantar through Sankhu. It had been expected that Sankhu would be flourished on the linking Melamchi to Sankhu with vehicle, but Sankhu is not being able to take advantage from opening of this road because buses from Melamchi go direct to Narayantar.

Lastly; now, there are several shops in each village; furthermore, today's business policy has been changed. Such shops do not need to come to main market to buy their needs because wholesalers themselves supply to these shops.

Lack of Tourism

During my ten days long continuous visit to Sankhu, I could meet only two foreign tourists visiting historic town Sankhu, whereas, we can see more and more tourists in similar type of old Newari settlements in the valley. Despite having great potential of tourism development with rich heritage, culture, and tradition, Sankhu is not being able to develop in tourism sector. They are getting neither proper maintenance nor any publicity. Therefore, Sankhu is not being able to utilize its economic potentials.

The main causes behind the difficulty of tourism development in Sankhu are

- Lack of Conservation of Heritage
- Lack of Publicity of importance of Sankhu
- Lack of good physical infrastructure
- Lack of Conservation of Heritage

There is not any formal conservation project in Sankhu. Only few works have been done especially in the Bajrayogini temple sanctuary on the initiation of local peoples and the support of Archaeology department. In the Sankhu town, there are only few patis and sattals have been renovated by local NGO, Friend's of Sankhu (FOS). In the past, they would get proper maintenance due to having management of some lands for its conservation. Now such guthi lands have been lost.

Loss of Guthi Lands

In the past, there were several guthis to maintain each monuments, patis, etc; and for performing cultural activities as well. Each guthi had several pieces of land as their property. When here was conducted land measurement under the Land reform act, landholders, whoever had held such lands, made those guthi lands as their own private. Hence, guthis could not be run smoothly and conservation works were affected badly.

Although the Land Reform Act had brought revolution for the farmers, it could not take stand for maintaining the traditional system of management of culture.

Lack of Industries

It is obvious that industries are the key factors for developing the economic activities in any place. In Sankhu area, there is not established so many factories or industries. However, there are seen some furniture factories in addition to a plywood factory in Sankhu. Moreover, some rice mills, few oil mills, and one tea-packaging factory are running in the town. Sankhu area is rich in herbal product, so there had been established an herbal processing center at the hilltop of Manichud hill in 2017 BS, but it was closed during 2051 BS.

Lack of good physical infrastructure

Although Motor-able road was constructed during reign of Chandra Samsher Rana (1907-1929), it was remained only for walking because road was muddy and not maintained, and vehicles were almost absent. It was graveled during 2025-26 B.S., and upgraded during 2035-36. Only after few years of that, it became black topped, and public vehicle facility became regular.

Although Road from Kathmandu was constructed about 100 years ago, it remained narrow for long period and there was very hard to travel by public buses as well as it would take almost one and half hour to reach Kathmandu city. It has total 22 m. right of way in the rule, but it has been widened to only 9m recently.

In similar manner, roads to Nagarkot and Nangle remained unchanged for long time. Sankhu-Jaharsinghpauwa-Nangle road was constructed in 2035-36 B.S., and 12 Km long Sankhu-Nagarkot track was opened in 2042BS. However, these roads are not still black topped. Therefore, there could not conduct public vehicles for long time after its construction.

An unforgettable road is 2.7 Km long Sankhu-Bajrayogini road. The road was constructed about four decade ago for making easy accessible through vehicles to Bajrayogini sanctuary, but it is still only on graveled condition. Due to which, pilgrims, as well as tourists feel very uneasy to reach to Bajrayogini sanctuary.

In the case of water supply, although data shows, most of the households are using water from the pipeline supply, only about 300 households (about 30%) in the city core and minimum number in rural area of three VDCs have their private taps. In one hand there is increasing demand of private water taps, on the other hand, there has become rare to see water on the public taps in the city core due to increase in number of private taps. Therefore, most people are suffering from the water scarcity in Sankhu. Despite having such fact, there is not any change in water supply system that was established during more than six decades ago in 2015-16 BS.

In the case of sewer line, three VDCs have developed three different sewerage systems in city core. All of them have no any kind of treatment and just have let to collect in the large septic tanks on the boundary of the city core. In the depth interview, leaders from the Sankhu told that it became impossible to apply integrated sewer line system mainly due to the division of Sankhu town into the three different administration units.

Hence, it shows that due to lack of such physical infrastructures, people did not show any interest on development of economic activities in Sankhu, rather they migrated to Kathmandu city for better opportunity. On being such lack of infrastructures, government budget and policy play major role. Therefore, it can be said that there was disparity in government budget and policy in the case of Sankhu.

Disparity on Government's Budget allocation

During the Panchayat period and early five years of revival of multi Party system, there was not system of allocation of budget for local governments. Only few amounts, i.e. 30 to 50 thousand rupees were allocated to each VDC until the year 2051 BS, only for the purpose of emergency activities. However, there was system of providing necessary budget to DDC if any particular development works should be done in rural area. On the other hand, municipalities hardly need to depend on central government's budget. They would have their own internal income sources. Hence, there was huge disparity between VDCs and municipalities until 2051 BS.

While comparing budgets of Sankhu (3VDCs) and KMC, it is found that Budget of Sankhu was only 90 thousand rupees in Fiscal Year2039/40 BS, whereas that of KMC was Rs. 18,483,511. If these are calculated in terms of per head, Sankhu had only Rs. 9 whereas KMC had Rs. 79. Similarly those of FS 2049/50 were Rs 14 and Rs 867 in Sankhu and KMC respectively.

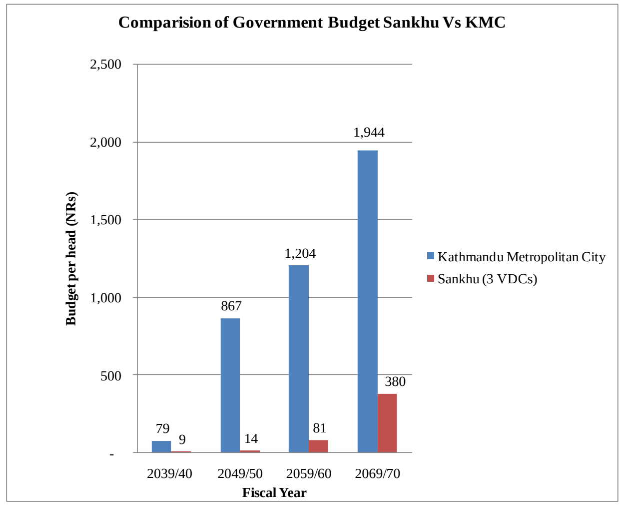

Figure 12: Government Budget

While testing variation of budgets by using statistical tool, T-test, the calculated T value is found to be 2.27, which is very larger than 1.943, the T-value for null hypothesis at 5% level of significance and 6 number of degree of freedom.. Hence, it is proved that there is disparity in budgets.

Of course, there were some projects of national interest, especially roads viz. Sankhu- Nagarkot road, Sankhu-Fatakshila road, that were conducted through Kathmandu DDC, and not included in above budget chart. Nevertheless, such types of projects were also in the boundary of KMC.

Disparity on Government Policy

It is obvious that Sankhu is the historic town in between Traditional trade route to Tibet. It was the shortest route to go to the Lhasa. Sankhu was working as custom center until few decades ago. Nevertheless, it was a service center as well as market center for the people of the Northeastern region of the Bagmati zone. Despite being this fact, government did not give any priority to the Sankhu. From the depth interviews with senior peoples in Sankhu, it is found that Araniko highway was firstly planned through the Sankhu because of its shortest distance, but it was constructed through Banepa and Sankhu was left to decline.

However, it had great potential to develop Sankhu as a satellite town of Kathmandu. If it would happen, Sankhu would be developed parallel to Kathmandu, but Government did not make any such policy. Moreover, it was left to divided position into three different administrative units rather than making as a unit. Although local peoples and leaders forced to make Sankhu as municipality, government did not show any interest for a long time, whereas government had announced several settlements as municipalities, which were more small and rural nature than Sankhu.

Nevertheless, government has been preparing several plans to manage the urban growth of Kathmandu. Like as, a first physical development plan of Kathmandu valley was finalized in 1969 to accelerate the urban development process of the valley. The plan aimed to preserve the historical and cultural heritage. The plan adopted the multi-nucleated regional growth strategy with linkage of dispersed settlements in the valley. The government promulgated a Town Development Implementation Act in 1972 to implement the plan. The Kathmandu Valley Town Development Committee (KVTDC) was formed under this act in 1976 in order to assign overall responsibility of planning and regulating urban growth in the Kathmandu valley (ICIMOD, 2007).

In 2002, the KVTDC prepared a Long Term Development Concept for Kathmandu Valley (Kathmandu Upatyakako Dirghakalin Bikas Avadharana - 2020). This plan focuses on developing Kathmandu as the central city core, Lalitpur and Bhaktapur as sub-city cores; surrounding satellite market centers (Gokarna, Thimi, Kritipur, and Harisiddhi as towns, Thankot, Tokha, Sankhu, Lubhu, Chapagaun, and Pharping as traditional settlements, and Nagarkot and Saibu Bhaisepati as nucleated centers.

Recently, on the concept of simultaneously developing all the three districts of the Kathmandu Valley, Government has formed the Kathmandu Valley Development Authority (KVDA) in April 2012, to give a shape to the idea envisioned over two decades ago in 1988. It has spent more than one year, but it is not being able to do anything more than continuation of road widening in Kathmandu and Patan cities. On the meeting with its official, it was found that government has made neither any action plan nor provided proper budget.

Hence, although such plans and policies mention about preserving the historical and cultural heritage, the multi-nucleated regional growth strategy with linkage of dispersed settlements in the valley, the action is not appeared in the case of Sankhu.

Due to lack of proper policies and action plans, Sankhu is not being able to grab the opportunities from its strengths. For instant, a black topped road through Sankhu has connected Melamchi and several trips of population go to Kathmandu through this route, but Sankhu is just watching them from the windows of buses.

Sankhu is just a representing case in the Kathmandu valley. There are several such historic settlements, which were suffered from intraregional disparity. Due to having such disparities, the historic important towns likely Sankhu lost their importance and registered as degraded towns on one hand, on the other hand, large cities Kathmandu and Patan suffered from high level of in migration and haphazard growth occurred there. Thus, government's disparity on policy and budget allocation did not become favor of any one neither large cities likely KMC and Patan, nor small towns likely Sankhu.

Of course, it is impossible to replay the history, but everyone should take lesson from the past. It is the fact that there were several mistakes from the government on different stages of development of capital city. Government aimed to do better for capital city and conducted several development works, but it forgot to analyze its impact over the other parts, for instant, impacts over the other small towns while constructing the Araniko highway. In future, government as well as planners should do such kind of impact analysis like as Environmental Impact Analysis (EIA) while conducting any projects. It has become more significant because Mid Hill Highway is on the top priority of the government.

In the case of Sankhu, there are still several potentials to develop socio-economic condition of the people. It can be developed if government gives little attention towards it.

Potential Analysis of Sankhu

It is obvious that Sankhu is seeking some economic uplifting programs. To launch any kind of programs, there need to find out its potentials so that program can be better effective. Based on analysis of the data available, and depth interviews with local peoples, the potentials of Sankhu can be listed out as follow.

Trade and Service center for eastern Kathmandu

It has been already mentioned that Sankhu was a trade center for eastern part of Bagmati zone. It is not possible to revive to such level, but it is possible to revive Sankhu as trade and service center for the population of eastern part of Kathmandu district. Due to concentration of social infrastructures and government services in the Kathmandu city, daily commuter to Kathmandu city has reached more than 3,000.

There are transport facilities on the routes Sankhu-Bhotechaur-Melamchi, Sankhu-Nangle-Melamchi and Sankhu-Nagarkot, but the passenger go direct to Kathmandu rather than halting in Sankhu. If Sankhu can be developed as service and trade center only filtered people need to go to Kathmandu city.

Moreover, if there are established service center for eastern Kathmandu, all people from villages at east of Bagmati river will need to visit Sankhu. Government just has started this kind of facility by establishing District Administration Office of Kathmandu for Northeastern area. Like as that office, if Land reform and Land registration office, a good hospital, and campus with several faculties can be established in Sankhu, in-coming people will increase and out-going will decrease.

Agricultural development

Sankhu region is known as best for production of paddy and potato, hence their demand is always on the top position. Sankhu export daily 15-20 ton of potato in average for three months during its season from Chaitra to Jestha. From last two decades, this region has been producing such potatoes also in Mangsir and Poush months.

Due to having good demand of its rice, Sankhu supply high amount of rice to Kathmandu and Patan, whereas farmers import low priced rice for them.

Nevertheless, Sankhu region is also suitable for farming other types of vegetables, likely tomato, skush, Pumpkin and several others. From last few years, some have started commercial tomato farming by taking lands on lease.

Despite having great potential of agricultural production, farmers always feel unsafe to invest on agriculture, and they are just doing on traditional way rather than taking it as profession. Therefore, they are not being able to achieve profit from the farming. Some of the reasons behind such factor are:

- Lack of proper training
- Lack of Irrigation
- Lack of seeds of good quality
- Lack of fertilizers
- Lack of awareness towards commercial farming
- Lack of Cold Storage, due to which farmers need to sell their production on lower price

Tourism development

Sankhu has great potential of tourism development. Mainly Sankhu might develop three kinds of tourism for national and international tourists.

Religious Tourism

Bajrayogini Sanctuary is taken as equally important for both of the Hindu and Buddhist pilgrims. Similarly, Salinadi is the holy destination for the Hindu pilgrims. There is the possibility of increasing of foreign Buddhist pilgrims in the Bajrayogini sanctuary. Similarly, Hindu pilgrims will be increased if it get publicity and good access to there.

On the other hand, pilgrims use to come to Salinadi only in one month of Magh mela. There can be seen no one pilgrims at rest of eleven months throughout the year. It is possible to develop Salinadi as destination forever, apart from Magh mela.

Research Tourism

Since being historic town, here are still remaining traditional cultures, urban fabrics, devotional songs etc. Town was planned with Ashtamatrika, Ganesh temple at every tole etc. Here, we found about sixty stone inscriptions. Beyond the town, Bajrayogini sanctuary has ancient history, which is also joined with the formation of livable valley from the lake. Salinadi and Swasthani/ Madhav Narayan Brat have linked with myths rather than history. Therefore, The Sankhu town and region might be destination for researchers of history of Nepal, traditional socio-culture, agriculture, ecology etc. Bajrayogini jatra itself might be a research topic.

Leisure Tourism

Apart from the religious space, Bajrayogini area is considered also as leisure space to celebrate picnics. On the study, it is seen that, the people of valley go to temples, picnics, parks, cinemas, theatres etc. at the leisure time. They go to temples not only inside the valley but also outside the valley for mainly religious purposes. Same way, they go to celebrate picnic at distant places.

Tea Farm with excellent views of Himalayas at Jaharsinghpauwa is another advantage of Sankhu area. People whoever want to go to Ilam to see he tea farm, but has not got such opportunity, can go to Sankhu to achieve that opportunity.

5. Conclusion and Recommendation

In the modern age, government could not recognize the traditional functional relations between the several settlements in the Kathmandu valley and focused only on larger cities on the name of urban development, and hence there remained intraregional disparity. Intraregional Disparity is the main cause as well as effect of deterioration of historic small towns in Kathmandu valley.

There are several historic towns and cities in national as well as international level, which are deteriorated with the time of modern science and technology. For instance, here are several towns in the Kathmandu valley and its surroundings that were functioning on their traditional way, viz. Tokha, Lubhu, Nala, etc., and declined with modern age. Similarly, Manchester city declined after invention of modern technology on industry, but it revived after having its regeneration. Similarly, Bhaktapur city was badly degraded after construction of Araniko highway. Bhaktapur could not achieve any profit from that road despite having that road on its own southern border. However, Bhaktapur could get its life back after the Bhaktapur Development Project (BDP), and now, it is considered as best town in the valley. Another example can be the Bandipur town in Tanahun district. That town was badly degenerated after construction of Prithvi Highway by bypassing it. After regeneration with some social infrastructures, now, it has become an example of regenerated towns. From these experiences, it is easy to say that there is possible to revive such degenerated towns if there are available proper policies as well as investments.

Based on the analysis, here has made recommendations regarding some about policies and some about action plans as well.

Recommendation on Policy Level

i. To minimize the socio-economic disparity in the Kathmandu valley, government should take Kathmandu valley as a single body and all the historic settlements as its important parts.

ii. For this, Kathmandu Valley Development Authority might be a responsible government body, so it should be fully functional as soon as possible.

iii. It is heard about Kathmandu valley as a single metro-city. It might be a solution to decrease disparity.

iv. The historic settlements should be considered as nation’s valuable property and hence they should be conserved.

v. Government should aim to develop such historic towns as satellite towns to decrease pressure in the large cities.

vi. In the particular case of Sankhu, division of Sankhu into three different administration units has created several problems on development works in Sankhu. Therefore, Sankhu should be functioned as municipality as soon as possible.

Recommendation for Action Plan in Sankhu

It has been proved that there are very low level of economic activities in the Sankhu and that resulted socio-economic disparities. Hence, Sankhu is looking for an integrated action plan regarding its economic development. Therefore, it will be better to recommend an integrated economic development plan by integrating mainly three sectors, viz. Trade and Service, Agriculture, and Tourism.

Economic Development Plan

- Development of Sankhu as Satellite town
- Agriculture Development
- Tourism Development

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Removal of Pb (II) from Aqueous Solutions using Activated Carbon Prepared from Lapsi Seed Stone by Chemical Activation

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***Abstract*: Activated carbon prepared from Lapsi seed stone by chemical activation with phosphoric acid was studied as an adsorbent for Pb (II) removal from aqueous solution. The activated carbon was characterized by Iodine number, SEM and FTIR.Batch adsorption experiments were carried out to describe the effect of pH and contact time on the metal removal process. The optimum pH and contact time for the removal process was found to be 5 and 180 min respectively. Langmuir and Freundlich adsorption isotherm models were used to explain the equilibrium data. Langmuir model best described the data with higher value of coefficient of determination as compared to that of Freundlich isotherm.**

Keywords: Activated carbon, Chemical activation, Adsorption isotherm, Lapsi seed stone, Lead.

1. INTRODUCTION

Heavy metal ions such as copper, iron, nickel, lead, cadmium etc in the environment are of major concern due to their toxicity to human beings. Unlike organic pollutants, which are susceptible to biological degradation, the metal ions do not degrade into any harmless end products [1] and tend to accumulate in living organisms, causing various diseases and disorders [2]. In recent years there has been an increased concern over the content of lead in drinking and natural water.The World Health Organization (WHO) recommended a limit of 0.01 mg L^{-1} of lead in drinking water [3]. Lead is highly toxic and cumulative poison. Being nonbiodegradable it accumulates in bones, brain, kidney and muscles. Lead when exceeded WHO limit in drinking water causes severe damage to kidneys, nervous and reproductive systems, liver and brain [4].Therefore a very low concentration of lead in water is very toxic. [5]. The removal of such a heavy metal from contaminated water bodies has been attempted by several scientists employing a wide variety of techniques including chemical precipitation, chemical oxidation or reduction, filtration, ion exchange, electrochemical treatment, membrane filtration, reverse osmosis and adsorption. However, most of these technologies are either expensive for the treatment and disposal of the secondary toxic metal sludge or ineffective when lead is present in the wastewater at low concentrations [6]. Among various techniques, the adsorption process has been used exclusively in water treatment and many studies has been carried out to find inexpensive and chemico-physically feasible adsorbent .Many reports have appeared on the development of low cost activated carbon from cheaper and readily available materials. There are a quite large number of studies regarding the preparation of activated carbons from agricultural wastes [7], fruit stones [8],hard shell of fruit stones [9] ,oil palm waste[10] ,agricultural residue from sugarcane [11], rice husk [12] , peanut[13] , sawdust [14] , coconut shell [15] , palm shell[16] , hazelnut husks[17] etc. have been tested in the production of activated carbon in developing countries. The use of these raw materials in carbon production shows from the past studies that they are available at low cost, contain high carbon content and may be effective in the removal of heavy metals. Number of fruit stones such as cherry stones, apricot stones [18], olive stones [19], dates stones [20], peach stones [21], sea-buckthorn stones etc.have also been used for the production of activated carbons.

Most of activated carbons are prepared by a two- stage process carbonization followed by activation. The first step is to enrich the carbon content and to create an initial porosity and activation process helps in enhancing the pore structure. The activation can be carried by two different processes physical and chemical. In physical activation carbonization and activation are carried out separately. The carbonization so called pyrolysis is carried out at high temperature in inert atmosphere in order to eliminate maximum of oxygen and hydrogen elements. The second one is thermal activation at the same temperature for pyrolysis or at a higher temperature in the presence oxidizing gases steam or carbon dioxide or both [22]. By chemical activation it is possible to prepare activated carbon in only one step. Pyrolysis and activation are carried out simultaneously in the presence of dehydrating agents (e.g. $ZnCl_2$, H_3PO_4, H_2SO_4, KCl etc) [23].In this study preparation of activated from Lapsi Seed Stone by chemical activation with phosphoric acid was carried out.

