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Impact of Floor Area Ratio (FAR) on Energy Load in Kathmandu : Case of Sinamangal Town Planning

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Abstract
Massive increase in population, high demand of urban infrastructure and limited availability of land resources is burning concern of growing urbanization. Kathmandu's increase of FAR for residential areas is one of the controversial subject. This decision neglects physical, social and climatic aspect of urban fabric of Kathmandu let alone be the energy aspect. The study aims to find optimum FAR for Sinamangal town planning in energy prospect and review the pattern of change in FAR in building bye laws of Kathmandu. In this study, various FAR (1.75, 2.5 and 3.5) will be explored for the study area. A comparison study is conducted using Ecotect software. All 3 models are analyzed using different height and keeping all the other parameter constant. FAR 2.5 shows energy saving at Sinamangal town planning in comparison to FAR 1.75 and FAR 3.5. Further, the light plane concept to determine FAR was found out to be contradictory for climatic condition of Kathmandu. FAR is contextual in nature and contextual study for determining FAR is essential.

Keywords
Floor Area Ratio, Energy Consumption, Heating load, Cooling Load

1. Introduction

1.1 Overview

Over the recent decades, riotous trend of population growth inside the Kathmnadu Valley demands high rise buildings to accommodate itself. According to World Population Review, 2020 [1]. Kathmandu has a population of 1.42 million in 2020 with the annual growth rate of 3.45%. It is estimated to reach 1.94 million population in Kathmandu in upcoming decade. The massive increase in urban population have higher demands of urban infrastructure which is hard to fulfill with limited resources available. Kathmandu have experienced and are still experiencing rapid economic growth and urbanization. This has led to the expansion of built up areas and Kathmandu Metropolitan City (KMC) recently amended building bye laws in term of Floor Area Ration (FAR) allowing higher building heights in urban texture of Kathmandu. In any urban texture, Floor Area Ratio (FAR) of the site is a debatable factor across various stakeholders. In this study, FAR calculation is put in place to shape the argument of renewable energy production and pathways towards energy use reductions. Interaction between energy systems and urban structure happen in all spatial scales, from regional and urban neighborhoods, to buildings [2]. Up to now, sustainable urban structures have had a key role in the reduction of energy consumption. With proper formation of building regulation (FAR) energy efficiency can be achieved that optimize the use of solar energy as well as create thermally comfortable space. FAR is expressed as a decimal number, and is derived by dividing the total area of the building by the total area of the parcel (building area ÷ lot area). Mathematically, Floor Area Ratio is given by: Floor Area Ration (FAR) = Gross Floor Area (G) / Buildable Site Area (B)

FAR often used in conjunction with other development standards such as building heights, lot coverage and lot area to encourage flexibility. Building Bye laws, KMC, 2018 has published allowable Floor Area Ratio in Kathmandu is 3.5, where it was 1.75 FAR previously [3]. Thus, concerning impact of this sudden changes on urban energy load, the study of urban form and policy has become imperative.

The argument of compact versus dispersed urban form has long been debated by Holden, 2005 [4] and Mindali, 2004 [5] recommending density as equivalent to energy efficiency with its negative impact on natural lighting, solar gains and ventilation. Several studies Aggarwal(2006) and Pandya and Patel (2017) have highlighted the fact that FAR can be augment wind direction in urban canyons, allow or block daylighting, provide shade etc. Although building regulation regarding FAR are used to limit densities due to environmental and congestion issues, save arable land, these aspect has often over looked significant impact of how passive cooling and heating approaches [6]. These overshadowed aspect are directly linked with energy consumption by user group. It is uncovered that energy is not primary motivator for spatial planning in Kathmandu, Nepal. Some studies on urban form and energy carried out at other countries are enlisted below in Table 1.

Similar contextual study in order define logical FAR for urban texture of Kathmandu is in need. The recent increase in FAR leads to high rise construction. High rise construction reduce the amount of sunlight at interactive, social space leading to destroy the social use value of community spaces to parking lots, dumping sites, and stranger's place" (Shrestha, 2011) [9]. Kathmandu's increase of FAR for residential areas and lack of energy in spatial planning is motivation of this study. The study investigates impact in energy load (heating and cooling load) in existing town planning of Sinamangal at various FAR. Sinamangal Town Planning was completed by 2011, the rapid development occurred since past few years. The recent development and buildings of Sinamangal follows increased FAR, i.e. 3.5, the study shows impact of energy consumption in different FAR.

