Comparative Study of the Modeling for the Long-Term Forecasting of Peak Electrical Power Demand for NEA

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Abstract: In this present study five different models have been considered for the forecasting of peak electrical demand of NEA. First three models are basically regression based parametric models; fourth one is time series model; and the fifth model is based on fuzzy linear programming. The parameters considered are GDP, population, electric population, GDP per capita, system Loss, load factor and time. Regression coefficients pertinent to the models have been determined with the help of relevant data of NEA and World Bank for the period 1986 to 2013. The regression is based on least square error. In case of fifth model, the various fuzzy coefficients have been determined with the help of Microsoft Excel Solver. Having set up the models, estimation for peak demand has been carried out thereby determining the corresponding errors viz. Root Mean Square Error (RMSE), Mean Percentage Error (MPE) along with Correlation Co-efficient (CC). On comparing the models statistically, it has been found that the considered third model exhibits minimum error (RMSE with 10.05 MW and MPE with 2.095%) and maximum CC with 0.9994. The fifth model based on fuzzy LP has slightly more MPE (2.5%) than third model. This is contrary to the general perception that fuzzy LP model yields considerable reduction in error. Thus, the third model considered in this study can be taken as most suitable estimator.

Keywords: RMSE; MPE; CC; GDP; SL; LF; Peak demand

1. Introduction

1.1 Background

Electrical energy is considered as superior to all other forms of energy because it is cheap, convenient, easily convertible, easy to control, and versatile. It has innumerable uses in home, industry, agriculture, transport, defense, aviation, telecommunication, and what not. It has today become the basis for enhancement to quality of life.

Per capita electricity consumption has now-a-days been reckoned as the measure of economic growth. If not delivered where and when needed causes serious impacts on the nation’s economic development. Considerable potential has been lost due to power cuts or load shedding in our country despite being country of immense hydropower potential.

Nepal has been undergoing load shedding period of average 12 hours. This has affected our economy in one way or another. Currently, electricity demand during peak time is around 1000MW, but supply is barely 700MW during summer and 400MW during winter, which includes total NEA production from hydro and thermal, purchase from the private sector, and import from India. Of the total availability, NEA supplies 55 per cent (including both hydro and thermal), private sector contributes 27 per cent, and 18 per cent is imported from India. Demand increases by around 100MW every year but electricity production is moving at a snail's pace.

First, due to the inadequate supply of electricity, firms will be forced to depend on petroleum products (especially diesel, which carries the most weight in NOC's losses and whose consumption more than doubled between 2007-08 and 2010-11) to power up their factories and offices. This will increase the cost of production and erode competitiveness of Nepali goods and services. Since cost of domestically produced goods might be higher than the cost of imported goods of similar nature, industrial activities may continue to further slowdown. Besides, power generated from diesel run generators can fulfill only 25 per cent of total electricity demanded by firms.

According to Enterprise Survey (ES) 2009, lack of electricity is the second biggest obstacle to investment and is inflicting losses of 27 per cent of annual sales. Second, exports, especially those of the manufacturing sector, will continue to be hit by mounting costs, leading to further slowdown of manufacturing output, which has already declined from 7.6 per cent of GDP in 2004-05 to 5.8 per cent of GDP in 2011-12. Meanwhile, new investments except for in services and hydropower sectors might decline as in the past. Worse, some of the existing firms will go out of business and most will operate below potential. All of these will hit economic activities and employment opportunities.

Third, consumption of petroleum products is generally inversely related to the supply of electricity. The increasing import of petroleum products, which was about Rs 96 billion against total merchandise export of about Rs 65 billion last year, will further widen the trade deficit.

Based on the current pace of construction, demand will continue to outstrip supply at least until 2017. And unless construction of hydro projects and new investment are ratcheted up drastically, the outlook remains grim.

Nepal has yet to make use of its abundant hydro resources effectively. The rural masses are still dependent on traditional sources of fuel. The total consumption of fuel wood is about 16.7 million tons, whereas the sustainable supply is 9.6 million tons. If this continues, the country will have no more forests left within a few years.

1.2 Rationale

In order to curb the perennial problem of the load shedding, Power generation should be made sufficiently but economically. Long-term electric peak-load forecasting is an important issue in effective and efficient planning. Over- or underestimation can greatly affect the revenue of the electric utility industry. Overestimation of the future load may lead to spending more money in building new power stations to supply this load. Moreover, underestimation of load may cause troubles in supplying this load from the available electric supplies and produce a shortage in the spinning reserve of the system that may lead to an insecure and unreliable system. Therefore, an accurate method is needed to forecast loads, as is an accurate model that takes into account the factors that affect the growth of the load over a number of years. Furthermore, an accurate algorithm is needed to estimate the parameters of such models. This necessitates the determination of load demand in future keeping in view of various aspects such as GDP , inflation, income elasticity, population growth rate etc. Once the forecasting of the demand is determined, the generation plan can be effectively prepared.

1.3 OBJECTIVE OF THE STUDY

The main objectives of this study are given below:

1. To study various models for long term forecasting of peak demand of electrical energy.
2. To compare the models statistically for the determination of most suitable one yielding most accurate estimation of peak load.

2. Methodology

The detail methodology adopted for this study is shown in figure 1.