Lapsi seed stone is the waste product of Lapsi fruits. (Lapsi) *Choerospondias axillaris* belongs to the family Anacardiaceous. It is a large, fruit bearing deciduous tree native to the hills of Nepal (865-1900m). Lapsi fruit is consumed fresh, pickled or processed into a variety of sweet and sour fruit products locally called “Mada” or“Titaura”. It is a rich source of vitamin C. It is also believed to aid in digestion and is often consumed after a protein rich meal. Seed stones are used as fuel in brick kilns in the factories and the trunk of the tree is used as fuel wood and timber [24, 25, 26] Iron impregnated activated carbon prepared from Lapsi seed stone had been investigated for the removal of arsenic from water [27]. In this study, activated carbon developed from Lapsi seed stones have been used for the removal of Pb (II) ions from aqueous solution since the stones are readily available and can be used as a viable adsorbent for the removal of heavy metals.

2. MATERIAL AND METHODS

2.1. Preparation of Adsorbent

The precursor used for the preparation of activated carbon in this study was seed stone of Lapsi fruits which were collected from Kalimati market, Kalimati, Kathmandu. The fruits were stripped for the pulp by boiling to expose rigid centres or stones. The seed stones were washed several times using tap water and then distilled water to remove impurities, dried at 110ºC for 24 hours and crushed with mortar and electric grinder. The crushed particles were then sieved to obtain the fraction 300 mµ.The particles were mixed with 50% H_3PO_4 in the ratio of 1:1 and dehydrated at 100 ºC for 24 hours in a hot box oven and then carbonized at 400 ºC for four hours in a horizontal tubular furnace under flow (75 ml / min) nitrogen. The resultant activated carbon was cooled at room temperature and was washed several times with hot distilled water. The washing was tested with lead nitrate for the detection of phosphate ions. The material was then dried at 110 ºC for 24 hours ,cooled and sieved to obtain the particles of size 106 µm.The activated carbon was indicated as PAALSSC and used for adsorption study.

2.2. Chemicals and Instruments

All chemicals and reagents were of analytical grade (Merck and Qualigen Company). Stock solutions of Pb (II) were prepared from lead nitrate in distilled water. Digital pH meter was used to measure the pH values of the solutions. The adsorption experiments were carried out by using Shaker (Digital VDRL Rotator-RPM-S.)The concentrations of lead (II) were determined by atomic absorption spectrophotometer (AAS –VARIAN-AA240FS). Solutions of 0.1 M NaOH and 0.1 M HNO_3 were used for pH adjustment. All the working solutions were prepared by diluting the stock solutions with distilled water.

2.3. Adsorption Experiments

Batch experiments of adsorption were performed in 50 ml stoppered conical flasks .The flasks were being agitated on Digital VDRL Rotator- RPM-S at 225 rpm for identified time intervals. The effect of contact time and solution pH was studied. Each experiment was carried out by suspending 0.025 g of adsorbent in 25 ml adsorbate solution taken in the conical flasks under the optimum conditions set out for the experiments. Since pH is a critical parameter in the process; therefore pH of the solutions was adjusted by addition of NaOH and HNO_3.

The effect of pH and contact time on the adsorption of Pb (II) by PAALSSC at different pHs and time points was studied using 25ml of Pb (II) 50 mg L^{-1} at room temperature. The optimum pH and time for the adsorption was confirmed from above experiments.

The uptake of metal ions in solution was calculated by mass balance equation as given below:

$$qe = \frac{(Co - Ce)V}{W} \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where C_o and C_e are initial and equilibrium concentration of metal ion (mg / L) respectively, W, the mass of adsorbent in gram (g) and V is the volume of the solution in litre (L).

The percentage of removed metal ions (*Rem %*) in solution is calculated by using following the formula.

$$\text{Rem}(\%) = \frac{(Co - Ce)}{Co} * 100 \ldots\ldots\ldots\ldots\ldots 2$$

3. RESULT AND DISCUSSION

3.1. Effect of pH

The pH of the aqueous solution plays an important role and influences on the metal speciation in aqueous solution as well as the surface properties of adsorbent and therefore can affect the extent of adsorption [30]. So the adsorption behaviour of Pb (II) on PAALSSC has been studied over a pH range of 2-7 at room temperature (Figure 1).

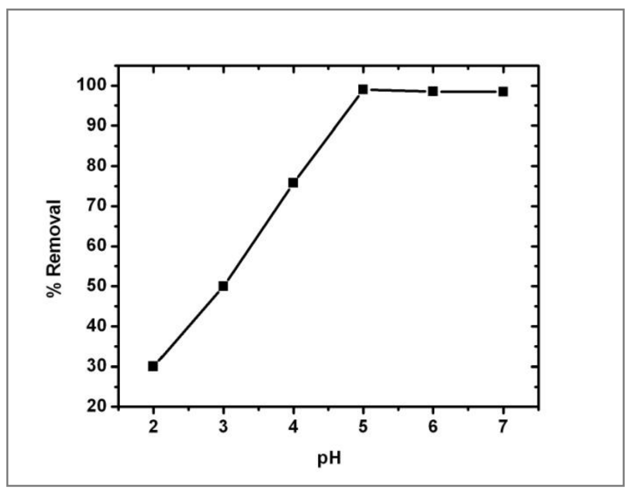

Figure 1: Effect of pH on the adsorption of Pb(II) ions onto PAALSSC

Higher value of pH was not tested due to lead hydroxide that could be formed as a solid phase precipitate. The percentage of Pb (II) adsorption on PAALSSC increased with increasing pH and reached a plateau value at pH range 5-7.Below and above these pHs the adsorption was decreased.

3.2. Effect of Contact time

The effect of contact time on metal ions removal is shown in Figure2 which shows that the adsorption rate was very fast initially about 58.2 % during first 30 minutes. The fast adsorption at initial state may due to the higher driving force making fast transfer of metal ions to the surface of adsorbent particles and availability of the uncovered surface area and the active sites on the adsorbent. With further increasing time the availability of the uncovered surface area and the remaining active sites diminishes and decrease in driving force makes it to take long time reach equilibrium for metal ions slowly diffusing into the particle pores of the adsorbent.

Thus adsorption rate becomes slower. It has taken 180 minutes to reach equilibrium for PAALSSC.

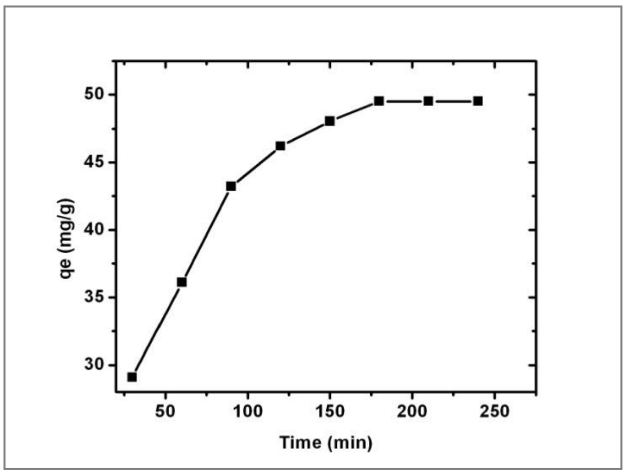

Figure 2: Effect of contact time on adsorption of Pb(II) onto PAALSSC

3.3. Surface chemistry

FTIR study confirmed the presence of oxygenated functional groups in PAALSSC. The spectrum of PAALSSC is shown in Figure 3.The bands at about 1560 cm^{-1} and 1718 cm^{-1} are attributed to v (CO) vibrations in carboxyl groups. The bands at about 1000- 1220 cm^{-1} are attributed v (O-H) vibrations in hydroxyl and phenolic groups. Two bands at about of 1206 and 1718 cm^{-1} are attributed to carboxyl groups. It is obvious that the main oxygenated groups present in PAALSSC are carbonyl, ethers, alcohols, carboxyl, lactonic and phenolic groups.

The prepared activated carbon was examined by scanning electron microscope (SEM) to analyse the surface of the adsorbent. The SEM image of PAALSSC is shown in Figure4. Well developed porous surface was observed at higher magnification of the adsorbent. The pores observed from SEM image are having diameter in micrometer (μm) range. From the figure it can be observed that the adsorbent has smooth surface and a variety of randomly distributed pore size.

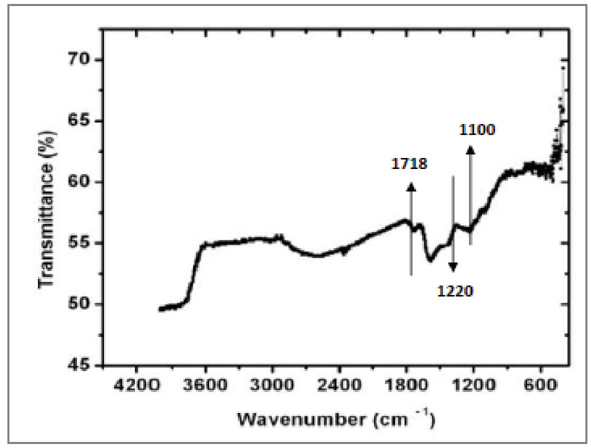

Figure 3: Fourier-Transform Infrared spectra of PAALSSC

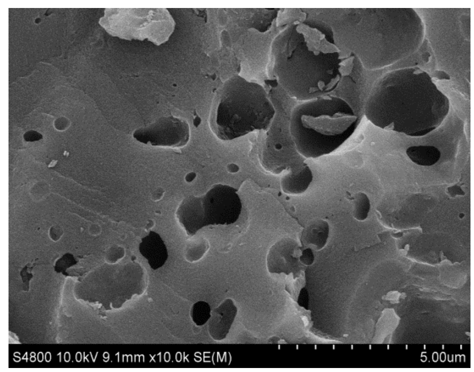

Figure 4: SEM image of PAALSSC

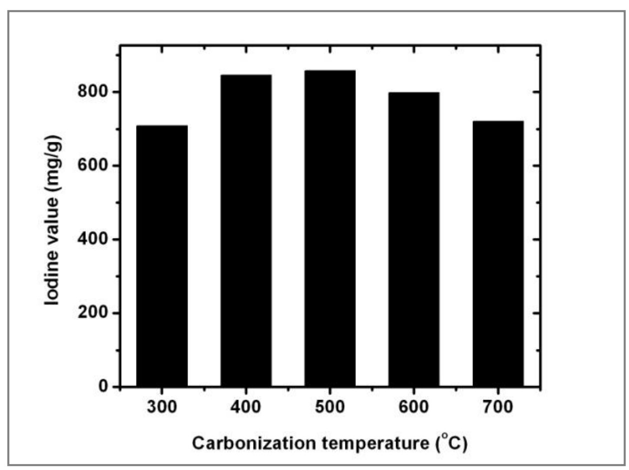

Figure 5: Effect of carbonization temperature on Iodine value

Iodine number is the most fundamental parameter used to measure activated carbon performance in terms of acitivity.The higher the value of iodine number, the higher will be the degree of activity of the activated carbon. Thus iodine number was measured to evaluate adsorptive capacity of the carbon sample produced after activation. The values of iodine number at different carbonization temperature are shown in Fig -5.

3.4. Adsorption isotherm

The adsorption isotherm shows how the adsorbate molecules distribute between the liquid and solid phase when adsorption reaches an equilibrium state [28]. Several isotherm models have been published in the literature to describe experimental data of adsorption isotherms. The Langmuir and Freundlich models are frequently used models [29].Here both the models are used to describe the relationship between amounts adsorbed and equilibrium concentration in solution at room temperature for 3 hours. The adsorption isotherms were determined at room temperature for a concentration range 50- 250 mgL^{-1}.

3.4.1. Langmuir isotherm

Langmuir assumed that adsorption occurs uniformly on the active part of the surface and when a molecule is adsorbed on an active site, the other molecules could not be interacted with this site.

$$qe = \frac{bqmCe}{1+bCe} \qquad \text{(Non-linear form)... … …3}$$

$$\frac{Ce}{qe} = \frac{1}{bqm} + \frac{Ce}{qm} \qquad \text{(Linear from)... … …4}$$

Where Ce is the equilibrium concentration of the adsorbate (mg/L) and qe is the amount of the adsorbate adsorbed under equilibrium while qm is the monolayer adsorption capacity (mg / g) and b is the Langmuir constant. Langmuir constant and adsorption capacity are determined from the slope and intercept of the plot Ce/qe versus Ce as shown in Figure 5.

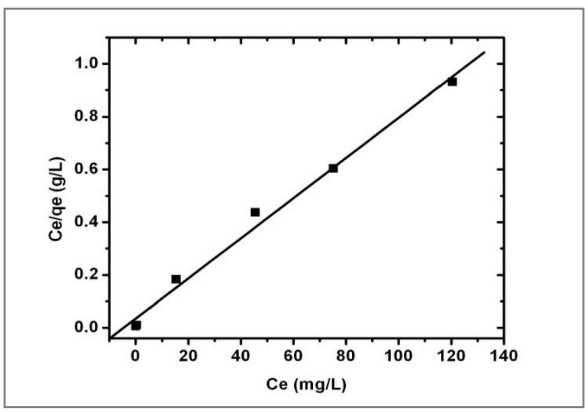

Figure 6: Langmuir adsorption isotherm of Pb(II) onto PAALSSC

3.4.2. Frendlich isotherm

Freundlich isotherm is an empirical equation which describes the heterogeneous adsorption and assumes that different sites with several adsorption energies are involved. Freundlich isotherm may be written as:

$$qe = K_f Ce^{1/n} \qquad \text{(Non –linear form)… … … 5}$$

$$\log qe = \log K_f + \frac{1}{n}\log Ce \text{ (Linear form)… … …6}$$

Where Kf and n are Freundlich constants related to adsorption capacity and adsorption intensity respectively. From the slope and intercept of straight portion of the linear plot obtained by plotting log qe versus log Ce, the values of Freundlich parameters can be calculated.

Langmuir and Freundlich constants are given in table-1 .Figures-6 and 7 show that the isotherm data better fits the Langmuir equation than Freundlich equation since the value of coefficient of determination (R2 = 0.99542) is higher than that of Freundlich isotherms (R2 =0.9775).

This supports the theory that the number of active sites on the carbon surface is limited and uptake of lead ions forms a monolayer on the surface.

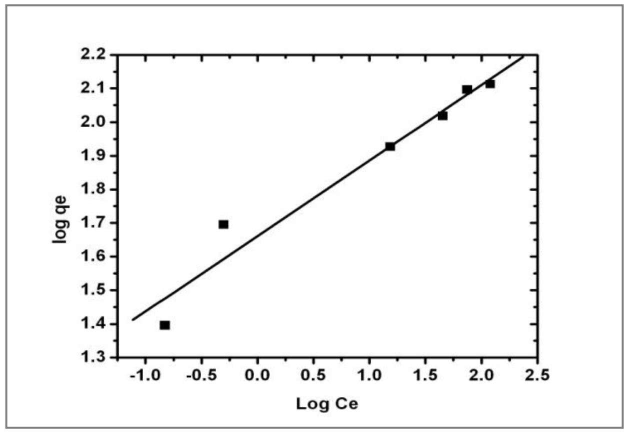

Figure7: Freundlich adsorption isotherm of Pb(II) onto PAALSSC

Table 1: Langmuir and Freundlich constants for lead adsorption onto PAALSSC

Adsorbent	Langmuir			Freundlich		
	b	q_m (mg/g)	R^2	$\log K_f$	1/n	R^2
PAALSSC	0.22	131.4	0.995	1.66	0.23	0.977

4. CONCLUSION

Activated carbon prepared from Lapsi seed stone by chemical activation with phosphoric acid was employed as an adsorbent for removal of lead (II) ions from aqueous solution. The adsorption of Pb(II) is found to be greatly dependent on the pH of sample solution and its concentration. Equilibrium data fitted very well in the Langmuir isotherm equation, confirming the monolayer adsorption capacity of lead (II) with adsorption capacity 131.40 mg/g. The result demonstrated that the PAALSSC from Lapsi Seed Stone is expected to be economically feasible for the removal of lead (II) ions from aqueous solutions. The adsorbent is in a good way of a promising low-cost adsorbent for Pb (II) removal.

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Earthquake Emergency Road Network: Framework for Prioritization of Road Network in Emergency Response, A Case Study of Lalitpur – Ward No. 12

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Abstract: **Transportation is the spine for the development of every nation. In Nepal, road network holds that role. Concerning many disasters, Nepal could not escape from earthquake, as it has carved its destructive events in its history till to-date. Great earthquakes of Nepal like of 1934 and 1988 have caused huge damages to every sector including road networks. Road networks vulnerability is the major obscurities in post disaster phase especially at the first 72 hours of rescue. Being on the lap of seismic prone country and existence of haphazard urban setup, situation will be perilous in Kathmandu Valley aftermath of earthquake. Thus, study focuses on road network accessibility for rescue operation.**

In the study, Inversion Hierarchical Weight Process (IHWP) – method used in Tehran for accessing road vulnerability, has been tested in piloted area of Lalitpur - ward no.12. Piloted area comprises of traditional settlements with high influence of modern structures with narrow and wide access roads. This setup resembles most of the core area of Kathmandu Valley. Thus, it manifests to develop the framework for prioritization of road network in emergency response phase.

Further, by analyzing road vulnerability, road blockage and priority routes in the piloted area, road networks have been prioritized. After conducting task on the area, framework for road network prioritization for emergency response in earthquake scenario has been developed which could be used in other urban sector of Kathmandu Valley for the same purpose.

Key Words: Road Vulnerability, Emergency Response, IHWP, Framework

1. Introduction

Transportation infrastructure is one of the communicating medium. In context of Nepal, road networks hold prime importance in this sector. There are basically nine different types of roads (NRS- 1998) that have embellished Nepal. Time and again, these embellishments have been affected by earthquake. Earthquake of 1988 has portrayed this fact reflecting both functional as well as physical impacts. These impacts account much in emergency response phase. Inaccessibility to the affected area due to debris on road network has imparted loss of lives in Haiti and result could be same in context of Kathmandu Valley too. Therefore, road network accessibility has prominent role in emergency response phase. These are generally termed as **Emergency Road Network**. Physical characteristics of this sort of road is basically govern by width of the road, redundancy, selection of the road avoiding man-made hazards as well as tall constructions and less selection number. Similarly, vulnerability of road network is basically governed by building vulnerability, road vulnerability and road blockage as well.

For the purpose, study area has been selected in the Lalitpur municipality Ward number 12. As per ward profile, this ward occupies 82 hectares of lands. Part of the community from Tangal to Lagankhel stretch has been considered. As the study focuses on accessibility, road stretches surrounding the study area and along ward 5, 15 and 19 has been considered as the study area.

Figure 1 : Study Area

Existence of mixed residential area incorporating old and new buildings alongside the road stretches; variation of road typologies ranging from alleys till black top road network and mixed land use pattern such as residential and commercial including street vendors has made the area vulnerable in aftermath scenario. On the other hand, Ward Report as well as report by NSET on ward number 12 has depicted on the fact about earthquake vulnerability of the area. Due to this reason area has been selected for the study. Figure below gives the glimpses of the area.

Figure 2: Alleys

Figure 3: Black Topped road

Figure 4: Mixed Land use

2. METHODOLODY

Research holds Positivist Paradigm as research is based on quantitative and some qualitative analysis. Quantitative Approach has been carried out to collect and analyze the current situation of the study area on road networks regarding earthquake emergency response. Further, data has been analyzed through various calculations. Research holds Deduction logic to analyze quantitative data through IHWP- method. Further, Induction logic has been considered to develop framework from the analyzed data.

Research has been conducted with all 225 numbers of buildings presented over there as each building accounts a lot in blockage of road network. Further, study has been processed following five steps such as Connectivity, Building Vulnerability, Road Vulnerability Rank, and Road Network prioritization for rescue, Road Blockage Analysis, Prioritization of road network for response operation and finally framework for prioritization of road network in Emergency Response has been developed.