1.2 Objectives of the Study

The aim of this research is to study strategies that would be an aid for policy makers to adopt energy efficiency in building bylaws. The major objectives of this study are as follows:

- To review Building policy of Kathmandu in terms of FAR
- To study impact on Energy Load (heating and cooling) based on various FAR

2. Methodology

An interpretative paradigm of researcher will be used to assess and analyze the indicators of energy consumption caused due to change in FAR. The researcher uses both qualitative and quantitative approaches to achieve above mentioned objectives. Existing policies collected with secondary sources and reviewed qualitatively. Climatic and contextual data collected through questionnaire survey and analyzed with interpretative paradigm. While for energy modelling positivist methodology was followed, carried out using simulation software. Further results were discussed with relatable aspects and summarized to a conclusion.

2.1 Bio-climatic Analysis

A bio-climatic chart will determine the boundaries for different passive and active design strategies. Regarding the climate of Kathmandu, the comfort zone lies between 22 degree C and 26.8 degree C. Placing the calculated month (indicated by lines in Figure 1) shows passive strategies like: thermal mass effect and air movement could be efficient techniques to obtain comfortable zone inside. Air movement seems to be more essential being a humid climate. For extreme summer active cooling is required. Due to obtainable solar radiation, during winter passive solar heating could be useful. The chart reveals, even in extreme winter passive solar heating could be convenient and during summer direct and indirect evaporative cooling is required.

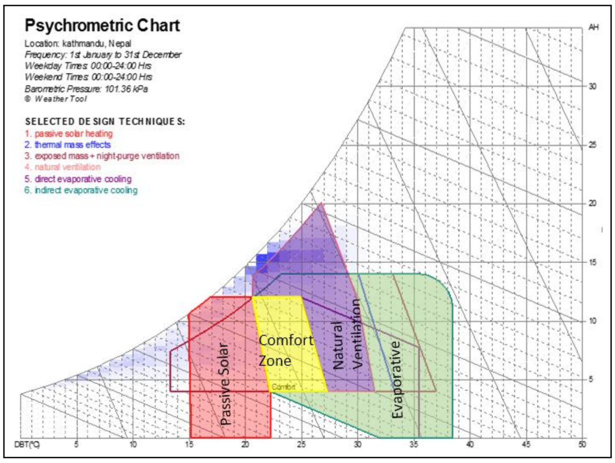

Figure 1: Bio-Climatic Chart of Sinamangal town planning

2.2 Sampling

Having numerous household, the sampling was done using Cochran formula. The Cochran formula allows you to calculate an ideal sample size given a desired level of precision, desired confidence level, and the estimated proportion of the attribute present in the

Table 1: Imapact of FAR in Energy and Urban Form in previous research

Study Area	Reference	Methodology	Findings
Ningbo, China Temperate Climate	Dawodu , Cheshmehzangi,2016 [6]	Ecotect Simulation	Higher buildings provide for more energy loss and less gain
		Comparison of various FAR	FAR 2.5 and 3 provide optimum solution to China's population and economy
Asyut, Egypt Dry and Desert Climate	Abdallah, 2015 [7]	Primary survey using data logger	11o C decrease in indoor temperature due to deep canyons
		Energy calculation	H/W ratio of 4 allows difference of 6 -9.4o C from outdoor temperature
Rome and Barcelona Warm- Temperate subtropical Climate	Morgnati et.al. , 2017 [8]	Heliodon2 Simulation	Façade to site ratio shows very good correlation with solar irradiation (R2= 0.91)
		Comparison of urban texture	And relation between other urban morphology indicators

population. Cochran's formula is considered especially appropriate in situations with large populations. A sample of any given size provides more information about a smaller population than a larger one, so there's a 'correction' through which the number given by Cochran's formula can be reduced if the whole population is relatively small.The Cochran formula is: $n_0 = z^2 pq/e^2$, where: e is the desired level of precision (i.e. the margin of error), p is the (estimated) proportion of the population which has the attribute in question, q is 1 – p. The z-value is found in a Z table. Thus for Sinamangal Town Pooling Consider, z = 1.64, for confidence level 90% p = 0.5, q = 0.5 and Taking error of 10 % e = 0.1 Then sample size is given by, N = $(1.64)^2$ x 0.5 x 0.5 / $(0.1)^2$ = 67.24 = 68