3. RESULTS

Connectivity

Connectivity of the study area till open space and hospital has been considered in the study as these are the important response function in aftermath scenario. So, road matrix from community area till Namuna Machhindra School and Patan hospital has been considered. These places have been approached in the area through two stretches from Ity tole and Lagankhel tole respectively following redundancy characteristics of emergency road network. Road stretches that connects those places holds different characteristics as portrayed in Table 1 below:

Table 1 : Road Typology

Road ID	Road width	Road length
R1 (Tangal – Prayakpokhari)	6'-11"	564'-9"
	11'-2"	
	5'-1"	
R (Prayakpokhari)	5'-3"	162'-3"
R2 (Prayakpokhari)	15'-4"	612'
R3 (Tangal – Lagankhel)	14'-6"	306'-9"
R4 (Thati tole-Lagakhel bus park)	17'-7"	849'-5"
R5 (Ity tole-Patan Hospital)	26'-4"	600'-3"
R6 (Ity tole Stretch)	16'-3"	584'-5"
R7 (Lagankhel)	36'-11"	553'-8"

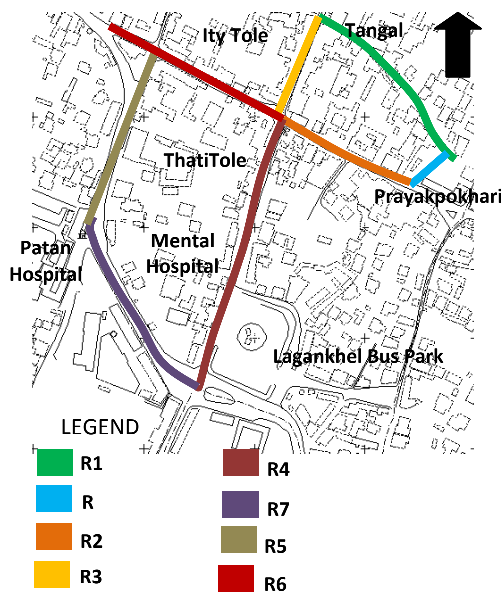

Figure 5: Road Typology

Building Vulnerability

Study area has been shaped with both old and new buildings ranging from adobe, brick in mud, brick in cement and reinforced buildings. According to the study carried out in the area through Rapid Visual Assessment tool, it has been found that each stretch holds more than 40% of vulnerable buildings. Among them, road R and R6 holds maximum vulnerable buildings.

Road Vulnerability Rank

Road Vulnerability Ranking has been carried out through IHWP-method that has been referenced through Tehran document. This method is applied when single entity has to be judge by multiple indexes. Indexes considered here are building quality, population and building density, inclusion degree, land use and PGA. These indexes have been ranked according to their importance as per expert's view and reverse scoring has been given accordingly. Table below portrayed the scenario:

Table 2: Indexes Ranking

Indexes	**Rank**	**Reverse score**
Building Quality	1	6
Building Density	2	5
Population Density	3	4
Inclusion Degree	4	3
Land use	5	2
PGA	6	1

Further, each index has been classified as per surveyed data and score of each class has been calculated through formulae presented below:

Primary Score, X = D/N

where, D = Reverse Score based on its rank

N = Number of classes of each indexes

Score for different classes of index,

j = D – (N – i) * X

where, i= Assigned number to different classes of each index

Calculated score for each class of indexes are presented in Table 3 below:

Table 3 : Indexes Classification

Indexes	**Classification**	**Score**
Building quality	0-0.4(1)	2
	0.4-0.8(2)	4
	0.8-1 (3)	6
Building density	0-0.0.1(1)	1.25
	0.1-0.2(2)	2.5
	0.2-0.3(3)	3.75
	0.3-0.4(4)	5
Population density	0-2(1)	1.33
	2-3(2)	2.67
	3-4(3)	4
Inclusion degree	0-1.0(1)	0.6
	1.0-2.0(2)	1.2
	2.0-3.0(3)	1.8
	3.0-4.0(4)	2.4
	4.0-5.0(5)	3
Land use	Low risk(1)	0.67
	Medium risk(2)	1.33
	High risk(3)	2
PGA	300	1

Based on these criteria, road vulnerability ranking has been carried out and data portrayed the following facts:

Table 4 : Road Vulnerability Rank

Road ID	**Road Vulnerability Rank**
R3	1
R2	2
R1	3
R6	4
R4	5
R	6
R5	7

Road Network Prioritization for rescue

Primary concern on rescue operation is to save life of the people. During this phase main obscurities will be vulnerable buildings and land use pattern of the area. So, concerning these factor roads has been prioritized in the study area and a result has been accounted in Table 5 below:

Table 5: Road Priority Rank

Road ID	**Road Priority**
R3	1
R2	2
R4	3
R5	4
R1, R6	5
R	6

Road Blockage Analysis

Road accessibility is accounted by the presence of vulnerable buildings along its side. Road blockage relates to the one third of the height of the vulnerable building. Based on this data, it showed the following facts (Table 6):

Table 6 : Road Blockage Analysis

Road ID	Accessibility
R1	Inaccessible
R	Inaccessible
R2	Accessible
R3	Accessible
R4	Accessible
R5	Accessible
R6	Accessible

Prioritization of road network for response operation

Different criteria have given different value and different priority. So, comparative analysis of road vulnerability, priority and accessibility has been carried out to figure out the road prioritization. Result has been depicted as:

Table 7 : Comparative Analysis

Road ID	Vulnerability Rank	Priority Road	Accessibility
R1	3	5	Inaccessible
R	6	6	Inaccessible
R2	2	2	Accessible
R3	1	1	Accessible
R4	5	3	Accessible
R5	7	4	Accessible
R6	4	5	Accessible

Priority Road for debris removal

Data has shown that road R3 holds high priority for rescue activity. But at the same time road vulnerability of R3 is high and it is impassable due to debris coverage. Therefore, as per the priority this section of the road must be cleared first.

Priority Road for Rescue Activity

Data portrayed that road R5 and R6 holds least priority for rescue activity with low vulnerability and are accessible so following road matrix has been selected as:

- **Road matrix R6-R5** has been selected for the passage towards **hospital**
- **Road matrix R4** has been selected for the passage to open space

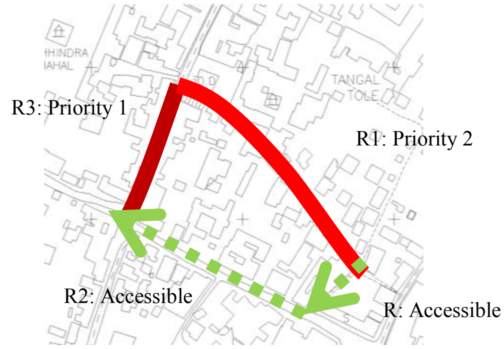

Figure 6 : Road Blockage analysis

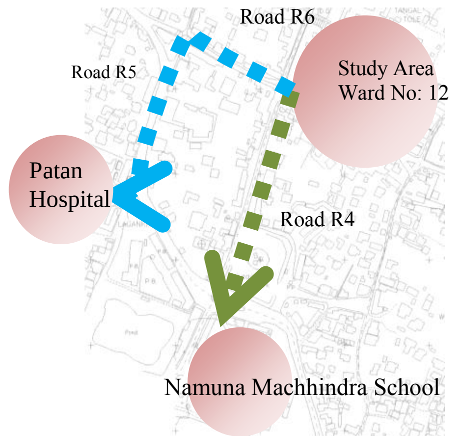

Figure 7 : Priority Route for rescue operation

3. Conclusion and Recommendation

Analysis has shown that IHWP- method is one of the methods that can be used for road vulnerability assessment. Based on the study carried out, framework for prioritization of road network for emergency response has been developed to figure out the priority routes in other urban sectors of Kathmandu valley. Recommended framework for prioritization of road network for emergency response has been presented in Figure 8 below:

This framework will be applicable for the urban area holding following characteristics:

a) Core urban area with conglomeration of modern buildings

b) Area holding all five types of buildings like AD, BC, BM, RC3 and RC5

c) Urban area holding different types of road typology ranging from alleys, under ways till main roads

d) Area holding less or no traffic flow

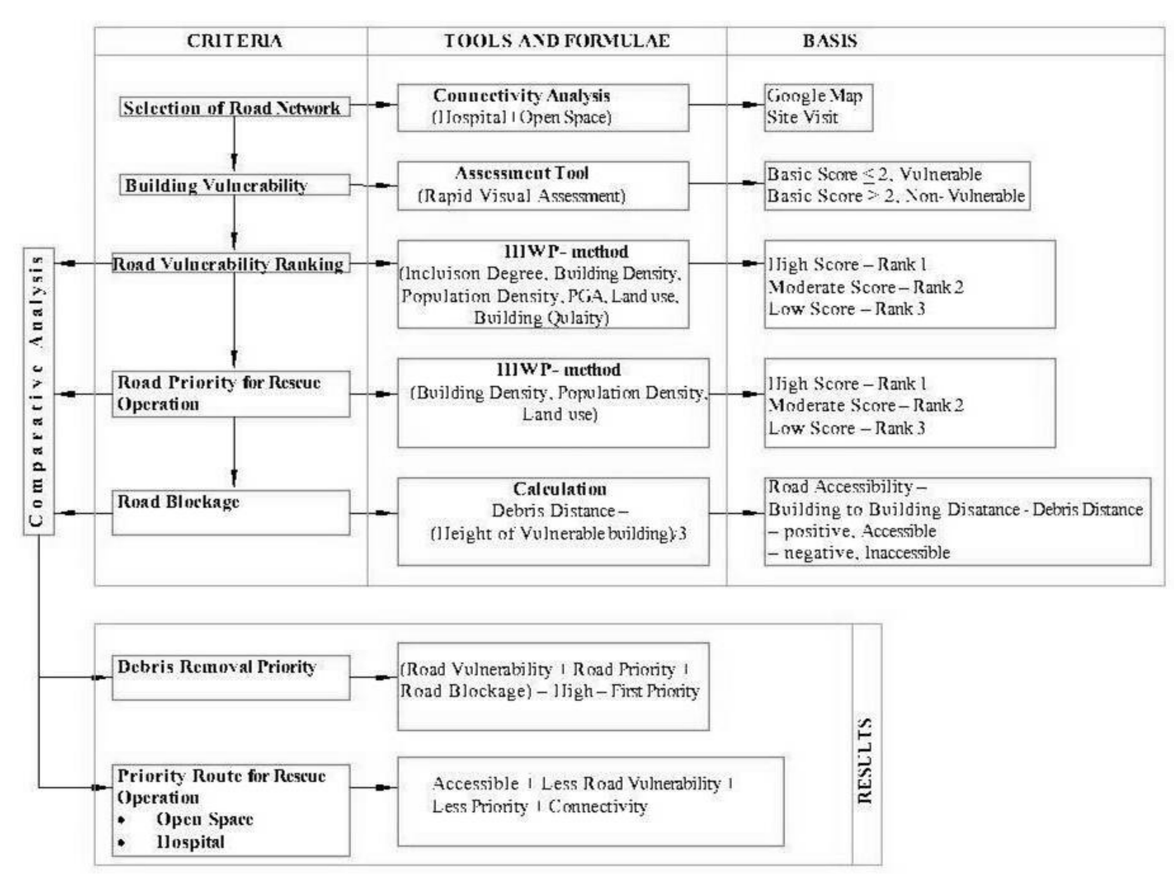

Figure 8 : Framework for road network prioritization in Emergency Response

Henceforth, the framework for road network prioritization has been developed from post disaster earthquake point of view to facilitate quick accessibility in aftermath scenario. This framework can further be used to prioritize road network in other urban sector of Kathmandu valley holding similar urban characteristics as that of the piloted area.

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Study on the Effect of Implementing Best Available Technology in Cement Industries of Nepal

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***Abstract*: In the context of Nepal, cement industry has shown a continuous growth from 1990 to 2010. Present production capacity of cement being 2.0 million metric ton is expected to reach 5.8 million metric ton, with a cumulative cement demand of 73.5 million metric ton, from 2011 to 2030. In this study, benchmarking of different energy consumption pattern in cement industry is conducted and later the average values were used for scenario base modeling analysis. This paper highlights the effect of introducing different energy efficient technology in the current cement industry during 2015 to 2030. The energy efficiency measures including the effect of Waste Heat Recovery for Power Generation (WHRPG) and the use of alternative fuels were studied. The energy demand in cement industry is expected to grow rapidly from 5.02 PJ in 2010 to 16.7 PJ in 2030. This is followed by the increase in the greenhouse gas (GHG) emission from 381 thousand tCO_2e to 1.28 million tCO_2e during 2010 to 2030 in the industry. With the strategic option of efficiency improvement in the current industry and implementation of best available technology, up to 36% of the cumulative primary energy demand and up to 37% of the cumulative GHG emission can be reduced during 2010 to 2030. With the implementation of WHRPG in the cement industry can be an alternative way to provide electricity during the peak load, when the grid supply is insufficient. The potentiality of WHRPG and alternative fuels has been studied to address issue of future energy security and sustainability of cement industry.**

Keywords: Cement industries; Energy consumption; Energy savings; Waste Heat Recovery; Alternative fuel; CO_2 emission

1. Introduction

Industries considered as backbone of the national development are facing different energy related problems at present in Nepal. Industrial sectors in the country account for 3.3% (13369.8 TJ) of the total primary energy demand, after residential and transport sector in 2010 [1]. However, due to the energy crisis, the energy demand has not been adequately fulfilled. Hence, it is necessary to develop appropriate framework for future energy security along with issues regarding GHG emission and climate change.

Nepal is a developing country with huge potential of investment in the sectors like agriculture, cement and hydropower. Industrial development in Nepal is at a pre-mature state and requires lot of technical and financial investment. Cement industry is one of the potential industries to grow in the future, mainly because of the availability of untapped limestone and increasing developmental activities. Nepal has 1.07 billion potential limestone reserve out of which 720 million metric tons is favorable for cement production. At current the annual demand for cement is 4 million metric tons, with domestic industries fulfilling up to 70% [2]. Moreover, development activities and commercialization would make a greater impact on the demand of cement in the domestic market.

Currently, there are 40 industries operating throughout the country. 14 industries produce clinker whereas 26 are clinker grinding industries. The grinding industries rely on the domestic and imported clinker. For the past four years (2009 to 2012) the cumulative clinker import was around 5 million MT worth around NRs. 30 billion [3]. A total of 7 rotary plant and 9 VSK plants are currently in operation.

2. Literature Review

With the increasing concern toward energy security and environment issues, new technologies have been introduced and conceived in different energy intensive industries especially in the developed countries. Being an energy intensive industry there are numerous areas for increasing energy efficiency and reducing emission.

2.1. Cement manufacturing process

Cement manufacturing include intensive process with throughput at different stages of raw material processing. Raw materials should be mixed precisely to manufacture cement. Cement manufacturing includes first the production of clinker from the raw mix composed of mined limestone, iron ore, bauxite, clay and coal. The cement clinker requires appropriate amount of compositions of the elements calcium, silicon, aluminum and iron. All these raw materials together with the fuel ash must be combined to form the typical clinker composition as shown in Table 1.

Table 1: Composition of dry cement manufacturing process [4]

Elements	Composition (%)
CaO	65 ± 3
SiO_2	21 ± 2
Al_2O_3	5 ± 1.5
FeO_3	3 ± 1

In dry cement manufacturing process, which uses nearly dry raw mix containing less than 20% moisture by mass. However, in a wet process, water is added to the raw mix to form slurry and then is transported to the kiln. Raw meals are grounded, blended, pre-calcined, and burned in manufacturing cement. In a cement manufacturing process, limestone and calcium, silicon, aluminum and iron oxides are crushed and then milled into a raw meal. This raw meal is blended in blending silos and is then heated in the pre-heating system. This will dissociate carbonate to calcium oxide and carbon dioxide. A secondary fuel is supplied to the preheating system so that temperature is sufficiently high. The meal then passed through the kiln for heating. Then a reaction takes place between calcium-oxide and other elements. This reaction will produce calcium silicates and aluminates at about 1500^{o}C. Primary fuel is used to keep the temperature high enough in the burning zone for the chemical reactions to take place. A nodular product named clinker is produced and then allowed to leave the kiln. The clinker will be inter-ground with gypsum, limestone and/or ashes to a finer product called cement [4].

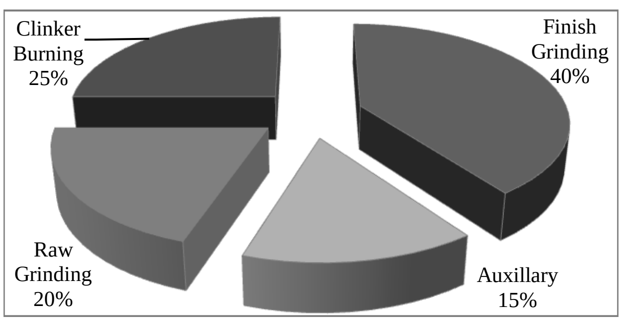

Figure 1: Energy Distribution among Cement Manufacturing Equipment [5][6][7]

Cement production is an energy intensive industry. Energy utilization in cement accounts for 50–60% of the total production costs [8]. Thermal energy accounts for about 20–25% of the cement production cost [9]. The typical electrical energy consumption of a modern cement plant is about 110–120 kWh per ton of cement [6]. The main thermal energy is used during the clinker making process, while electrical energy issued for cement grinding and other auxiliaries [10]. Figure 1 shows electrical and thermal energy flow in a cement manufacturing process.

Demand for cement depends on various socio-economic parameters. Cement production in China has been studied as a function of GDP growth, cement consumption per capita, non linear effect and saturation effect [11]. Similarly, study in Iran has verified the impacts of population and GDP growth on cement demand and production over the next 20 years [12].

Lawrence Berkeley National Laboratory (LBNL) has developed a guidebook which contains different energy efficiency improvement technologies and measures which are commercially available for the cement industries throughout the globe [13]. Likewise, [4] have reviewed the different energy efficiency technologies

Different energy analysis techniques have been employed in industrial energy modeling. Modeling techniques like decomposition of energy trends, econometric methods, and 'top-down' models, 'bottom-up' models and industry-specific micro-economic analyses are common in analyses of industrial energy [14]. The bottom-up CO_2 abatement cost curve (ACC) model was used for the Thai cement industry to determine the potentials and costs of CO_2 abatement, taking into account the costs and CO_2 abatement of different technologies. Different 41 CO_2 abatement technologies and measures for the cement industry were analyzed in the study [15].

An optimization model for CO_2 reduction in cement production process was developed by [16]. The economic model on the basis of best selection strategy with the least cost was analyzed for a cement industry and found that up to 23.6% reduction in CO_2 emission per ton of cement can be achieved.

3. METHODOLOGY

3.1. Data Collection

Detailed data collection questionnaire were developed and used to collect information on cement production and energy use from the surveyed plant (5 rotary plants, 4 shaft kiln and 12 clinker based plant). Similarly, the data from the baseline study of cement industry for grinding and clinker manufacturing were also used in the study [17] (Nepal Energy Efficiency Programme (NEEP)/GIZ, 2012). The baseline study includes the study in 26 cement industries, and intends to increase the efficiency level of the industries by implementing different efficient measures. Hence, the compilation of the primary and survey data encompasses around 86% of cement production in Nepal.

The data forms requested for specific information on the plant lines, their age, their clinker and cement-making capacity, annual data of clinker making and cement production. The energy consumption sheet were developed for important processes like raw quarrying, raw material grinding, additive processing, pyro-processing and clinker cooling, cement grinding and auxiliaries. Similarly, the questionnaire requested for the information on the implementation of the recent available best practice technologies, as found in different literature. Table 2 shows the base year fuel consumption. Electricity comprises the grid electricity and electricity generated by on-site diesel generators. Diesel generators produce around 26 % of electricity in the base year. Likewise the clinker to cement ratio is found to be 0.88.

Table 2: Base year fuel consumption [17]
(Nepal Energy Efficiency Programme (NEEP)/GIZ, 2012)

Fuel Type	**Consumption**
Coal (GJ)	3836603
Electricity (GWh)	168

3.2. Benchmarking and energy-saving potential

Benchmarking is a commonly used term that generally means comparing a defined characteristic of one facility to other facilities or other 'benchmarks'. This study focuses in the energy consumption benchmarking with the international best practice. Different international energy benchmarks are considered as found in literature [4][13][18] and the reference from BEST-Cement[1]. A spread sheet model is generated and domestic energy consumption is compared with the international best practice using and energy intensity index (EII), calculated on the basis of facility's energy intensity and the benchmark energy intensity, as in Eq. (1) [19].

$$EII = 100 * \frac{\sum_{i=1}^{n} P_i * EI_i}{\sum_{i=1}^{n} P_i * EI_{i,BP}} = 100 * \frac{E_{tot}}{\sum_{i=1}^{n} P_i * EI_{i,BP}} \quad (1)$$

where:

EII = energy intensity index

n = number of products to be aggregated;

EI_i = actual energy intensity for product i;

$EI_{i,BP}$ = best practice energy intensity for product

P_i = production quantity for product i

E_{tot} = total actual energy consumption for all products.

The EII is one of benchmarking method which performs analysis by comparing the production intensity of the facility to the benchmark or reference intensity. The international benchmark will have an EII of 100. In reality, plant facilities will have EII greater than 100, which shows the potential saving opportunities.

Table 3: Fuel energy intensity at base year and projected years

Scenario	**Technology (Kiln)**	**Final energy intensity by technology (GJ/t clinker)**				
		2010[2]	**2011**	**2015**	**2020**	**2030**
Base Case	Rotary	4.54	4.54	4.54	4.54	4.54
	Shaft	7.90	7.90	7.90	7.90	7.90
Efficiency	Rotary	4.54	4.54	3.90	3.50	3.28
	Shaft	7.90	7.90	7.90	0	0
Best Practice	Rotary	4.54	4.54	3.90	3.50	3.28
	Shaft	7.90	7.90	7.90	0	0

3.3. Demand Forecast

The historical cement production data have been collected from the economic survey 2012. The data presented in the survey do not seem to present correct data. Even the total production of the surveyed industries is more than the data presented.

The end use demand of cement is estimated using the following equation, as mentioned in [20]:

$$ESD_{cement,t} = \left(\frac{VA_t}{VA_t}\right)^{\beta} x\ ESD_{cement,0} \quad (2)$$

where,

$ESD_{cement,\ t}$ = end use service demand in year t for cement sector

VA_t = value added in the cement sector in year t

β = sectoral value added elasticity of demand for cement industry

The future growth of GDP is forecasted using the regression model from the data available from the World Bank. The GDP growth rate is calculated at 4.45% per year. The forecasted GDP growth rate is used to generate the future growth rate of value addition of manufacturing sector. The sectoral value added elasticity for cement sector is calculated using Eq. The data used is 20 years from 1990 to 2010. The elasticity of demand for cement industry was determined to be 1.36. Present production capacity of cement being 2.0 million metric ton is expected to reach 5.8 million metric ton, with a cumulative cement demand of 73.5 million metric ton, from 2011 to 2030.The historical and future cement demand is shown in Figure 2.

[1] BEST-Cement is the cement industry energy benchmarking software package developed for China by Lawrence Berkeley National Laboratory. It can be downloaded from:

http://china.lbl.gov/research/industry/benchmarking/best-cement/best-cement-china.

[2] Calculated from the primary data

According to the IEA cement roadmap, the cement output in developing Asian countries, will grow continuously from 200 million in 2006 to 800 million ton in 2050 [21]. Hence, the constant elasticity is throughout the analysis period.

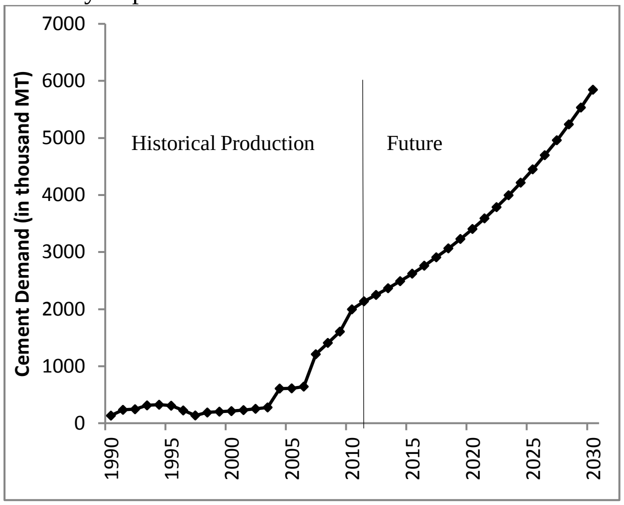

Figure 2: Cement production growth (Historical and Projected)

3.4. Scenario Assumption

The Long-range Energy Alternatives Planning system (LEAP) modeling tool is used for the scenario based modeling and analysis of potential energy savings and CO_2 emissions reduction. The scenarios have been projected for base year of 2010 up to 2030. To analyze the impact of different energy efficiency and carbon reduction measures and policies, three scenarios are constructed consisting of Base Case scenario, Efficiency scenario and Best Practice scenario. Scenarios have been defined on the basis of various national and international level objectives [21].

The Base Case scenario has been considered as business as usual or reference scenario for this study. The Efficiency scenario is constructed with the objective to observe the energy consumption pattern with energy efficiency measure as mentioned in Table 3. On the contrary, Best Practice scenario observes the effect on environmental emission due to the inclusion of energy efficiency measures, use of alternative fuel and reduction of clinker to cement. It also accounts the penetration of waste heat recovery for power generation (WHRPG). The penetration of WHR for power generation would be 100% by 2030 and average of 36 kWh [11] of electricity can be produced per ton clinker through WHR power generation.

The average emission factor of 73.3 ton CO_2 per TJ for alternative fuels is assumed, which indicates the use of alternative fuel could reduce about 23% of CO_2 emissions overall compared to burning bituminous coal of which assumed emission factor is 94.5 ton CO_2 per TJ [22]. The cement process emission is calculated according to the [23]. As most electric energy is generated from clean hydropower technology, the grid emission has been neglected; where as the emission from diesel combustion has been considered.

Table 4: Assumed penetration of alternative fuels (in % of coal substitution)

Scenario	2010	2011	2015	2030
Base Case	0	0	0	0
Efficiency	0	0	0	0
Best Practice	0	0	5	15

Table 5: Assumed penetration of waste heat recovery for power generation (WHRPG) (% of clinker production)

Scenario	2010	2011	2015	2020	2030
Base Case	0	0	0	0	0
Efficiency	0	0	0	0	0
Best Practice	0	0	10	50	100

4. RESULT AND ANALYSIS

4.1. Benchmarking Result

The domestic benchmarking of the rotary kiln technology have been performed and the template generate incorporates different process flow of the cement industry. Special focuses were given to the rotary kiln technology. Since, all plant do not produce cement the energy per unit clinker basis is formulated.

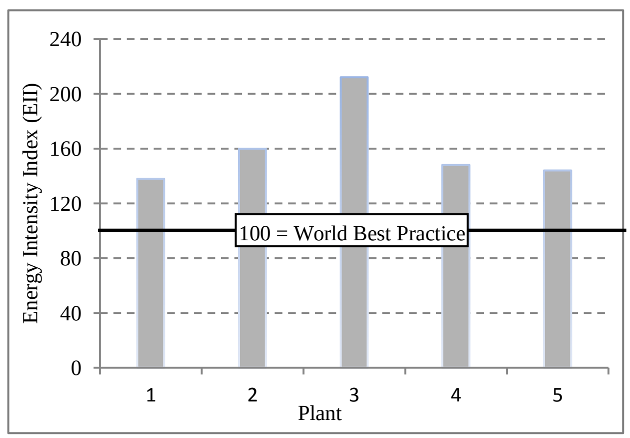

Figure 3: Energy Intensity Index (EII) benchmarking of surveyed plant

The difference between the actual plant and its corresponding best-practice technology illustrates the technical potential for energy improvement. In order to compare the 5 plants, an energy intensity index (Eq. 1) is used to illustrate the distance between best practice and the plants improvement opportunity.

Fig. 3 shows the EII score for the 5 plants compared to the world best practice based on primary energy use. All 5 plants scored above the 100 value which hints the opportunity for efficiency improvement above the 100 value. Plant 1 scores the lowest value (138) suggesting 28% of technical potential saving. Likewise, Plant 3 scores the highest value (212) suggesting 53% of technical potential saving.

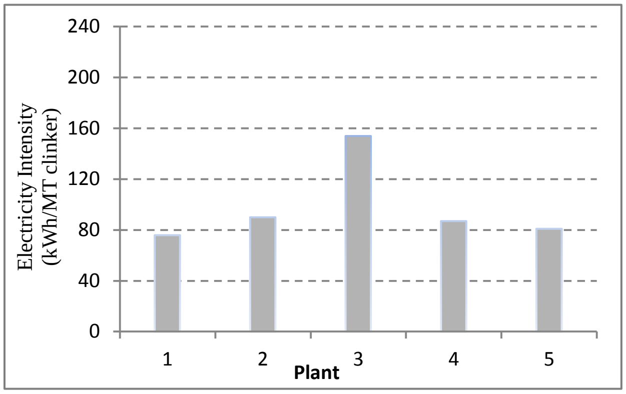

Figure 4: Electricity intensity in surveyed plants

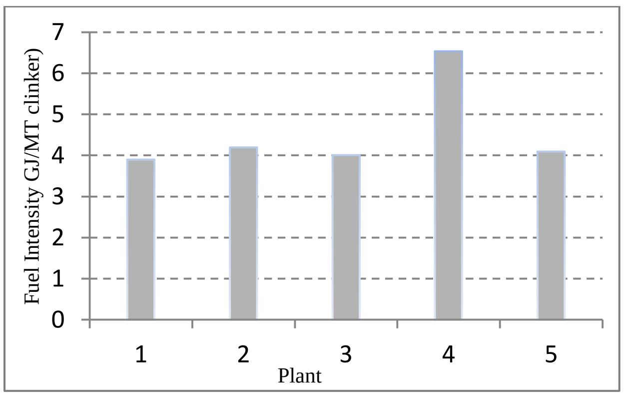

Figure 5: Fuel energy intensity in surveyed plants

Likewise, Fig. 4 and Fig. 5 show the electricity intensity and fuel energy intensity of clinker production. The average values have been used for the scenario analysis.

4.2. Result of Scenario Analysis

The base case scenario, the cumulative primary energy consumption is found to be 211.6 PJ during 2010 to 2030. There is subsequent reduction in the cumulative primary energy consumption under efficiency and best practice scenarios to 148.6 PJ and 135.3 PJ respectively, as shown in Table 6. Hence, the energy consumption can be reduced by 30% and 36% in the Efficiency and Best Practice scenario respectively. The energy consumption patterns in different scenario is shown in Fig. 6

Table 6: Projected primary energy demand for different scenaraios in 2010-2030 (in PJ)

	2010	2011	2015	2020	2025	2030
Base Case	5.020	5.469	7.128	9.637	12.713	16.700
Efficiency	5.020	5.260	5.908	6.898	8.108	9.686
Best Practice	5.020	5.114	5.580	6.279	7.181	8.484

Similarly, the cumulative CO_{2e} emission, in the base case scenario, is 16 million tCO_2e increases from 381 thousand tCO_2e to 1.28 million tCO_2e from 2010 to 2030. This can be reduced by 29% and 37% under Efficiency and Best Practice scenario respectively, as compared to the Base Case. The CO_2 emission pattern in different scenario is shown in Fig. 7.

Table 7: Projected CO_2e emission for different scenarios in 2010-2030 (in thousand tCO_2e)

	2010	2011	2015	2020	2025	2030
Base Case	381	416.7	549.2	747.7	988.1	1,297.90
Best Practice	381	386.5	422.4	476.2	548.8	655.3
Efficiency	381	400	452.8	536.1	643.3	791.9

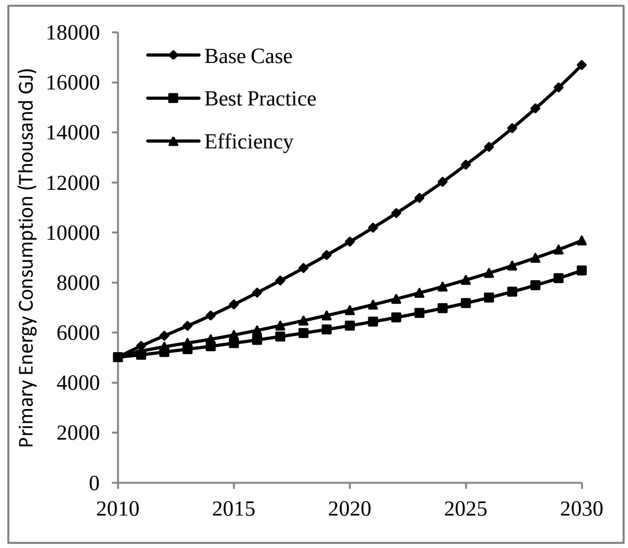

Figure 6: Projected Primary Energy Consumption for different scenarios in 2011-2030

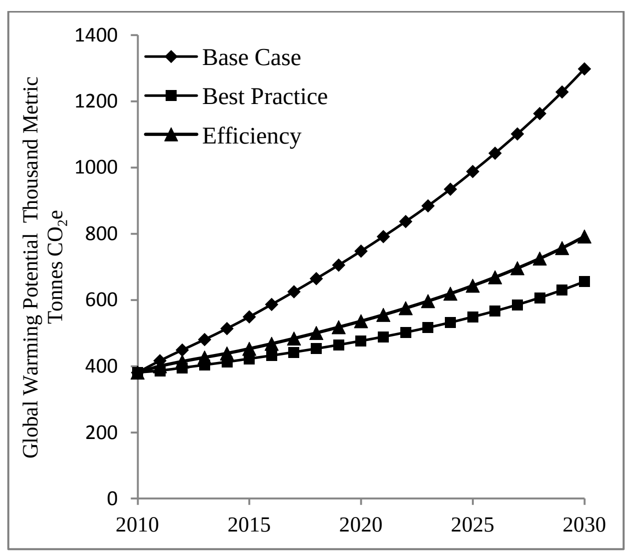

Figure 7: Projected CO_2 Consumption for different scenarios in 2011-2030

5. DISCUSSION AND CONCLUSION

Overall, there is a tremendous potential for improvement in cement industry. Many countries have benefitted from the efficiency improvement in cement industries. The potentiality of Waste Heat Recovery for Power Generation (WHRPG) is highlighted in this study to address the issue of future energy security. The use of alternative fuel for combustion process provides the opportunity for emission reduction and curtails the future energy scarcity. The alternative fuels have already reached the level of saturation level in European countries.

In context of Nepal, the output of cement has shown a continuous growth during 1990 to 2010. The increase of the domestic demand and it fulfillment, in future perspective, expects more cement industries to commence. The future outlook on the energy demand in cement industry is seen to grow from 5.02 PJ in 2010 to 16.7 PJ in 2030. This growth of energy consumption can be reduced by efficiency improvement in current industry and implementation of best available technology. Similarly, the cumulative emission reduction can be greatly reduced from up to 37%, of the 16 million tCO_2e The energy efficiency programs and WHRPG in other countries have been implemented as an integration of CDM projects [24][25]. The possibility of such opportunities can be studied and accessed [26]. Positively, WHRPG provide the use of alternative energy and switch to cleaner energy.

Moreover, government policy [27] provides specified privilege to those industries prompting for the use of new technology which promote low carbon and provide future energy security. Hence, WHRPG can be seen as an opportunity for future sustainability of cement industry.

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Impact of Renewable Energy in Total Energy Consumption and CO_2 Emission in Rural Tourist Destination: A Case of Ghandruk

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***Abstract*: Energy dependency on traditional sources and fossil fuel in commercial sector of rural tourist destination is the matter of discourse to maintain eco-tourism and protect environment of conservation area. This paper summarizes change in the energy consumption pattern and CO_2 emission before and after implementation of renewable energy technologies (RETs) in rural tourist destination considering the case of Ghandruk VDC. Result shows the replacement of kerosene by electricity from micro-hydro plant and solar home system, and small change in cooking trend from fuel wood to electricity and LPG. No significant reduction on fuel wood consumption has been identified rather CO_2 emission is increasing against government plan and policies. Finally, this paper strongly recommended that there is a need for development and implementation of an effective and sustainable rural energy strategy that would protect local and global environment and ecosystem and promote eco- tourism in the potential rural tourism area.**

Keywords: Renewable Energy Technologies; Fuel wood; Energy consumption; Eco-tourism; Co_2 emission

1. INTRODUCTION

In Nepal, residential sector is the major energy consuming sector which accounts 89.1% [1] share of total energy consumption. More than 80% of the country's total households are in rural area [2]. Biomass, mostly fuel wood, occupies larger portion of the energy resource i.e. 78% [3] used for cooking in residential sectors and energy from hydropower source, fossil fuels, renewable energy technologies (RETs) such as micro-hydropower, solar home system, institutional solar PV system, solar water heating system and wind power plant contributes in smaller portion [1]. The consumption of solid biomass (traditional forms of energy) has a negative effect on the quality of lives of the people, since it takes much time to collect wood and causes adverse effects on health. Besides, the use of these traditional energy sources is neither sustainable nor desirable from environmental considerations. Therefore, there is a need to replace or supplement those energy supply system by modern forms of renewable energy.

To reduce high dependence on traditional fuels government emphasize to increase the supply of renewable energy sources including hydropower to meet the increasing demand for energy, first time in fifth national plan (1975-1980), the first sector specific policy statement in the energy sector [4]. This trend continues till thirteen national plan (2013-2016) which states to reduce fuel wood consumption by adaptation of Improved Cook Stove (ICS), Biogas, Gasifier, Bio-briquette and community biogas [5]. Rural Energy Policy 2006 has also been conceptualized with a sector-wide approach. This policy specifically targets improved biomass technology, micro-hydro power and solar photovoltaic system with white LED light [6]. Main goal of all the plans and policies is to reduce local and global pollutant emission by introducing clean energy supply and efficient device to protect environment.

In tourism area demand of energy for local people and tourist is high. Some researchers analyzed the relationship between tourism and energy in different sectors, for example, destination and accommodation [7][8][9][10]. They focused on energy consumption and efficiency of various sources. Gossling (2002) estimates 6% share of total energy consumption of 14,000PJ by tourism related activities in tourist accommodation sector and activity sector, remaining on transportation sector [8]. Ghandruk is in Annapurna Conservation Area, endowed with its immense natural beauty; this village is famous for tourist destination and trekking route in and out of country. Being tourism area energy consumption is high but being the conservation area it has definitely fragile ecosystem. Any man made activity should be limited to protect its environment and maintain eco-tourism[1].

Some researches are conducted in tourism related energy consumption in Annapurna region. Nepal (2008) studied in tourism-induced rural energy consumption in Annapurna region of Nepal [11]. This research result indicates the increasing use of renewable energy and locally developed energy saving technologies. His study concluded that tourism- induced energy demand at rural destination aggravates problems of natural resource conservation at local level and poses a long term threat to the global climate. Baskota (1997) studies the impact of alternative energy technologies in reducing pressure of forest resources in Hotel and Lodge of Ghandruk and

[1] Eco -tourism is defined as environmentally and socially responsible tourism which minimizes degradation of natural environment, cultures and socio - economic conditions and provides economic benefit to local people through employment and services.

Ghorepani area. Studies show the low pace on using renewable energy technologies because of low subsistence rural economy [12].

On this ground this paper is oriented to find the impact of renewable energy in total energy consumption and CO_2 emission in commercial sector of rural tourism area in Ghandruk VDC. This paper consists of four sections. First section contains introduction and second section shows the energy consumption pattern in commercial sector of Ghandruk and compares with the energy consumption pattern reported by Baskota(1997) in his paper [12]. It finds the CO_2 emission in tons per year and its trend. Third section of the paper analyzes result and key findings in energy consumption and CO_2 emission pattern because of introduction of renewable energy technologies. Finally, last section provides discussion and conclusion with some recommendations.

2. ENERGY CONSUMPTION PATTERN IN GHANDRUK

2.1. Research Setting

Ghandruk lies to the north of the picturesque city of Pokhara, the second largest urban area of Nepal, the district headquarters of Kaski and is in the Annapurna Conservation Area (ACA). It is the largest VDC of kaski with area of 296.5 Sq Km, that rises from a height of 1,000 m to 8,091 m above sea level and stretches from subtropical to cold tropical climate [13]. Endowed as it is with immense natural beauty, a region with several high mountains including Dhaulagiri (8167 m), Annapurna (8091 m) and the picturesque Mt. Machapuchre, fast flowing rivers, colorful villages and high mountain scenery, this village is well-known both inside and outside the country as a tourist destination and trekking route for Ghorepani and Annapurna Base Camp [14]. Ghandruk is well known as a model village even in south Asia [15]. Tourism is main economic activity of the commercial sector of Ghandruk. Studies suggested potential of solar water heating, solar photovoltaic, wind power extraction and hydro power as renewable energy source in Ghandruk VDC [13][16][17].

2.2. Data Collection Method

Energy consumption in rural commercial sector is conducted by random household survey. Among the 170 hotels present in Ghandruk, 30 hotels are surveyed and data obtained are validated by comparing with published data source of Water and Energy Commission Sectarian (WECS) and Central Bureau of Statistics (CBS) data [1][2]. For household energy survey, a questioner containing four sections is developed including general information, information of household member, household property information and energy consumption information. In general information section household head name, address, caste, religion and family size are noted. In the information of household member section education level, occupation and average monthly income are noted. Land holding, number of livestock and house structure are noted in household property information. Finally, energy consumption section is further divided into five subsections i.e. lighting, cooking, space heating, water boiling and other electric devices. Type of device, no of devices, fuel type, fuel consumption and operation hours are noted in these sections.

Energy end uses device used are generally traditional cooking stove, improved cooking stove, kerosene stove, charcoal stove, LPG stove, rice cooker, Ceramics heater, Fan, kerosene tuki, Compact Florescent lamp (CFL), incandescent lamp, florescent tube, refrigerator, grinder/ mixture, television and radio. Electricity from Micro hydro plant and Solar PV, solar heat, kerosene, fuel wood and Liquidified Petroleum Gas (LPG) are major source of Energy in Ghandruk.

Wattage rating of electric devices, energy source and their running time are noted for the devices using electricity and for devices using fuel wood energy, fuel wood consumption in bhari[2] is noted. Unit used for kerosene consumption is liter and LPG is number of cylinder[3]. Total consumption for cooking, lighting, water heating and other electric is calculated in gigajoule. Total consumption from fuelwood, kerosene and LPG are converted to gigajoule using heating values (1 GJ = 23.4 kg of fuel wood or 9.28 l of kerosene or 0.2 tanks of a 30-l LPG) according to published sources [11]. Energy consumption is summarized in section 2.4.