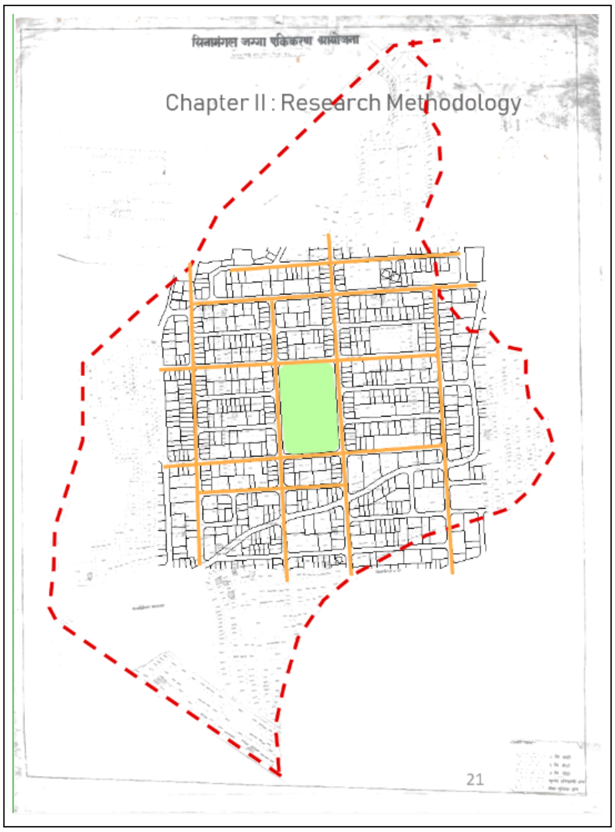

Figure 2: Sampling site at Sinamangal Town Planning

2.3 Energy Modeling

The sample size were simulated in Autodesk Ecotect 2011. Climatic data and zone setting would be done in this energy modelling software which then simulates and results the heating and cooling load. Thermal Analysis of heating and cooling load for FAR 1.75, 2.5 and 3.5 are carried out. Ground Coverage are kept constant, as per current building bye laws, GCR is 80% for all three models. Only number of storey is kept variable for different FAR, refer Table 3

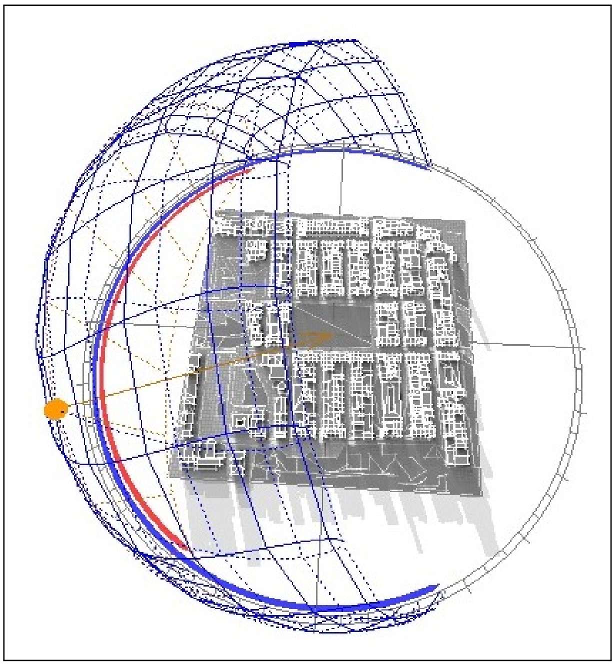

Figure 3: Energy Modeling of Sinamangal Town Planning

Table 2: Model Specification for Simulation

FAR	Storey
1.75	2
2.5	3
3.5	4.5

cooling load. All the results are calculated and divided y number of floors to obtain data in terms of per floor to have uniformity in result. Indirect Solar Gain helps to understand radiation in terms of energy absorbed by building. Figure 4 FAR 1.75 has highest indirect solar gain whereas FAR 3.5 has the least, likely because taller building cast wider shadow to adjacent buildings. Here, figure 5 shows Annual Energy Gains and Losses based on FAR and FAR 2.5 shows highest Energy loss and Gain, probably due to surface area of buildings.