Energy consumption data on year 1997 is collected from published source of ICIMOD [12]. Tourism statistics are collected from Nepal Tourism Statistics 2012 published by Ministry of Culture, Tourism & Civil Aviation, and Government of Nepal (Ministry of Culture, 2013).

2.3. Data limitation

Data collected in this study have some limitation. Firstly, actual useful energy consumption data is difficult to obtain in rural areas, so this study relies on the lodge owner's estimate for fuel wood, LPG and Kerosene and the author's personal observations of hydroelectricity, solar panel and solar water heater at each lodge. Secondly, it does not take into account the energy consumed in space heating from cooking stove separately rather included into cooking energy consumption. Finally, energy consumption is not taken separately for personal use and guest use. This data provides the basis

[2] Bhari is a local unit used to measure fuel wood in residential sector of Nepal, which is approximately equal to 30kg

[3] According to Nepal Oil Corporation, 1 cylinder contains 14.2 Kg of LPG in average.

for only comparing the change in energy consumption pattern by source and end use and total CO_2 emission.

2.4. Energy Consumption Data

Energy consumption data are summarized by end use type and source type. Energy consumption in 1997 A.D. is presented in Table -1. Total hotel number is 25.

Table 1: Total energy consumption in 1997 A. D. in MJ

Source / End Use	Elect-ricity	Solar Heat	Fuel Wood	LPG	Kero-sene	Total
Cooking	28.78	0.00	860	42.87	84.82	1016.36
Lighting & Electric Device	27.62	0.00	0	0.00	125.7	153.31
Water heating	0.00	0.16	704	10.72	219.9	934.39
Total	56.40	0.16	1563	53.59	430.5	2104.06
% share	2.7 %	0.01%	74.3%	2.5%	20.5%	100 %

Source: Baskora et al., Conference Preceding, ICIMOD, 1997

Total Energy Consumption is 2104.06 MJ. Share of cooking, lighting and electric devices and water heating in total energy consumption is 48.3%, 7.29% and 44.41% respectively. Maximum energy is used in cooking followed by water heating and lighting and electrical device. For cooking fuel-wood is the major source contributing 84.6%, kerosene contributes 8.35%, LPG Contributes 4.22 % and electricity contributes 2.83%. Kerosene is the major source for lighting with share of 91.9% followed by electricity with 18.1%. For water heating 75.35 % of energy is supplied from fuel wood, 23.54% from kerosene, 1.15 % from LPG and 0.02% from solar heat.

Energy consumption in 2013 A. D. is presented in Table-2. Total hotel number is 170. Among total energy consumption of 5559.36 MJ maximum share of energy supply source is from fuel wood, followed by LPG, electricity, solar heat and kerosene.

Table 2: Total energy consumption in 2013 A. D. in MJ

Source/ End Use	Elect-ricity	Solar Heat	Fuel Wood	LPG	Kero-sene	Total
Cooking	39.99	0.00	3885	728.74	9.60	4663.55
Lighting & Other Electric	698.85	0.00	0	0.00	0.00	698.85
Water heating	21.62	94.08	9	71.80	0.00	196.97
Total	760.46	94.08	3895	800.54	9.60	5559.36
% share	13.7%	1.7%	70.1%	14.4%	0.17%	100 %

Source: Household survey conducted by author in 2013 A.D.

Share of cooking, lighting and electric devices and water heating in total energy consumption is 83.89%, 12.57% and 3.54% respectively. For cooking maximum share is from fuel wood energy source i.e. 83.3% and LPG, electricity and kerosene has 15.63%, 0.86% and 0.21% share respectively. For lighting all hotel and lodge use electricity from micro-hydro plant and solar home system. 47.7% of energy for water heating is supplied by solar using solar water heater and 36.45%, 10.97% and 4.81% share of energy is supplied by LPG, electricity and fuel wood.

3. Analysis of Data

Study shows that there is an increasing trend of establishing hotels at the rate of 11.98 % per year, (from 25 hotels in 1997 A.D. to 170 in 2013) and there is increasing number of tourist arrivals for trekking and mountaineering by 21.79% in recent year (Ministry of Culture, 2013). This has resulted significant increase in the consumption of total energy at the rate of 6.07 % per year (from 2104.06 MJ in 1997 A.D. to 5559.36 MJ in 2013A.D). From data presented on section 3.4, consumption of kerosene is decreased heavily i.e. 430.48 MJ to 9.6 MJ (17.22 MJ/HH to 0.06MJ/HH) during 1997 to 2013 A.D. Heavy increase in kerosene price from NRs 25/liter to NRs 100/liter is the main reason liable to decrease in kerosene consumption [19]. Furthermore, electricity from micro hydro plant, total installed capacity of 361 kW from 19 MHP [13] and solar home system used for lighting and people's tendency to using user friendly technology also cause decrease in kerosene consumption. Also, fuel wood consumption is increasing as the increasing trend of hotels. However, fuel wood consumption per household is decreasing because of shift of cooking device from traditional cooking stoves to LPG stove and electric rice cooker and increasing use of solar water heater for water heating use. Figure1 shows the comparison of energy consumption per household by source type in two years 1997 A.D. and 2013 A.D. Consumption of electricity is increasing from 2.26MJ to 4.47MJ, solar energy from 0.01MJ to 0.55MJ and LPG from 2.14 MJ to 4.17 MJ. Fuel wood and kerosene consumption is decreasing from 62.54 MJ to 22.91 MJ and 17.22 MJ to 0.06 MJ respectively.

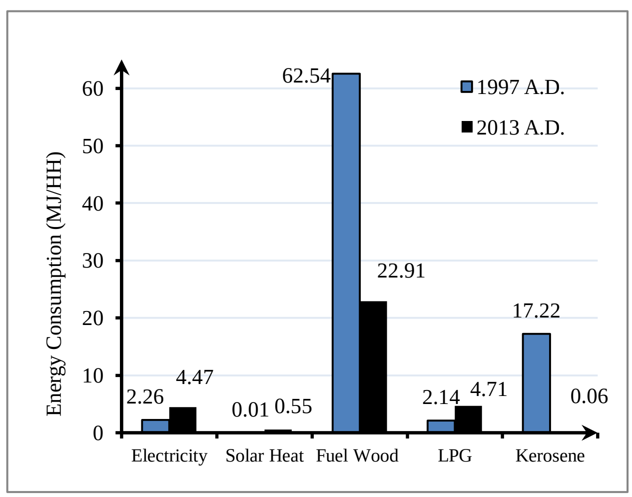

Figure 1: Comparison of Energy consumption in Mega joule per house hold (MJ/HH) for year 1997 and 2013 A.D

By end use cooking consumes 48.3% share of total energy in 1997 A.D. which increase to 83.4% in 2013. Also, lighting and other electric share increase from 7.29% to 12.57 % and water heating share decreases from 44.41% to 3.54 % in the same time horizon.

Emission coefficient for CO_2 in Ton/GJ is summarized in table 3 [12]. Using emission coefficient total CO_2 emitted is calculated for fuel wood, kerosene and LPG. Emission from fuel wood and LPG is increasing and kerosene is decreasing. In 1997 A.D. total emission is 0.1651 Tons which has increases to 0.3775 Tons in 2013 A. D.

Table 3: Total CO_2 Emission

Energy Source	**CO_2 Emission Coefficient (Ton/GJ)**	**CO_2 Emission(Tons/year)**		
		1997 A.D.	**2013 A.D.**	**Change**
Fuel wood	0.0832	0.1301	0.3240	0.1940
Kerosene	0.0732	0.0315	0.0007	(0.0308)
LPG	0.0659	0.0035	0.0528	0.0492
Total		**0.1651**	**0.3775**	**0.2124**

4. Discussion and Conclusion

Above result shows success of introduction of renewable energy technology i.e. electricity from micro-hydro and solar photovoltaic in replacing kerosene used for lighting. Further, electricity facilitates the use of modern electric devices like refrigerator, grinder/mixture, television and communication equipments. Utilization of solar energy by solar water heater for water heating is remarkable one and need to be continued for reducing dependence on fuel wood. Though, the development of micro-hydro power have proved to be successful in improving health, sanitation, education, environment and economy, it does not reduce dependence of traditional resource and CO_2 emission [20]. There is no significant reduction seen on the use of traditional fuel resources, mainly fuel wood which are undesirable from environmental consideration and unsustainable though some renewable energy sources are implemented as per government plans and policies. The trend of cooking fuel is shifting to some extent from fuel wood to LPG which is non renewable energy source and has increasing trend of price [19]. Use of renewable energy technology in cooking and water heating is increasing but at a slower pace. Total Co_2 emission is increasing and has to reduce to protect fragile environment of conservation area.

Adaptation of renewable energy technology in conservation area are influenced by several factors like consistent policies, location-specific interventions, matching energy needs and supply sources, appropriate technology, device efficiency, environment, technical acceptability, socio-cultural and economical acceptability of the consumers, community participation and financial support. Implementing biogas technology in low altitude area, efficient devices like improved cooking stove (ICS) and clean energy devices like electric heater, rice cooker and hot plate can significantly change the energy consumption pattern, limits CO_2 emission and reduce dependence on forest resource and fossil fuels. It is strongly recommended that there is a need for development and implementation of an effective and sustainable rural energy strategy that would protect local and global environment and ecosystem and promote eco-tourism in the potential rural tourism area.

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Planning for Pedestrian in Urban Area: A Case of Kathmandu

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***Abstract*: Urban areas belong to the people acting as a generator of social and cultural interactions as such pedestrians are the lifeblood of urban area and their role has significant contribution to maintain its character of making live and vibrant place. Walking, besides its innumerable benefits is responsible for creating livable communities. Hence, priority for pedestrian should be of given prime concern at both local and national levels.**

In this 21st century, transportation heavily relies on automobiles. The vehicles make our life a lot easier but at the cost of several environmental and health hazards. Hence, pedestrian friendly environment is a priority concern in developed countries. They have already incorporated proper planning for pedestrian and sufficient provision of pedestrian facilities while designing their cities to motivate people to walk more. However, this aspect is significantly lacking in our urban setting even though walking is the second highest mode of transportation.

Kathmandu though is a walkable city but walkability is largely unmeasured and grossly underappreciated component of urban transport system. Our urban roads are vehicular centric. Pedestrian traffic is not considered while designing the cities. In our context, there are no standard norms and guidelines regarding planning for pedestrian and the existing institutional arrangement available to educate and enforce the vehicular and pedestrian traffic management is insufficient and fragmented. This is the reason for the poor pedestrian infrastructure, services and facilities in urban areas of Kathmandu.

If pedestrian planning is carefully addressed, it will directly substitute the use of automobiles for short trips. So, this research is carried out to identify the existing pedestrian problems, condition of pedestrian infrastructure, services and facilities provided for pedestrian in urban setting. The study is carried out in three different sites which include streets of urban core, mix land use of Baneshwor and planned residential area of Kuleshwor. These three sites with different profiles with regards to land use and issues have been selected to give an insight into how the existing scenario of pedestrian environment with its challenges and obstacles differ with different land use.

This study has come up with the conclusions that, the major reason behind the poor pedestrian environment in our context is the lack of proper planning for pedestrian in urban areas, lack of norms, standards, insufficient and fragmented institutional arrangement. The existing pedestrian environment can be improved if regularized with appropriate policy and regulatory measures and such measures are recommended by the study for the careful assessment to make our urban areas pedestrian friendly.

***Key words:* Walking behavior, planning for pedestrian, pedestrian traffic**

1. INTRODUCTION

Every journey begins with a walking step. Walking is the primary mean of people moving around and reaching destinations, of integrating and living the urban space and of accomplishing salutary physical activity. Besides, Walking has also been associated with many benefits, ranging from reducing air pollution, traffic congestion and resource consumption to solving obesity and other health problems. It has been regarded as an essential factor in the creation of "livable communities", encouraging neighborly interactions and making the urban environment a more enjoyable and safer place to live.

In this 21st century, the major transportation depends upon automobiles. For running automobiles, lot of price has to pay. The unsustainability issue of current transport mode through automobile has been raised due to extensive use of fossil fuel. Besides, it has negative ecological foot prints as well as negative impact on human health too.

This is the reason; why the whole world today is concerned for promoting walking. In developed countries, pedestrian traffic has already been considered in designing the road networks. Planning for pedestrian has already been carefully addressed while designing the cities to encourage people to walk over using vehicles for short trips. This not only helps for the long run sustainabiltity of current transport mode but also helps in the creation of livable and socially and culturally interactive urban areas. In contrast, pedestrian movement is still a neglected and underappreciated component of urban transport system in most of developing countries. Despite of pedestrian being the lifeblood of urban areas, planning for pedestrian is not properly incorporated in majority of Asian countries.

The ancient settlements of Kathmandu valley are very organized and compact settlement within walkable distance. Streets developed during Malla period were not only ‘paths’ for movement of pedestrians and goods but also formed the backbone of friendly, interactive, safe and secure neighborhoods . But after 1934 earthquake, roads are constructed to facilitate vehicular movement only rather than giving priority for pedestrian movement.

This trend of giving utmost priority to vehicular traffic and negligence for considering pedestrian traffic is more prevalent in these modern days. At present time, our capital city Kathmandu is at the stage of suburbanization. The entire streetscape of the city has been planned to favor the vehicular traffic. So, a pedestrian is always a neglected factor in planning a city road networks. Roads are constructed in every part of the city for vehicular transport facilities without considering the pedestrian traffic.

The peak-hour modal split in Kathmandu Valley shows that pedestrian travel constitutes the second largest transport modes in the valley. In order to plan the whole urban transport system in the valley, pedestrian traffic is too important to ignore as the planners are practicing today. The major roads in an urban area of Kathmandu are mostly devoid of any of pedestrian facilities while few of them are provided with inadequate footpaths and other facilities. The pedestrians have always been kept at the lowest order in road user’s hierarchy which has been the major cause of automobile dependency in Kathmandu and it has been the cause of for many problems such as traffic congestion, excessive fuel consumption, air pollution, road accidents and many more. In Kathmandu, out of 834 km of total paved road length in valley only 39 km segment has the proper footpath which is less than 5% of total length of the same *(ADB, 2007)* which shows that pedestrian are given very less priority in our context.

The recent road widening is also carrying at the expense of pedestrian footpaths. The pedestrian environments in the cities of Kathmandu valley are always remain disorganized and unplanned. The pedestrian facilities are mismatched and inadequate. There are no govt. norms and standards to evaluate and assess the pedestrian facilities in these areas.If the pedestrian environments are improved and planning for pedestrian is properly incorporated in urban roads, lot of benefits will be achieved. The reduced traffic congestion, lively and equitable urban area, pollution free environment, sustainable urban transports are some of the examples. Thus planning for pedestrian should not be neglected but should be given high priority in road design as town planning schemes in urban areas.

So, this research is carried out for the identification of the problems and issues related with pedestrian environment, to identify various measures and ways to solve the existing pedestrian problems, to identify the measures for proper planning for pedestrian in urban area and to formulate recommendations to make urban areas pedestrian friendly.

2. RESEARCH METHODOLOGY

The research is based on qualitative and quantitative data collected through both primary and secondary sources. Quantitative data is collected through pedestrian volume count, physical measurement at study area and qualitative data is collected through direct observation, questionnaire survey with pedestrian and interview with key informants. Quantitative data is collected to study the distribution and pattern of pedestrian volume to analyze how pedestrian volume differ according to different land use and purpose whereas qualitative data is collected to identify the condition of existing pedestrian infrastructure and pedestrian problems. Interviews with the key informants were taken to know how the provisions for pedestrian are determined while designing road networks and the interview especially focus the issues of current road expansion program. Based on the collection of data, analysis of the current issues of pedestrian traffic and pedestrian environment as a result of lack of proper planning for pedestrian and lack of norms and standards was done and recommendations were given to improve the existing pedestrian environment.

3. FINDINGS

From the study of three different sites, it is found that the pedestrian environments are not user friendly in urban areas in Kathmandu. The problems and issues faced by the pedestrian are almost same whether it is the narrow streets of urban core or wide roads of planned area.

The streets and roads of urban areas either lack the sidewalk or have minimum width of footpath with lot of ugly and hazardous potholes. So, there is risk of pedestrians falling down and getting injured every now and then every here and there. It puts the differently able people at further greater risk. Over the narrow footpath, the unmanaged footpath business and the street encroachment further made the condition more worsen for pedestrian leaving very little space during peak hours. The heavy flow of vehicles all the day along with weak traffic management system and people disobeying the traffic rules have put pedestrian in the risk of accident at one hand and in the other, it cause long traffic jams making discomfort to the pedestrian.

The pedestrian environment is more pitiful due to excessive noise pollution caused by the continuous and unnecessarily horning and walking is more problematic in rainy season due to poor drainage system causing water logging problem. The narrow pedestrian streets and footpaths are even captured by the haphazard bike parking in the absence of proper parking space in urban roads. The haphazard bike parking at street side along with heavy encroachment by vendors and shopkeepers leave very little space pedestrian making the narrow street much narrower to walk.

The pedestrian environment even lacks minimum facilities. The insufficient and unequal distribution of street lightings at different locations has made the pedestrian environment problematic and unsafe to walk, especially at night. Further, due to the lack of regular replacement and maintenance, fixtures in many street lighting are not working. Hence, crime, robbery and accidents have soared up.

The ongoing road expansion has created lots of pockets and potholes causing water logging problem. The unmanaged debris and rubbles lying on roads, haphazard and long time storing of large sewer pipes etc has further escalated the situation. Beside these, the poor drainage system and consideration of appropriate slope in construction are other contributing factors during rainy days. Further, the blockage of manholes due to lack of proper maintenance and ongoing road widening activities has heightened the problem making the footpaths virtually a swamp for the pedestrians. The roads and footpaths have no provisions for street furniture such as street benches, dustbins, litter boxes and sign boards. So, unfamiliar pedestrians have hard time finding their way. Litters are seen scattered here and there due to lack of dustbins. Other pedestrian facilities such as public toilet, public drinking water supply and telephone booths can be hardly found.

There are no provisions for differently able people as such even after road widening. The road expansion has just provided ramps to get from footpath to road in some case but most of the footpaths are narrow for wheelchairs and also lot of physical disturbances. Despite of the heavy flow of pedestrians, urban roads lacks proper means of crossing the road i.e. overhead bridge and subways. So; people are forced to cross the road on road putting people at great risk of accidents.

The poor visual quality of the surrounding built environment is another demotivating factor for pedestrians. The haphazard placing of hoarding boards remained in critical and dilapidated condition for years and are likely to fall apart any time have not only marred the city's aesthetic value but also raising the likelihood of injuring the passerby. Besides, the haphazard placement of electrical poles and live wires hanging loose are even more dangerous and hazardous to electric shock and fire causing risk to pedestrian.

The status of air pollution is so bad that many people prefer vehicles to walking even for short distances. The increased density of vehicles then adds to more air pollution and the vicious cycle continues.

4. CONCLUSION

Urban areas are the center of attraction for people from all over the country in terms of better employment opportunities and other urban facilities. Thus urban areas are highly populated. In the context of Kathmandu, Transportation is one of the sectors among all, which has been greatly affected by the skyrocketing population in Kathmandu. The increased population every year demands for more vehicles to run on the narrow streets which were designed many decades back for the limited no. of vehicles. Due to the lack of provision of sufficient public vehicles and improper planning for pedestrian, there is a growing trend to use private vehicles even for shorter trips these days instead of walking in our urban areas.

Walking is the most fundamental form of mobility. It is inexpensive, emission-free, uses human power rather than fossil fuel, offers important health benefits, is equally accessible for all – except those with substantially impaired mobility – regardless of income, and for many citizens is a source of great pleasure. Yet walking presents challenges to society's least robust individuals. The vitality of a city is closely linked to people being out and about on foot for many purposes. Walking is at the heart of urban life and contributes to liveable, attractive, prosperous and sustainable cities.

Walking is, however, the neglected transport mode and, despite being at the start and end of all trips, is rarely captured in government statistics on mobility and is often neglected in planning and policy development. Public institutions representing specifically the interests of pedestrians – including the socially disadvantaged members of society who rely heavily on walking – are rare.

The pedestrian environments in the urban areas of Kathmandu are in worse condition in many cases. The roads even lack the minimum basic elements of pedestrian requirement such as minimum footpath width, sufficient street lighting, dustbins; signage boards etc. The urban design facilities such as public toilet, street benches, drinking water, greeneries along the footpath, and facilities for proper parking are still far to incorporate in our urban roads. The urban roads in Kathmandu; either they are the narrow streets of Assan or the wide footpaths of Kupondole, movement of differently able people are not even thought. Not only in the unplanned, but also in planned settlement, has pedestrian environment even lacked minimum standard.

Even recent road expansion campaign have discouraged pedestrian movement, degraded the streetscape and replaced public spaces with traffic. Movement of differently abled people is not even thought in any of the road section. Ramps are provided somewhere without having sufficient assessment and also do not match the standard to use by differently able people along with no provision of urban design facilities for pedestrians.

The major reason behind the poor pedestrian environment in our context is the lack of proper planning for pedestrian in urban areas, lack of norms, standards in our country regarding planning for pedestrian.

4. RECOMMENDATION

As such the objective of this research is to improve the pedestrian environment and to propose ways to incorporate planning for pedestrian while designing the new roads as a part of the town-planning schemes, certain regulatory measures are required to improve existing pedestrian environment whereas some are required to establish standard and norms for planning for pedestrian. The recommendations thus will be useful to improve the existing pedestrian environment as well as to incorporate suitable planning for pedestrian while designing cities.

The poor physical condition of the footpaths in context of our urban roads should be improved with regular inspection and timely maintenance if damaged. The surface of footpath should be evenly paved throughout and different functions along footpath can be differentiated by different color pavements. The streets or footpaths paved with slippery stone pavement should be discouraged and removed.

Street vendors being the essential character of urban areas which makes them live and vibrant all the time should be incorporated while designing the urban roads as a part of town -planning schemes whereas the existing problem of pedestrian environment caused due to encroachment of street vendors can be reduced by providing specific street vending space to incorporate specific category of street vendors in certain sections with permitted time schedule and regulatory measures. In the wide footpaths, clear marking for the pedestrian way and street vending space may be done which limits street vendors to occupy only the provided space leaving the pedestrian walkway free for them.

To motivate people to walk over using vehicles in urban areas of Kathmandu, urban design elements and street furniture; such as benches, bus shelters, dust bins should be provided wherever possible. A pedestrian facility with these features creates an environment that encourages walking and social interactions. Specific pedestrian signage should be introduced with information of origin and destination places including the time distance for walking to reach the places. The haphazard use of signage and hording boards should be discouraged. The pedestrians' space should be clearly divided into distinct four zones as Edge, Furnishing, Throughway and Frontage zones wherever adequate space is available for pedestrians. These zones should be then properly designed with necessary elements to facilitate efficient pedestrian movement.

The existing behavioral pattern of road users has to be changed for efficiency and convenience of road users including pedestrians. Driver should change their behavior of stopping at wrong places, overtaking from the wrong side, honking unnecessarily, and bike riders riding their bike through footpaths, neglecting pedestrians, speeding up dangerously, giving less regard to sign and signals. Pedestrian should change their behavior of walking on roads rather than footpath and not crossing road through overhead bridges or zebra crossing.

Besides these, appropriate means of crossing the road i.e. overhead bridge with ramp facilities for differently able people, special crossing design at junction should be introduced to facilitate pedestrian. The traffic management should be strengthened. One way traffic management system and restricting flow of heavy vehicles during certain hours of day at the inner core of cities may be the better solution to facilitate pedestrian.

At policy level, street vendors must be regularized in their street occupying activities. The probable vending pockets are to be incorporated in pedestrian space planning. For derivation of effective width of footpath in the transportation hub, the vendor factor must be included for design. The pedestrian environment is largely affected by the surrounding buildings. In our context, due to the lack of strict enforcement of bye-laws, there is un-uniformity of building heights making the urban streetscape visually disturbing. The unequal plinth height of buildings, private building’s steps encroaching public footpath, house owners projecting cantilever over the footpaths are few more examples causing pedestrian environment more problematic due to strict enforcement of bye-laws. Thus, the concerned institution should be strengthened to implement the building bye-laws strictly so as to regulate the buildings uniformity and footpath encroachment by private buildings.

As a general policy on-street parking should be prohibited in all central area streets apart from designated areas. The off street parking policy should be enhancing for better pedestrian facilities on the streetscape. The strict building regulation should be implemented in order to provide spaces for off street vehicular parking. The off street vehicular parking integrates pedestrians into the destination land use reducing less congestion on the street.

To achieve an integrated approach, a different type of hierarchy called a ‘road user hierarchy’ should be used, which suggests that Pedestrians should always be kept at the top in road users hierarchy and their space should be clearly marked on the street. Most roads must accommodate a range of users. Their often conflicting requirements require a balance to be struck in the level of service provided for each user group and the allocation of limited space to each.

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Informal Sector at Nodal Points: Spatial Competitions and Complementarities

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***Abstract*: Informal sector activities including, street vending have been found increasing and has always been a source of conflict between different urban users. Vendors demand for spaces in urban areas which results in a distinct competition and initiates struggle for spaces between different actors. The present study thus explores how space as a major factor links different sectors i.e. competition for space and complement through space and how public sector's intervention on space changes and shapes informal sector locations and livelihood; spatial analysis. It is overall argued through the research that, informal sector operations are ever shifting, ever-configuring and worth exploring as they can be an asset to the urban setting generating municipal economy and creating vibrancy in urban areas but needs to be regularized with appropriate policy and regulatory measures. A case of Sundhara-Newroad stretch, Bhotahity-Ratnapark stretch and Jamal junction, in the capital city of Kathmandu is proved as a basis for grounding the theory. Examples cited include nodal points which are the strategic locations selected by the street vendors.**

***Keywords:* competition , complementarities, spatial analysis, nodal points, regulatory measures**

1. BACKGROUND

Informal sector (IS) is an intrinsic part of cities, especially in developing countries. Although referred as unregistered/unorganized, micro-enterprises, it is the most common thing every passer by notices at side of streets, junctions or at public places. Comprising the largest part of the economies of developing countries, from the last couple of decades it has received increasing attention. IS market which in general, is characterized by ease of entry and exit lacks the component of 'space' (Brown, 2005).

Space is valuable in cities, and vending at strategic locations like intersections, transport deports adds to the competition and complementarities for space between the vendors and other sectors. When space changes to place, activities boost and city gains its wealth itself. In the context of Kathmandu, the past has witnessed an informal market system, like the traditional bazaars of Ason, but with the need of taxation formal and informal sector got separated resulting competition and complementarities.

It is against this background that this paper seeks to unravel the nature, new dimensions, scope, shape, variations by the informal actor in urban economy, highlighting the age and gender aspects. It shall give an air of finality by finding ways planning can help to minimize competitions and maximize complementarities.

2. RATIONALE OF THE STUDY

For urban planning, it is essential to know how urban space is utilized by different users. Informal sector workers being one of the major stakeholders, the research thus illustrates its struggle for space and explores its relationship with public user, vehicles and how they compete for space and complement each other in roadsides, majorly at the junction i.e. the "spatial analysis".

The research is not only limited to interaction at human level but with urban development project at socio economic level by defining the impacts and consequences informal sector had to bear due to these projects and how IS workers adapt and react to it. Even though IS market is such a crucial issue, it is not put in our development agenda and the policies lack to address it.

This paper thus seeks to describe the spatial linkage of informal sector with other sectors through competitions and complementarities in terms of socioeconomic, spatial, environmental aspects and for provision of infrastructure development projects and thus ends by identifying possible ways planning can help and a design approach to deal with.

3. STATEMENT OF PURPOSE AND STUDY AREA

The research is based on certain questions like how do the economic aspect, functional use of space, social utilization and environmental aspect change the use of space and result competitions and complementarities, how important is the interconnection between urban infrastructure development and informal sector welfare and how far has government policy been able to address it? Answering such questions, the study is expected to present scenario of informal sectors in city space and how creation of new spaces have a impact on them.

The nodal points selected for the site area represent difference in the way of competitions and complementarities i.e., the stretch from Sundhara to Newroad, Bhotahity - Ratnapark and Jamal junction. The site basically defines an interesting land use pattern i.e.

the whole area represents a cross road of traditional and modern development; pedestrian and vehicular traffic. The area is even ideal to view the relationship between the municipal institutes and the informal sector that lies in close proximity. The site elaborates the relationship between the violator and regulator and the immediate adaptive measures used by the informal sector workers in those areas.

4. Methodology

The research is exploratory and uses both the qualitative and quantitative approach. Primary data was collected through reconnaissance survey, non-intrusive survey, questionnaire survey and key informants interviews. In order to visualize the situations of vendors, their extension, market shape and place, vulnerability in terms of congestion and road encroachment etc photographs were used too.

Direct observation was conducted regarding issues like competition for space with different public user, how vendors cope while the metropolitan police oppose them. A sample of seventy, vendors was selected by accidental sampling method and questionnaire survey was conducted whereas technique like participant observation was also used being a consumer.

For the other stakeholders the interviews were then based on snowball sampling method. Similarly for quantitative research secondary data was referred i.e. several policy documents as well as other acts and regulations related to the street vendors were also collected concluding the analysis with Descriptive Empirical Analysis.

5. Results

A utilitarian perspective on the urban centers especially by the poor got inevitable from the observation, and through the analysis. Different characteristic of IS market emanated through the research. In the selected nodal points there was a concentration of informal players with about 60% of them being women i.e. the market encompasses higher presence of female vendors. Mostly the people of economically active ages (26-45) were involved in street vending occupation and higher proportion of vendors were found literate. It clearly illustrates, lack of jobs and incompetence in formal sector, as the key reasons of involvement of people in vending activity. While looking at the other side, the involvement of people in vending occupation had decreased with increase in level of education.

There are different dimensions of the informal sector, the micro-economic relations and the macroeconomic relations which have operated over a long period of time but in the new economic situation and urge of space the urban informal sector has taken a particular nature. For example, at a glance it seems that the vendors place themselves or chose commodity randomly but the research clearly showed that it is purely strategic i.e. majority of vendors chose commodity according to location and commodity type varied according to age group. Even the medium of display depended upon the types of goods sold.

In other circles, like the economic sectors too represented an interesting pattern. Majority of street workers were own account workers with very low investment in their business as compared to formal sector. Their income level was not constant and depended on type of merchandise and location. As the actual income and reported income (monthly) , was tabulated it was found monthly income was higher than the actual income with few exceptions.

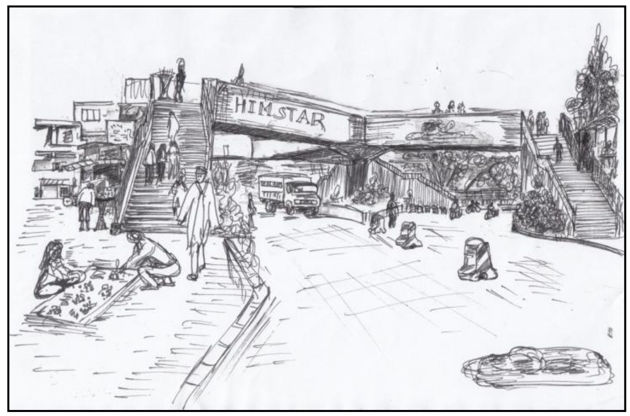

Figure 1: Sharing of space at Ratnapark
Source: *Fieldwork (2012)*

Relatively about the relationship of IS with other sectors varied i.e. in a way vendors were seen competing with them but they had something common in them too. For example, majority of vendors bought their goods from formal markets at proximate distances which witnessed that the products which found difficulty to reach the users from the formal markets got their outlet through the vending centers (Rouse, 2004). A link between the vendor and informal market could also be noticed making commodities from formal sector as a medium. The major factor of competition seen was for the commodity type, for the strategic location, for the space. Even though the space is public the formal sector suffered from the illusion of false ownership. But in some cases it was found formal sector provided spaces to informal sector but on certain condition i.e. some sort of sharing of space was observed according to time duration.

Whereas between the vendors too, they share a special relationship. As for example, some vendors selected same commodity as their nearby vendors, causing cluster effect resulting agglomeration and localization economies whereas some of them sold different products to make their product unique and easily profitable. It was also observed, vendors staying nearby did not compete for commodities and as such took care of each other commodities in absence of original vendors to develop social comradiece.

In the case of pedestrians and vehicles it is found to be a bit different. Pedestrian show dual behavior in the sense that when they need items they view vendors as relief otherwise as nuisance. The clubs present also had a negative approach towards the vendors. Due to the formation of several group of political ideologies even within vendors community, such organizations have lost its grip on the vendor.

Even the vehicles dominated the informal sector and controlled their location. Vehicles promoted vendors when stopped but when moved created problem for the vendors. Clearance of road and walkways from the authorities also was found conditional i.e. the space for which the competition took place is observed as a breeding place for corruption.

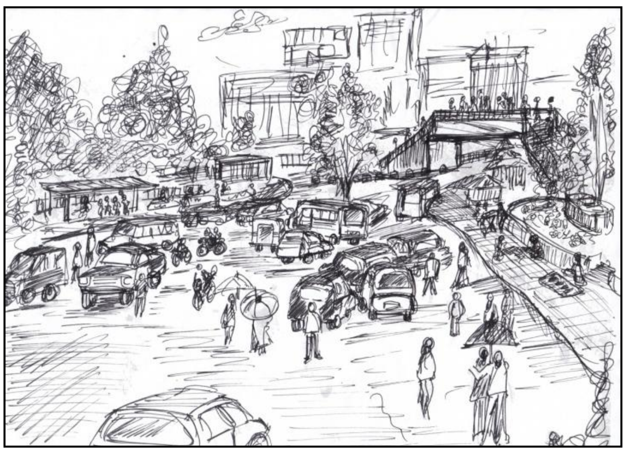

Figure 2: Competition for space at study area
Source: *Fieldwork (2012)*

The spatial distribution of vendor was the most interesting character in the IS market i.e. change in number of vendor and commodity according to time difference in the same area. For example in Bhotahity-Ratnapark stretch in morning time fruit and vendors were highest in number and evening time garment vendors were higher in number. One more peculiar characteristic came in notice from the study, that most of the migrant street vendors had short distance migration and resided in walking distance to their residence. The trend clearly shows there is a locational preference for vending occupation and residential space. Even though the family size is big majority of the vendors lived in rented houses or rooms in small areas i.e. slum type of condition. Even though the sector provides a big room for unemployed and is providing a productive activity changing a simple space to a vibrant and lively place there exists a game of tug of war in which one side consists of the IS and the other side is held high through the other actors (Rouse, 2004).

In institution's vision too, lack of clarity is seen with differing opinion through the bureaucrats working under same organization, so it clearly illustrates there is a long way in the recognition of informal sector. Literature on the informal sector is plenteous yet real understanding of the sector remains in obscurity. The sector continues to wear a new face each time (Kushma, 2011).

6. Conclusion and Recommendations

The objective of the study is to solve the problems and enhance potentials i.e. manage competition and promote complementarities. The recommendations thus are provided to maximize social welfare benefitting all the actors and activities in the society.

The major problem identified through the research was competition led conflicts in use of space which can be solved by designing junction for creating discipline in traffic behavior and vendors could be incorporated by allocating spaces in it.

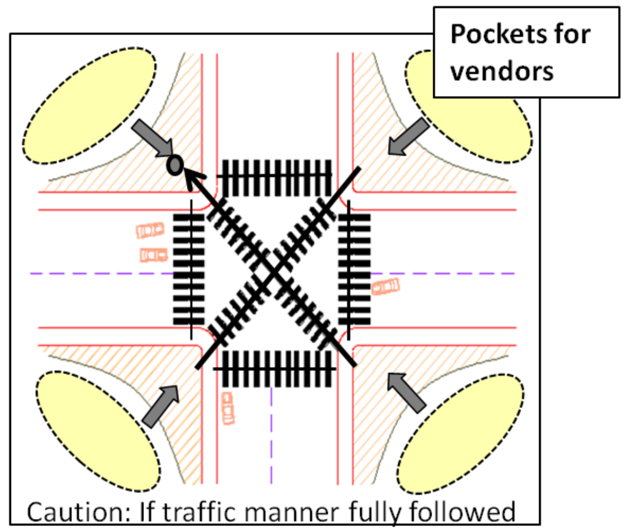

Figure 3: Spatial inclusion through urban design

Multilane overhead bridges with compatible scales could be also a viable option to incorporate vendors along with flow of people. And basically while designing the new roads as on street vending provisions could be done. For existing roads, negative and incidental spaces could be used for the vendors allocation which would result in making unused spaces productive and vice versa the vendors could help in making municipal economy vibrant. The best option followed by other countries and could be used in our context is commercial complexes could have space reservations for vendor stalls which could create pool of consumer of lower and middle class people having direct benefit to the formal sector shops and create vibrancy and liveliness in the place.

Another problem identified was waste generation which could be solved by establishing local vendor markets at area abutting major roads. Street food vendors could even be grouped together in pedestranized area like Basantapur developing it into food court and the vendors could pay certain charges per square meter as cleansing fees to a group formed in that locality.

Whereas the major problem in policy level was found to be short distance migration which could be solved by planning in regional level i.e. addressing root cause like insufficient employment in rural area and market towns could thus be developed as a response to increased trade or to the settling of sparsely populated frontier areas.

Since urban challenges are complex, participation of marginalized groups at all stages of planning is required realizing their vision in long run and thus deserve attention and space. As such, policies should be directed as much as possible to embrace the phenomenon of IS and consider them as a part of cityscape.

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A study on thermal performance of traditional residential buildings in Kathmandu valley

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Abstract: **This thesis seeks to investigate into the aspects of thermal performance of traditional residential buildings in traditional settlements of Kathmandu valley. This thesis posits that, it is possible to achieve thermally comfortable environment in cool winter and hot summer in Kathmandu through the use of time-tested, thermally comfortable traditional design, materials and technology. The present thesis takes a closer look at the theories, practice and psychology of thermal environment in general and residential environment of Kathmandu in particular. It begins with a brief review of the concept of traditional residential building from the past to the present. This thesis then proceeds to analyze the detailed field data collected, with a view to identify the indoor thermal environment with respect to outdoor thermal environment in different seasons taking into consideration various variables such as design, planning, orientation, material, construction technology, room height, etc. This collected field data is then compared with the contemporary residential buildings of Kathmandu. Therefore, a detailed field data has been conducted, in order to get a deeper understanding of thermal behavior of these buildings in traditional settlement of Kathmandu.**

Regression analysis has then been performed to obtain thermal performance of buildings with different conditions. A new formula was invented from regression analysis to predict indoor air temperature from outdoor temperature in these buildings. This thesis then analyzed the data collected in a laboratory with experiments of different materials and construction technology adopted in traditional, contemporary and modern green buildings in Nepal. This collected lab data has been analyzed with a view to identify the role of materials and technology with collected field data for indoor thermal environment. There is field information about the thermal comfort sensation, preference and recommendation of residents of different buildings of these settlements. The thesis concludes that, thermal performance of traditional residential building, adapted in various ways to the changing thermal regime for thermal comfort is better than that of contemporary buildings. It finds evidence to prove that planning, material and technology used better for local climate are to the satisfaction of the local people.

Keywords: Traditional, Modern, Residential building, Indoor, Outdoor, Air temperature, Thermal comfort, Brick and CSEB

1. INTRODUCTION

There is a general perception that traditional architecture is better in terms of thermal environment than contemporary architecture (Tiwari et al. 2004). The present study has been set out to investigate thermal environment of traditional residential buildings in traditional settlement of Kathmandu valley in Nepal. The study also compares the thermal environment of the contemporary residential building with traditional buildings of Kathmandu. This study clarifies the thermal performance of the traditional and modern residential building in a composite climate of Kathmandu. This doctoral research was initiated in May 2008 under the Trans-Himalayan University Network for Development, Education and Research (THUNDER) program in the Department of Architecture and Urban Planning, Institute of Engineering, Tribhuvan University.

The aim of this research is to find out how the materials, forms and construction technology of traditional residences in Kathmandu addressed thermal comfort of the occupant for long time in the history. It also aims to know the perception of thermal comfort of the people from the traditional and modern residences of Kathmandu. The study aims to examine how the traditional houses of Kathmandu may inform thermal comfort for future with the same materials, building forms and construction technology. It studies to find out any need of correction in the traditional houses to address thermal comfort of occupant in future. The purpose of this research is to help to stop the degradation of traditional architecture from cityscape of Kathmandu. Another main purpose is to help for conservation of this architecture with its materials, technology and form in future. The study also recommends the material and technology for thermal comfort and energy saving in future.

2. OBJECTIVE

This research has following objectives:

1. To evaluate thermal performance of traditional houses

2. To compare thermal performance of traditional houses with modern houses
3. To know perception of people for thermal comfort in traditional residential building
4. To develop new equation to predict the indoor thermal environment with the help of outdoor temperature
5. To experiment to study role of materials and technology used for traditional, modern and green houses for the thermal performance
6. To compare thermal performance of traditional, modern and selected green materials for creating thermally comfortable buildings
7. To help for conservation of energy efficient traditional building

3. METHODOLOGY

In order to fulfill the objective, the present research has adopted mixed method. This research has two basic methods of investigation. It has both quantitative and qualitative components. The research has designed and divided in to three areas to study the thermal performance of traditional residential building. One of quantitative methods adopted was experimental research which was carried out intensively in field as well as in a controlled environment lab. This research study investigates thermal performance mainly with different field experiment focusing especially the role of materials and technology.