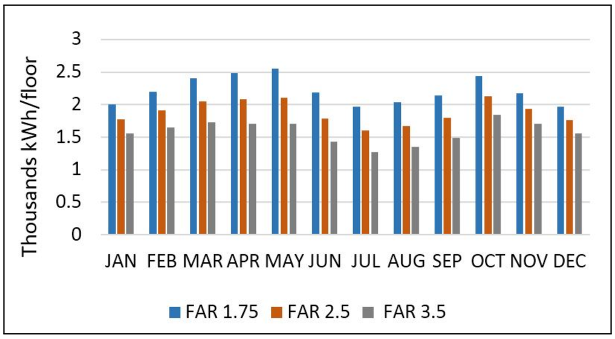

Figure 4: Monthly Indirect solar gain of various FAR

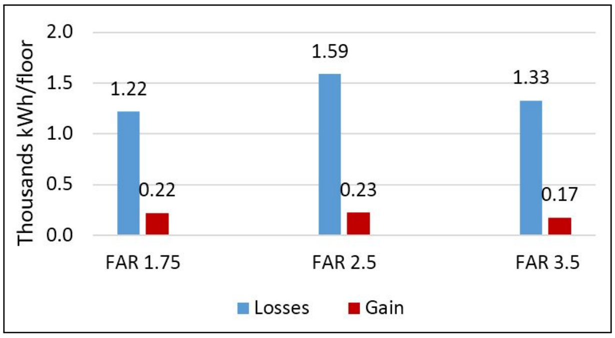

Figure 5: Annual Energy Gains and Losses of various FAR

3. Results and Discussions

3.1 Energy Load on various FAR

The modelling parameters such as climatic data were inserted, model was developed and zone setting was arranged for the simulation town planning. All the other parameters such as floor area, floor height and set back were kept same – only the height varied in 3 models. Thus simulation is carried over to study, indirect solar gain, heat gain and loss and heating and

The breakdown of heat gain and losses by different FAR models are shown in figure 6. Here, FAR 2.5 displays good amount of Heat Gain through fabric, sol air and ventilation as well comparative to FAR 1.75 and FAR 3.5. This indicates potentiality in renewable energy for model with FAR 2.5. Also, FAR 3.5; shows relatively higher thermal loss. It suggests higher buildings provides more losses and less heat gain. Climate like Kathmandu may benefit from building heights that reduces ventilation loss.

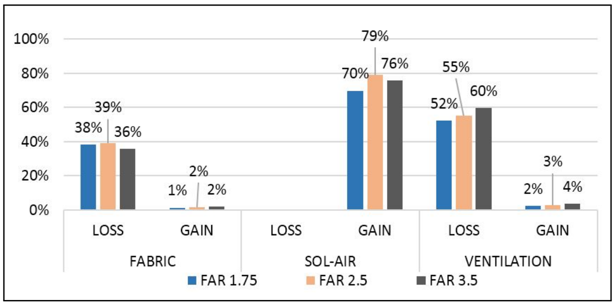

Figure 6: Annual Energy Gains and Losses Breakdown of various FAR

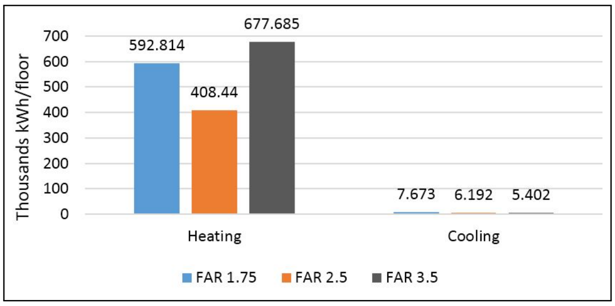

Figure 7: Annual Heating load and Cooling load of various FAR

Overall, the result concludes more energy is being spent on heating than cooling. Energy optimization can be done by increasing possibility of heat gain by building envelop. The table 3 gives the comparison of various FAR model in terms of heating and cooling load. This clarifies FAR 2.5 is optimum alternatives over FAR 1.75 and FAR 3.5. Similar methodology and contextual study can be used to determine efficient FAR to optimize consumption of energy in urban fabric.

3.2 Policy Review

Kathmandu valley adopted its first building and construction regulations in 1976–not based on social structure, but based on economic opportunities (Tiwari, 2000, 2) [9]. The economic opportunities and development pressures were highest in the core–subsequently, this sub-zone as a commercial zone to allow for maximum building flexibility. The total amount of area allowed to build per square foot of land in this zone is the highest anywhere in Kathmandu (F.A.R. is 4.5 for this zone) [9]. Building byelaws were aimed at introducing the development control measures to organize the rapid urbanization of the Kathmandu Valley. In 2050 BS, FAR was introduced with light plane concept. Local development council reserves the right to recommend the FAR within their territorial jurisdiction [10]. The Light plane concept provides the possibility of defining the proportion between building height and width of the street. A major drawback only considers diffused day lighting and neglects thermal gain associated with solar access. It does not take into account the dynamic nature of the sun and applies it for all orientations [3]. This shows that the building height that follows light plane concept would not have been able to ensure solar access at public open space during winter, when solar access is required the most.