This research is designed as mainly applied research and main purpose of research is to discover the thermal performance of traditional buildings. In this sense, the main research focuses to field study with monitoring thermal performance of different residences for a year. The field experimental research carried out in traditional residences in Patan and Kirtipur of the Kathmandu valley. The evaluation of thermal environment of buildings contains with field data, sample analysis, regression analysis, followed by discussion and aiming to draw the results and conclusions. The other experimental research area carried out in a lab. The experimental research adopted in a controlled environment lab in the architecture department of Pulchowk campus.

The next qualitative method adopted as household questionnaire survey to access the thermal comfort of the residents of different buildings in traditional settlements of Kathmandu valley. The qualitative household questionnaire survey adopted for the local residents of different buildings in traditional settlements of Kathmandu valley. The objective of qualitative household questionnaire survey is to study the perception of thermal sensation and comfort of local people in traditional and modern residential building. The detail methodology of these three studies was explained below.

All the data collected from field and household questionnaire survey was analyzed statistically with the help of SPSS software.

A. Field study: Evaluation of thermal performance of building

The study area is located in traditional residential buildings in traditional settlement of Kathmandu valley. The fourteen numbers of different traditional residences listed as research sample randomly with photographs and drawings. This paper focuses randomly selected only five residences among these residences for detail study for evaluation of thermal environment with measurement of temperature data. Also two modern residences were selected for detail study with measurement of temperature data to compare with traditional buildings (Table 1).

Table 1: Description of the investigated residential buildings

S.No.	House	Type	Location	Area	Layout	Orientation	Construction	Planning	Roof
1	D B Maharjan	Traditional	Dev Dhoka	Kirtipur	Street	South	Loadbearing	Vertical	Slope
2	A Maharjan	Traditional	Yelmul	Patan	Courtyard	South	Loadbearing	Vertical	Slope
3	S Maharjan	Traditional	Subahal	Patan	Street	North	Loadbearing	Vertical	Slope
4	N D Maharjan	Traditional	Dupat	Patan	Courtyard	North	Loadbearing	Vertical	Slope
5	N L Maharjan	Traditional	Pilanchhe	Patan	Courtyard	East	Loadbearing	Vertical	Slope
6	P Tandukar	Modern	Konti	Patan	Street	East	Frame	Not Vertical	Flat
7	R M Shrestha	Modern	Kobahal	Patan	Courtyard	West	Frame	Not Vertical	Flat

Figure 1: Sample of investigated traditional residential buildings in Kathmandu

The investigations of thermal environment of the building were conducted by measuring air temperature in summer, autumn, winter and spring seasons. The air temperatures were measured for normally thirty days in each season. There were five measurement points in each building. The four points were inside from ground floor to top floor. The one point was located outside the living room in third floor below the roof overhang to know outdoor air temperature. Care was taken to avoid direct sunlight on the thermometer throughout the day. The indoor measurement points were 1.5 m above the each floor level. All data were measured three times a day in each season by simple room thermometers (Omsons ISO 9001:2000 Company) manually. All data were measured seven o'clock in the morning, two o'clock in the afternoon and ten o'clock in the evening of each day. The measured data were calibrated.

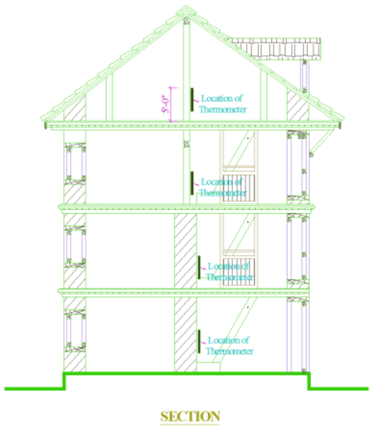


Figure 2: Views of locations of wall thermometers (Omsons ISO 9001:2000 Company) inside and outside of the building

B. Lab study: Thermal experiment of material and technology

This is another study area of this research. The lab research area is supporting study for main field study in this research. One of the most important factors for thermal performance of any building is the material and technology. The study contains the lab experiments of thermal behavior of different materials and technology. This lab experiment shows how materials get affected by high or low temperature in a controlled environment. The lab experiment area focused to study the thermal behavior of different individual materials, combination of different materials, thickness of materials used in different types of wall in traditional, modern and green buildings. The lab study focused on study of multilayer wall of burnt brick (*pakki apa*), sun dried brick (*kachi apa*) and mud mortar as well as modern wall of burnt bricks and cement mortar and modern green wall of compressed stabilized earth block (CSEB). So this lab experiment was conducted with five different walls as follows; 600 mm thick traditional wall, 450 mm thick traditional wall, 230 mm thick modern wall, 110 mm thick modern wall and 200 mm thick CSEB green wall. The study area concentrated especially on materials and technology in wall which can be compared with the field experiment data for conclusion.

Figure 3: A wall constructed for experiment in the insulated thermal box in a laboratory, Department of Architecture, Pulchowk Campus

To study the role of thermal performance of material, technology of building with experiments, a controlled laboratory was established in the architecture department of Pulchowk campus. Before start the laboratory experiment of all materials and technology of different walls, a mini pilot experiment was tested in the environment of laboratory. For this purpose, the insulated thermal box was designed and constructed. The box was equipped with heater for heating and compressor and air blower device for cooling. AC duct was installed to blow hot or cool air for heating and cooling. A 450 mm thick traditional wall was constructed inside the thermal box (Figure 3).

The wall for experiment was constructed in the middle part of the box. The outer layer of wall considered as south side where AC system was installed for heating and cooling. The six thermo sensors were located in six locations inside the box. The first sensor R1 located in air of outer layer in south part of wall. It records the air temperature as outdoor air in a lab. The second, third, fourth and fifth sensors R2, R3, R4and R5 were located within middle level of the wall. These sensors record the surface temperature data of different layers in a wall. The last sixth sensor R6 located in air of inner layer in north part of the wall. It records the air temperature as indoor air in a laboratory.

The maximum of 36°C of hot air was passed through outer layer (R1) to know the heating effect as summer condition in each layer of wall and inside layer in this thermo box. First of all, date, time and temperature of lab were recorded in a paper. After the power was switched on, initial temperatures of six layers were recorded to compare after heating effect. The maximum temperature was fixed for heating to blow the hot air. The maximum 36°C was set in changeover switch to control the temperature for blowing hot air constantly. The air was blown for five hours in the lab. Then the final temperatures were recorded in all six layers for comparison of heating effect in each layer. Same way; the minimum of 9°C of cool air was passed through outer layer (R1) to know the cooling effect as winter condition in each layer of wall and inside layer in the thermo box.

C. Questionnaire survey: Thermal comfort of residents

This is the third study area of this research. As present research has adopted mixed research method, it has both quantitative and qualitative components. So this qualitative research is supporting study for main field study in this research. This qualitative research is designed to study the thermal comfort of residents in different types of residential building in traditional settlement of Kathmandu valley. But this questionnaire survey has not been done intensively with local occupants as compared to previous thermal comfort study done in Nepal (Rijal et al. 2010). But the inferences of previous thermal comfort study done in Bhaktapur, Nepal by Rijal also have considered in this study. The household questionnaire survey was designed with reference to previous thermal comfort study done in Nepal by Rijal (Rijal et al. 2010) and ASHRAE thermal comfort standard.

This questionnaire survey was developed and done with only fifty local occupants of selected residence in participatory methods. Household is a house and its occupants regarded as one unit. The questionnaire is a set of printed questions with choice of answers and devised for the purposes of statistical study. The survey is an investigation of opinions and experiences of occupants. Altogether five areas were conceptualized to seek the answer to the existing information regarding the thermal comfort, thermal sensation, thermal preference and recommendation for type of building for future.

Figure 4: Views of household questionnaire survey for Mini pilot survey

An orientation was given to local assistants before starting questionnaire survey. The pilot survey area was chosen householders of residential buildings at Konti in Patan of the Kathmandu valley. Before collecting detailed household survey, a pilot survey had tested and reviewed the answers from questionnaire survey with local assistants. There are mainly three different types of residential buildings. They are traditional, modern and mixed type residential building. The survey focused on the answer of question like thermal behavior for comfort environment and opinion for future building in the traditional settlements of Kathmandu. This mini study clarifies people's perception for thermal comfort, sensation, perception and willingness to construct type of residential building in core city area for future. The sample of household questionnaire survey was discussed and analyzed with experts and local assistants. Then the sample of questionnaire form organized and printed in Nepali language and translated in English.

4. FINDINGS FROM FIELD STUDY

A. *Mean comfort temperature*

The Nicol graph (Nicol et al. 1994) starts from findings that the temperature which people finds comfortable indoors varies with the mean outdoor temperature for free running building (not mechanically heated or cooled). This is especially true for people in 'free running' building of Kathmandu also. The figure 5 shows an example for monthly mean temperature of Kathmandu drawn from the www.weatherbase.com and compare Nicol graph and Rijal et al. (2010). The relationship between indoor comfort temperature and outdoor temperature can be used to compare for buildings of Kathmandu. The lowest temperature considered comfortable might be nearly 18°C during winter and highest to 26°C in summer from Nicol graph and nearly 15°C during winter and highest to 26°C in summer from Rijal et al. (2010).

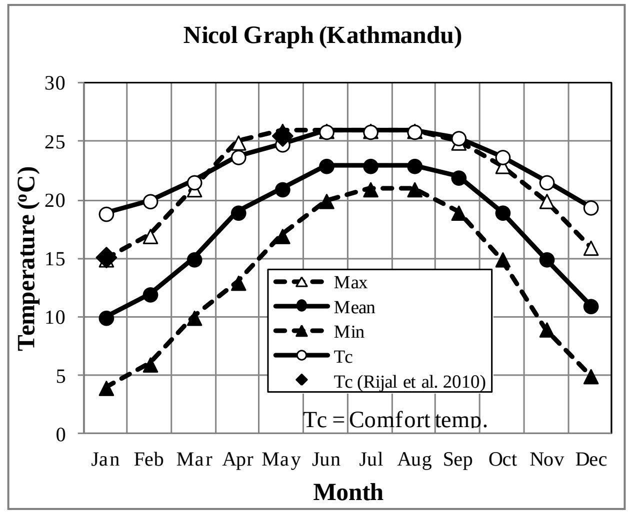


Figure 5: Outdoor air temperatures and the comfort temperature (Tc) for residential buildings of Kathmandu, Nepal (source: Nicol graph (1994) & Rijal et al. 2010)

B. *Indoor and outdoor temperature of traditional building*

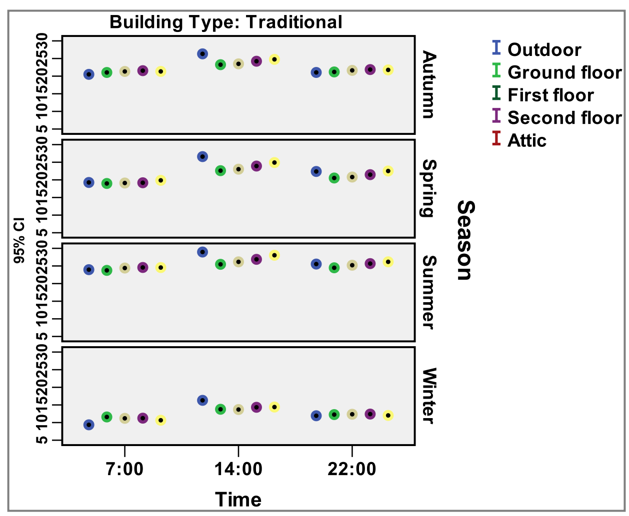


Figure 6: Indoor and outdoor air temperature in traditional residential buildings during different time and seasons

In order to clarify air temperature, the results were analyzed by dividing each traditional building in different seasons. Figure 6 shows the mean indoor and outdoor air temperatures of traditional buildings in all four seasons over one year period with 95% confidence interval. The most of traditional building indoor air temperature was lower than outdoor during daytime in the summer. The outdoor mean maximum air temperature ranges from 25 to 28°C whereas indoor mean maximum air temperatures range from 25 to 26°C.

During winter, most of traditional buildings indoor air temperature was either same or higher than outdoor air temperatures. The outdoor mean maximum air temperature ranges from 11 to 14°C whereas indoor mean maximum air temperatures range from 12 to 15°C during morning and evening. The comfort temperature of Kathmandu is 15°C in winter and 26°C in summer (Rijal et al. 2010). The result shows that the traditional residential building maintain comfort temperature in summer and little bit less than comfort range in winter without any mechanically heated or cooled.

C. Indoor and outdoor temperature of traditional building and modern building

In order to compare the thermal behavior of traditional and modern buildings, air temperature were analysed by dividing in two different seasons of winter and summer. The figure 7 show normally during summer, mean indoor air temperature of traditional buildings were less than mean outdoor air temperature whereas mean indoor air temperature of modern buildings were higher than mean outdoor air temperature. The mean indoor air temperature during summer is 24.5°C, 25.5°C, 25.8°C, 26°C from ground to attic respectively when 26.3°C outdoor in traditional and 25°C, 26°C, 27°C, 27°C ground to attic respectively when nearly 25°C outdoor in modern building. The indoor mean air temperatures range from 24 to 26°C in traditional building when nearly 26°C outdoor and indoor mean air temperatures range from 25 to 27 °C in modern building when nearly 25°C outdoor. This shows that traditional residential buildings were minimum 1 to 2°C cooler than modern residential buildings during summer.

Same way, during winter, in most of traditional residences mean indoor air temperature was either nearly same or little bit higher than mean outdoor air temperatures (12.5 °C). But in modern residences indoor air temperature was either nearly same or 1°C lower than mean outdoor air temperature (11.5 °C). This shows that traditional residential buildings were 1 to 2 °C warmer than modern residential buildings during winter.

In order to know the thermal behavior of buildings, air temperature were analysed further by dividing the traditional and modern building in three different times a day in different seasons. Figures 6 and 8 show the daily mean outdoor and indoor air temperature in the morning, day and evening of different seasons in traditional and modern buildings. During summer daytime, the indoor mean air temperatures range from 26 to 27°C in traditional building when nearly 29°C outdoor whereas indoor mean air temperatures range from 27 to 29°C in modern building when nearly 27°C outdoor. This shows that traditional residential buildings were minimum 1 to 2°C cooler than modern residential buildings during summer. Same way, during winter morning time, the indoor mean air temperatures range from 12 to 13°C in traditional building when nearly 9°C outdoor whereas indoor mean air temperatures range from 10 to 11°C in modern building when nearly 10°C outdoor. This shows that traditional residential buildings were minimum 2°C warmer than modern residential buildings during summer.

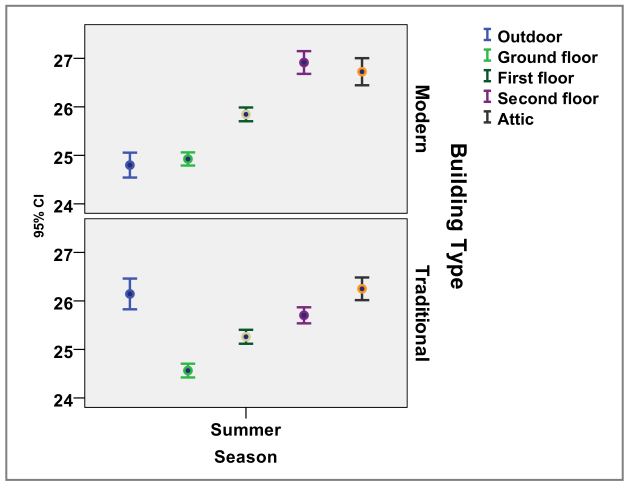


Figure 7: Comparison of indoor and outdoor air temperature in traditional and modern residential buildings during summer

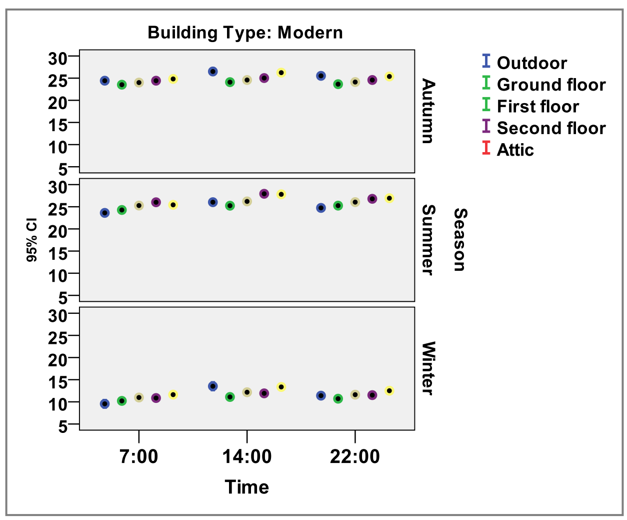


Figure 8: Indoor and outdoor air temperature in modern residential buildings during different time and seasons

D. Prediction of indoor air temperature by regression analysis

To predict the indoor air temperature of a residential building, the regression analysis of the indoor and outdoor air temperature was conducted. Figures 9 and 10 show the examples of traditional and modern residential buildings. Table 2 shows the result of the linear regression analysis of the each floor of traditional and modern residential buildings. The equations for all traditional and modern residential buildings are given below.

Traditional: $T_i = 0.8905T_o + 1.6125$ (1)

Modern: $T_i = 0.9392T_o + 1.3379$ (2)

According to regression equation, when outdoor air temperature is 10°C, the indoor air temperature in ground floor of traditional residential building is 12°C whereas the indoor air temperature in ground floor of modern residential building is nearly same 10°C (Table 2).

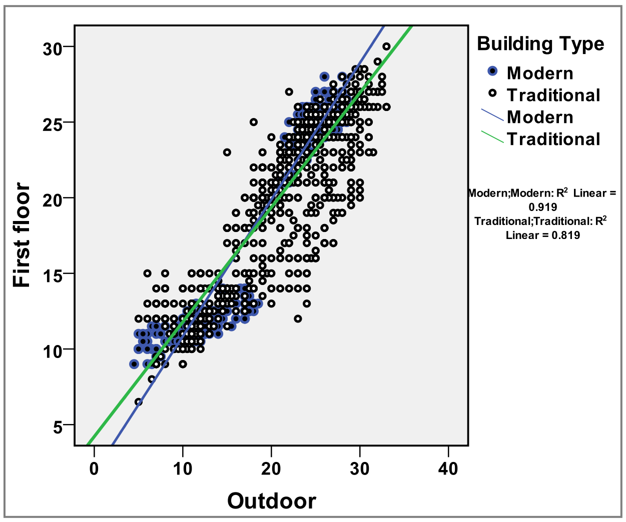
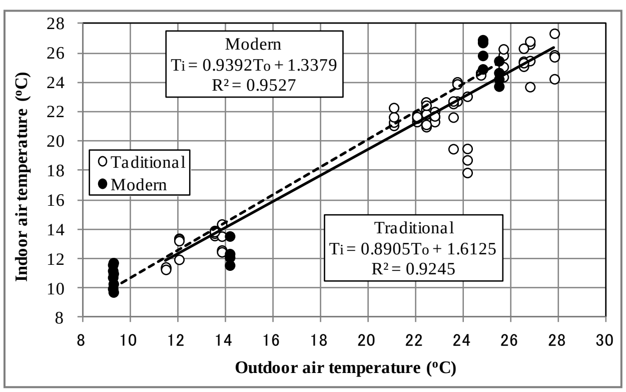


Figure 9: Regression analysis of the first floor and outdoor air temperature in traditional and modern residential buildings



Figue 10: Relation between indoor and outdoor air temperature in traditional and modern residential building

Table 2: Regression equations of the indoor and outdoor air temperature

Type	Floor	n	Equation	R^2	S.E.	p	Tp Max °C	Tp Min °C
Traditional	Ground	1292	$T_i = 0.714T_o + 4.829$	0.82	0.009	<0.001	24.8	12.0
	First	1295	$T_i = 0.758T_o + 4.211$	0.82	0.010	<0.001	25.4	11.8
	Second	1276	$T_i = 0.806T_o + 3.610$	0.86	0.009	<0.001	26.2	11.7
	Attic	1295	$T_i = 0.885T_o + 2.301$	0.90	0.008	<0.001	27.1	11.2
Modern	Ground	325	$T_i = 0.922T_o + 0.655$	0.93	0.014	<0.001	26.5	9.9
	First	325	$T_i = 0.904T_o + 1.802$	0.92	0.015	<0.001	27.1	10.8
	Second	325	$T_i = 0.975T_o + 0.805$	0.92	0.016	<0.001	28.1	10.6
	Attic	325	$T_i = 0.937T_o + 2.165$	0.95	0.012	<0.001	28.4	11.5
Traditional	All	5158	$T_i = 0.890T_o + 1.612$	0.92		<0.001	26.5	10.5
Modern	All	1300	$T_i = 0.939T_o + 1.338$	0.95		<0.001	27.6	10.7

T_i : Indoor air temperature (°C), T_o : Outdoor air temperature (°C), n: number of sample, p: significant level of the regression coefficient, $T_{p\ max}$: Predicted indoor air temperature when outdoor air temperature is 30° C, $T_{p\ min}$: Predicted indoor air temperature when outdoor air temperature is 10° C

5. Findings from Lab Study

This study has presented the data from the lab experiments regarding the material and technology used in buildings of Kathmandu. This experiment deals in great findings on the thermal performance of the different walls with the conclusion that 600 mm traditional thick wall performs best followed by 450 mm thick traditional wall and 200 mm thick CSEB (Compressed Stabilized Earth Block) green wall. This experiment also recommends the use of traditional materials and technology or green materials and technology like CSEB for better thermal comfort in indoor environment.