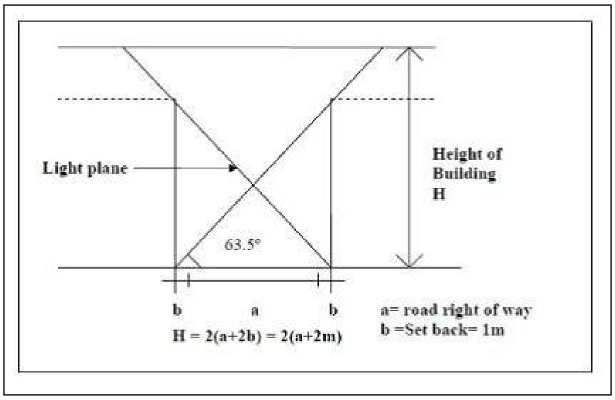

Figure 8: Light Plane Concept to restrict the building height

Table 4: Solar Altitude Angle for Summer and Winter Solstice [9]

	9:00 AM	12:00 PM	3:00 PM
Winter Solstice Dec 21	24.97	38.74	20.79
Summer Solstice 21-June	51.55	85.22	47.27

After amendment of Building guidelines of 2007, the Basic Guidelines for Settlement Development, Urban Planning and Building Construction- 2072 (2015) was prepared soon after devastating earthquake of 2015. The building bylaws for the municipalities in Kathmandu Valley and emerging towns have been revised in 2018 to accommodate for the changing urban context of the valley; these changes included plot ratio, ground coverage and setbacks. The major change seem to be increase in FAR to cater rapidly growing population that has led to congestion and high density. In Kathmandu, a high density in the range of 1000 persons per hectare has been achieved in traditional housing with three- and four-story

Table 3: Comparison of Various FAR interms of Heating and Cooling Load

Category	Heating Load (Thousand Kwh/floor)	Cooling Load (Thousand Kwh/floor)	Total Load (Thousand Kwh/floor)	Energy Saving	Remarks
Survey	0.18	0.01	0.19		41.43% room heating, 65.71 % room cooling
FAR 1.75	592.81	7.37	600.48		
FAR 2.5	408.44	6.19	414.63	30 % and 40 %	From FAR 1.75 and 3.5
FAR 3.5	677.85	5.41	683.26		

buildings. From the study it has been found that gross density of approximately 500 persons per hectare is economically optimum level, and is feasible in the present technological context of Kathmandu [10]. According to the planning regulations, the maximum FAR has been defined as 4.5 for residential in core area in full development whereas in new residential development. The recent amendment totally neglected physical, social and energy aspect in any urban fabric.

Moreover, Kathmandu lies in an earthquake prone zone and in the traditional settlement, community squares were used as a place of refuge during earthquakes. However, with tall buildings, these squares have become death traps, as the addition of floors onto the old foundation have made them vulnerable against the seismic forces (Shrestha B. K., 2002)[9]. High rise building in context of Kathmandu can be threat to social well being and sustainability.

Figure 9: Impact of allowing higher FAR [9]

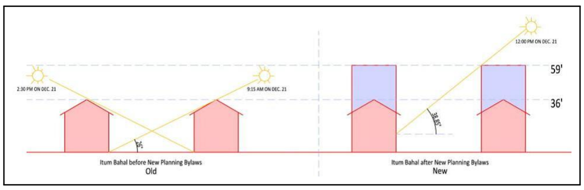

Figure 10: Diagrammatic representation of decrease in solar access after the introduction of new planning policies [9]

4. Conclusion

Climate has strong role to play in energy consumption of a place and FAR is contextual in nature that interrelates to the climate of the place. There is clear relationship between FAR, energy production and consumption; wider surface areas and higher buildings allow more indirect solar radiation also affect productivity of solar energy. In the study of Sinamangal Land Pooling, it is found that FAR 2.5 provide safe middle ground between FAR 1.75 and FAR 4.5, further research should be carried out to use FAR as a tool in energy and urban planning. This recent and sudden increase of FAR in Kathmandu have created controversy over the validation of this decision. Although this became an act to counteract increasing land price and growing density of the city, it is seemingly up surging energy load to user group, degrading thermal comfort and potential of renewable energy, well-being and sustainability of a community and leading towards un-sociable neighborhood. It is also found that passive strategies are well efficient for climate of Kathmandu, active heating might require during the few days of the year. A critical revision to existing building policies with scientific calculation is must to achieve better future.

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