The lab experiment shows that when thickness of sun burnt brick is more or equals to 500 mm as in traditional wall, the temperature begins reverse from initial layer R3 of sun burnt brick. This creates cool in summer and warm in winter condition. More the thermal mass reverse will be the action in indoor environment. That is why the 600mm thick wall has the best thermal performance in indoor and used in our traditional houses. Also these buildings were nearly 2 °C warmer in winter and nearly 2 °C cooler in summer than modern buildings. This may be role of thermal mass which create reverse effect of indoor thermal environment as in laboratory experiment. Compared to modern building, this type of material and construction of traditional building saves minimum 1-2 °C temperature in both hot and cool seasons for thermal comfort. But this also saves minimum 10 -20% energy for either heating or cooling in these building both in summer and winter than a modern building (Nicol et al. 2012). It gives knowledge for saving energy and prepares an energy efficient design.

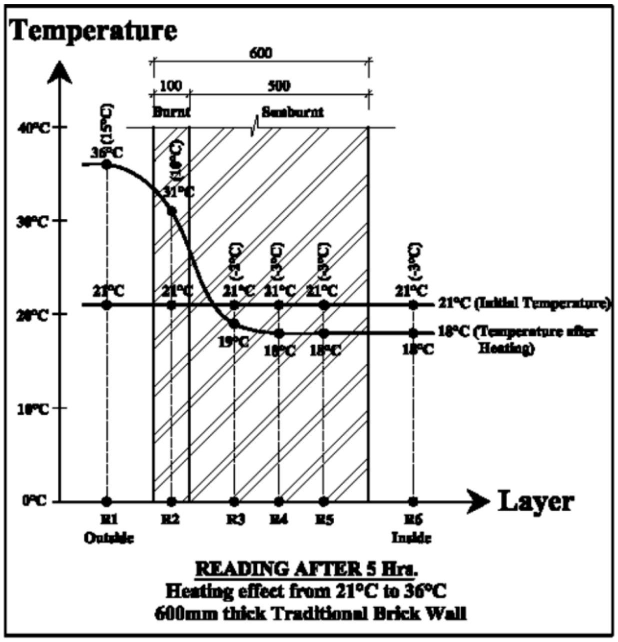


Figure 11: Temperature gradient after heating effect as summer condition in a 600 mm thick traditional wall in the laboratory

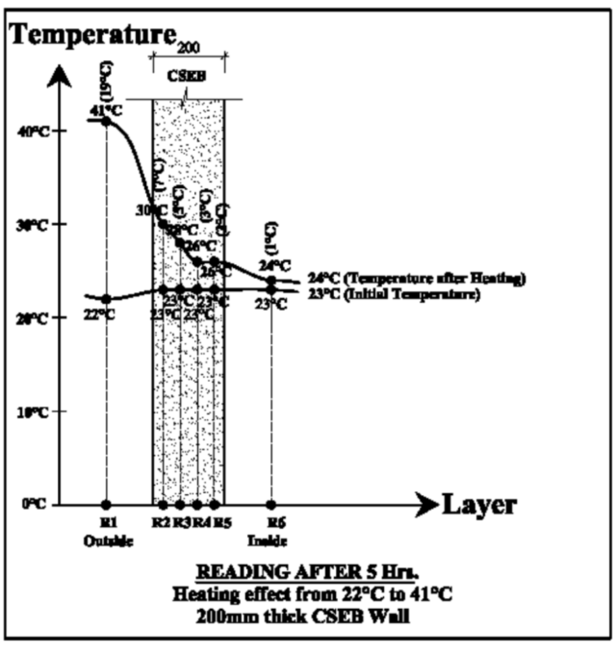


Figure12: Temperature gradient after heating effect as summer condition in a 200 mm thick CSEB wall in the laboratory

The findings show that rate of heat flow in CSEB layer is very slow than burnt brick layer of the traditional and modern walls. Compacted Stabilized Earth Block (CSEB) compressed in machine AURAM -300 is better thermal properties and its performance same like sun burnt brick of traditional wall. To reduce thickness of sun burnt brick, the compactness should be applied. The 200 mm thick CSEB wall and 450 mm thick traditional wall has same thermal environmental effect in indoor layer R6. The thermal performance of modern CSEB wall could be better for future in modern buildings. So Jagadish et al. (2007) wrote the alternative Technology needed to solve the problem of development in a developing country rather than high technology.

Figure 13: Views of manufacture of CSEB by AURAM -300 machine and the CSEB model classroom building in the Department of Architecture, Pulchowk campus, Lalitpur, Nepal

Hudco India (1986) has remarked that rooms in mud houses are often dark and badly ventilated but they provide comfortable living in the extremes of the tropical climate, warm in winter and cool in summer. This is true if we compare the lab experiment results that rate of heat flow in sun burnt layer is very slow than burnt brick layer of the traditional wall. From both of the traditional walls, the rate of heat flow is either reverse way or very slow in the sun burnt brick layer. One of the important outcome of this lab work, the sun burnt brick has maximum role to create thermal environment better in summer and winter condition in the traditional buildings.

6. FINDINGS FROM QUESTIONNAIRE SURVEY

The results shown variety of positive aspect attributed to traditional residential buildings of Kathmandu. These positive attributes relate to better thermal performance than modern building, higher rate of willingness for construction and better comfort feeling in traditional building in both summer and winter season. The research finding shows that traditional buildings are not out-of-date but more acceptable to local people in Kathmandu. If we compare this in Iran, same types of study results were found in Iran. The people of Iran also noticed highly cultural and historic values of their traditional houses (Ahmadreza 2012).

Till today, this demand of local residents show the positive aspects in traditional buildings compared to modern buildings. In total, forty-four (44%) percentage of resident of different residential buildings and sixty seven percent (67%) of residents of traditional residential buildings like to construct their house in traditional style using traditional technology. These opening shows very strong results pointed towards traditional buildings in Nepal as in other places of world.

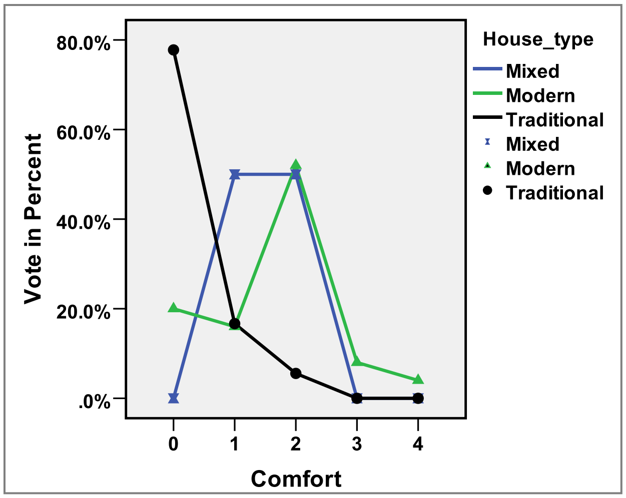


Fig.14 Percentage of thermal comfort of local residents in different building

In addition, the findings show that the local peoples' perception is very contrasting in traditional and modern buildings in Kathmandu. Overall, seventy eight percent (78%) of residents of traditional residential building feel comfortable in their building whereas sixty percent (60 %) of residents feel uncomfortable in their modern residence. Neither of the surveys shows that eighty-three percent (83%) of people feel neutral neither cool nor warm in traditional buildings whereas only twenty four percent (24%) of people living in modern building feel neutral in their residence. As studies done in Libya (Ahmad et al. 1985) and Yemen (Algifri et al. 1992), they also find traditional old building more comfortable compared to modern building as in Kathmandu.

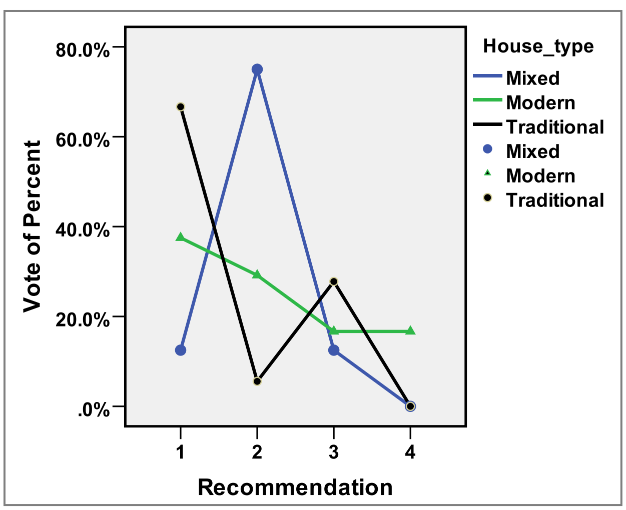


Figure 15: Percentage graph of local residents willing for type of building construction for future

Finally we can say why people feel that traditional residential building has better thermal performance than modern residential building in Nepal and all over the world. There is a general perception that traditional architecture has a better thermal environment than contemporary architecture (Tiwari et. al. 2004). This proves the general perception that traditional architecture has better thermal environment than contemporary architecture. This shows how local people find thermal comfort far better in traditional buildings than modern buildings. This result show that most of the people living in traditional and modern building still like to construct the traditional building in future.

7. Results and Discussion

In this research, we conducted a thermal measurement of the indoor and outdoor thermal environment of traditional as well as modern residential buildings in Kathmandu. We also conducted thermal experiments for materials and technology in a lab and perception survey of thermal comfort. The following results were found:

1. The field study identified traditional residential buildings maintain comfort temperature within 24 to 26°C during summer season.
2. Especially in the morning and evenings during winter season, indoor air temperature (12 to 13°C) is 3 to 4°C lower than comfort temperature (15°C) for people in “free running” building of Kathmandu (not mechanically heated or cooled).
3. Indoor air temperatures were lower than outdoor air temperatures in summer whereas indoor air temperatures were higher than outdoor in winter in these traditional buildings.
4. Compare to modern residential buildings, the traditional buildings were 1 to 2°C warmer in winter and 1 to 2°C cooler in summer.
5. It saves minimum 10-20% energy for either heating or cooling in these building (Nicol et al. 2012) as it economizes 1-2°C temperature compare to modern residential buildings.
6. The indoor air temperature can be predicted by the outdoor air temperature. If we know the outdoor air temperature, we can predict the indoor air temperature using the linear regression equation.
7. The findings from questionnaire survey shown positive index to traditional buildings which supports field results.
8. The 78% residents feel comfortable in traditional building compare to 20% residents feel comfortable in their modern building. The 60% residents feel uncomfortable in their modern building
9. Local residents feel better thermal comfort in traditional building in both summer and winter

seasons. The traditional buildings are not out-of-date but more acceptable to local people.

10. This support the Nicol theory of adaptive thermal comfort. That is why, till today, people like to construct these traditional buildings in future. This is the strongest point of this survey with field work.
11. The findings from lab experiment shown cause of better thermal performance of traditional buildings.
12. Thick traditional wall with more sun burnt brickwork is the best with reverse effect in indoor thermal environment both in winter and summer seasons.
13. The 600 mm thick traditional wall has reverse effect in indoor where as 450 mm thick traditional wall has no effect in indoor after heating or cooling in a lab.
14. The modern green 200 mm thick CSEB wall has same effect in indoor as 450 mm thick traditional wall. The indoor temperature remains same without any effect in indoor thermal environment.
15. But the modern 230 mm thick wall has direct effect in indoor. The rate of heat flow in sun burnt brickwork either reverse or very slow. The rate of heat flow in CSEB layer slower than burnt brick layer.
16. That is why: even orientation also has no effect in indoor thermal environment in traditional buildings in traditional settlement of Kathmandu.

There are many findings in this research to be discussed with other research finding before drawing conclusion. One of the research findings shows that traditional buildings are not out-of-date but more acceptable to local people. Till today, this demand of local residents show the positive aspects in traditional buildings compared to modern buildings.

The finding has identified one of the most important aspects that are orientation of a building does not effect in the heating and cooling of traditional building in Kathmandu. This may be due to cluster system with courtyard and street planning. But the orientation and location of heavy thermal wall affect more for the heating and cooling of the building. Even in North facing building, it is noted that thermal environment is better during day time in summer because of the indoor temperature 3 to 4°C less than outdoor temperature of 30°C. During winter evening also, this building has better thermal performance than others due to heavy thermal wall placed in south face. It should be noted that the openings and main façade of traditional building in urban settlements of Kathmandu is oriented towards open spaces either courtyard or street. It is not directed towards Sun as practiced in most of traditional buildings in hilly and mountain region of Nepal.

The findings show that for summer and winter season, the lower the room height better is the thermal performance. A large room requires more heating or cooling energy to create comfortable thermal condition than small room. A research finding shows volume of a room of traditional building is nearly two times less than that of a modern building. The volume of air of any space directly demands energy to create comfort thermal condition during extreme cold and hot season when extra energy is needed to control thermal condition. This is true in mechanically ventilated modern buildings than free running buildings. A big room requires more heating or cooling energy to create comfortable thermal condition than a small room. This is true in traditional bed room which demands less energy to heat and cool due to small size from the history and life style of people living in traditional building in the past. In the past, people use fire on a local stove (*Makala*) to keep warm themselves which keeps warm during morning and evening of cold winter. During summer, they open the single ventilated window to operate cooling in the room which create cool inside. This is possible only due to small bed room having low ceiling height and less surface area in a room.

All the alternatives were developed from the traditional materials and technology. Jagadish et al. (2007) wrote the alternative Technology needed to solve the problem of development in a developing country rather than high technology. VSBK (2008), wrote this Rat Trap Bond technology saves 30% on bricks, 50% on cement and 130MJ energy and emits 30 kg less CO_2 than English bond. But one of important things is that it also good for thermal comfort. The 110 mm air cavity inside brickwork works for better insulation in modern buildings. It is better to use either traditional material and technology or modern green material and technology like CSEB for thermal comfort in indoor environment of building in future.

8. Conclusion and Recommendation

The research achieved the targeted goal and objectives with its findings from three different field, laboratory and qualitative studies. It is understood that every traditional building perform better thermal environment than contemporary buildings. There were many researches generally speaking, the thermal performance of traditional dwellings is better than that of modern dwellings (Ahmad et al.1985, Algifri et al. 1992, Meir & Pearlmutter 1995, Rijal 2010). However, a quantitative analysis is necessary to give the information needed to prove better thermal comfort. A qualitative understanding can easily be formed from the information. But no such study can be found in Nepal and world, so this study focused on the measurement of thermal performance in field and laboratory experiments.

The study focused on the measurement of thermal performance in field with monitoring thermal environment for one year. To know the practically for the thermal performance of materials and technology only, laboratory experiments helped correlate with other results from field. Then the qualitative study sought to get support to these studies. The outcomes of this study show that it achieved the results and fulfills its purpose. This research has presented the data from thermal measurement in the field, laboratory and household questionnaire survey regarding the indoor and outdoor thermal environment of traditional residential buildings in Kathmandu. The research findings has identified traditional residential buildings has its own merit that it maintains thermal comfort. Compared to modern residential buildings, the traditional buildings have better thermal performance in winter and summer.

One of the most important findings is linear regression equation to predict indoor air temperature. The indoor air temperature could be predicted by knowing the outdoor air temperature from weather forecast of meteorological department. The findings show the local people's perception very contrasting in traditional and modern building. This data show that most of people living in traditional and modern building still like to construct the traditional building in future.

The findings from laboratory experimental research identified the traditional 600 mm thick wall are the best with reverse effect in the indoor thermal environment both in winter and summer. That is why; field study finding show even in North facing building has better thermal performance than others due to heavy thermal wall placed in south face. This type of material and technology of traditional building saves minimum 1-2°C temperature in both hot and cool seasons compared to modern building. But this also saves lot of energy. It saves minimum 10 to 20% energy for either heating or cooling in these building both in summer and winter than a modern building (Nicol et al. 2012). It gives knowledge for saving energy and prepares an energy efficient design. These could be done in further research study in future.

One of the objectives of this research is to develop building with traditional character for future. The application of design principle of traditional building should be better to apply in modern building in Kathmandu. The new design principle should be better thermal performance of modern building with traditional building form, material and technology for future generation in Kathmandu. If possible use thick multilayer wall with sun burnt brick inside as thermal mass in exposed and central wall. If it is not possible to use thick multilayer wall, then it is better to use 230 mm wall combination with 110 mm burnt brick outside and 110 mm sun burnt brick inside as thermal mass in exposed and central wall. If possible better to use thick layer of sun burnt brick and mud inside in wall, roof and floor. This will create not only better thermal environment but also save energy and economize in long term. It is better to use CSEB as building material and technology in wall, roof and floor in new housing for future. It reduces the building cost, saves energy to maintain thermal balance and cleans environment. It can be reused, recycled and clean materials. Its embodied energy and carbon emission is low. The sloped roof is better than flat roof. Low volume with small sized rooms is better for energy efficiency than large room. It helps to design and construct energy efficient building in future.

One of the objectives of this research is to help for conservation of energy efficient traditional residential building of Kathmandu. As Madhavi (2010) study calls for a code of practice balancing modernization with the vernacular in Marikal town of India somehow our studies also similar to call for a code of practice balancing modernization with the vernacular architecture in Kathmandu in future. The implementation of Bye-law with conservation purposed shall be helpful to conserve traditional residential buildings of Kathmandu for future. The latest Bye-law (2064) of Kathmandu valley was developed for conservation purpose in chapter -4 of bye-laws of Bhaktapur. The traditional cultural residential zone is separated for the conservation purpose. The bye-laws of traditional cultural residential zone are better for the conservation purpose of traditional residential buildings among the five municipality of the valley. First of all, traditional cultural residential zone is separated in all municipalities and in old towns of Kathmandu valley. Then these bye-laws shall be implemented with these findings as in Bhaktapur in all five municipalities and traditional settlement of Kathmandu valley for the conservation of traditional architecture.

The researcher being a full time faculty member of the Department of Architecture and Urban Planning, Institute of Engineering, Tribhuvan University, the outcome of the research will also be instrumental in setting up a future elective course in Department of Architecture and Urban Planning, Institute of Engineering Tribhuvan University, Nepal as well as in all architecture school of the country. The findings shall be published in research papers in national and international journals and conferences for awareness and further research development. The author will try to collaborate and interact with local government and government to make policy to design building with thermal comfort and conservation of traditional architecture in future with research findings.

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Graduate Programs at IOE

History of engineering education in Nepal can be traced since 1942, when Technical Training School was established. Engineering section of the school offered only trades and civil suboverseers programs. In 1959, Nepal Engineering Institute, with the assistance of the government of India, started offering civil overseer courses leading to Diploma in Civil Engineering. The Technical Training Institute established in 1965, with the assistance from the Government of Federal Republic of Germany, offered technician courses in General Mechanics, Auto Mechanics, Electrical Engineering and Mechanical Drafting. In 1972, the Nepal Engineering Institute at Pulchowk and the Technical Training Institute at Thapathali were brought together under the umbrella of the Tribhuvan University to constitute the Institute of Engineering and the Nepal Engineering Institute and the Technical Training Institute were renamed as Pulchowk Campus and Thapathali Campus respectively. Since then, the Institute of Engineering has expanded considerably. The technician programs in Electrical, Electronics, Refrigeration/Air-conditioning Engineering were started in the Pulchowk Campus, with the assistance from UNDP/ILO. The Architecture Technician program was started by the IOE in its own effort. With the assistance of the World Bank and UK, later, the existing technician level courses were strengthened and Bachelor's Degree level course in Civil Engineering was started. Similarly, with the assistance of the World Bank, the Swiss Government, and the Canadian Government, Bachelor Degree level courses in the Electronics, Electrical engineering were started in 1994 and Mechanical engineering and Architecture were started in 1995 in the Pulchowk Campus. From academic year 1998/99 IOE has started Bachelor's Degree program in Computer Engineering.

In 1996, Pulchowk Campus started four masters program with initial support from the Norwegian Government. Since then, a lot of other masters programs have been running with a total of sixteen as of 2013. In addition, there has been regular Ph.D. intake from academic session 2010/11 in all central departments. Currently running masters programs are given below along with their start year and yearly intake capacities.

Program	Start Year	Intake Capacity
Urban Planning	1996	20
Structural Engineering	1996	20
Environmental Engineering	1996	20
Water Resources Engineering	1996	20
Information & Communication Engineering	2001	20
Renewable Energy Engineering	2001	20
Geotechnical Engineering	2001	20
Power System Engineering	2001	20
Technology and Innovation Management	2010	16
Transportation Engineering	2011	20
Disaster Risk Management	2012	20
Computer System and Knowledge Engineering	2012	20
Energy System Planning and Management	2012	20
Construction Management	2012	20
Climate Change and Development	2013	20
Material Science	2013	20

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