2.1 Process Flow Chart

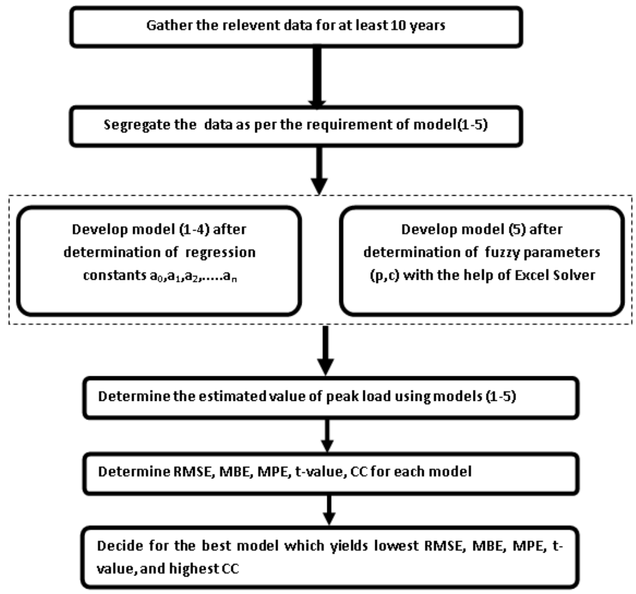


Figure 1: Flow chart showing various activities

2.2 Proposed Models

1. Model-1

$$P_L = a_0 + a_1(GDP) + a_2(POP) + a_3(EP) + a_4\left(\frac{GDP}{CAP}\right) \quad \text{..........(1)}$$

2. Model-2

$$P_L = a_0 + a_1(GDP) + a_2(POP) + a_3(EP) + a_4\left(\frac{GDP}{CAP}\right) + a_5(SL) + a_6(LF) + (Price) \quad \text{.......(2)}$$

....

3. Model-3

$$P_L = a_0 + a_1(GDP) + a_2(POP) + a_3(EP) + a_4\left(\frac{GDP}{CAP}\right) + a_5(SL) + a_6(LF) + a_7(Price) + a_8(T) \quad \text{..........(3)}$$

4. Model-4

$$P_L(k) = a_1P_L(k-1) + a_2P_L(k-2) + a_3P_L(k-3) \ \ldots + a_nP_L(k-n) \quad \text{..........(4)}$$

5. Model-5

$$P_L = (p_0, c_0) + (p_0, c_0)(GDP) + (p_0, c_0)(POP) + (p_0, c_0)(EP) + (p_0, c_0)\left(\frac{GDP}{CAP}\right) + (p_0, c_0)(SL) + (p_0, c_0)(LF) + (p_0, c_0)(RS) + (p_0, c_0)(T) \quad \text{..........(5)}$$

Objective Function:

$$O = min\left\{\sum_{j=1}^{m}\left[c_0 + c_1(GDP)_j + c_2(POP)_j + c_3(EP)_j + c_4\left(\frac{GDP}{CAP}\right)_j + c_5(SL)_j + c_6(LF)_j + c_7(RS)_j + c_8(T)_j\right]\right\} \quad \text{..........(6)}$$

Subject to constraints

$$(P_L)_j \geq \left\{p_0 + p_1(GDP)_j + p_2(POP)_j + p_3(EP)_j + p_4\left(\frac{GDP}{CAP}\right)_j + p_5(SL)_j + p_6(LF)_j + p_7(RS)_j + p_8(T)_j\right\} - (1-\lambda)\left\{c_0 + c_1(GDP)_j + c_2(POP)_j + c_3(EP)_j + c_4\left(\frac{GDP}{CAP}\right)_j + c_5(SL)_j + c_6(LF)_j + c_7(RS)_j + c_8(T)_j; \mathrm{j} = 1 \ldots \mathrm{m}\right\} \text{.......(7)}$$

$$(P_L)_j \geq \left\{p_0 + p_1(GDP)_j + p_2(POP)_j + p_3(EP)_j + p_4\left(\frac{GDP}{CAP}\right)_j + p_5(SL)_j + p_6(LF)_j + p_7(RS)_j + p_8(T)_j\right\} + (1-\lambda)\left\{c_0 + c_1(GDP)_j + c_2(POP)_j + c_3(EP)_j + c_4\left(\frac{GDP}{CAP}\right)_j + c_5(SL)_j + c_6(LF)_j + c_7(RS)_j + c_8(T)_j; \mathrm{j} = 1 \ldots \mathrm{m}\right\} \text{.......(8)}$$

Here, P_L , GDP, POP, EP, SL, LF, RS and T are actual peak load, gross domestic product, population, electric population, system loss, load factor, rate of sale perkWh and time respectively.

Model- 1 through 3 are regression based parametric model whereas Model-3 is time series model and Model-5 is based on fuzzy linear programming. For first four models, regression is performed to get the regression constants which, on substitution, builds respective model.

In case of fifth model, objective will be to minimize total spread contribution subject to constraints 7 and 8. There will as many constraints as the number of year considered. This LP model is solved by Microsoft Excel Solver to get the "p" which is estimated value.

Various statistical parameters as shown below will be calculated using equations 9 through 11 and the performance of models will be evaluated thereafter.

2.3 Statistical Test

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}\left(\widehat{P_L} - P_L\right)^2\right]^{\frac{1}{2}} \quad \text{..........(9)}$$

$$MPE = \left[\frac{1}{n}\left(\sum_{i=1}^{n}\frac{\widehat{P_L} - P_L}{P_L}\right)\right] x\ 100\% \quad \text{....... (10)}$$

$$CC = \frac{\sum(\widehat{P_L} - \overline{\widehat{P_L}})(P_L - \overline{P_L})}{\sqrt{\left[\left\{\sum(\widehat{P_L} - \overline{\widehat{P_L}})^2\right\}\left\{\sum(P_L - \overline{P_L})^2\right\}\right]}} \quad \text{....... (11)}$$

Where RMSE, MPE, and CC are respectively the root mean square error, Mean percentage error, Correlation co-efficient and n is the number of observation. $\widehat{P_L}$, P_L ,$\overline{\widehat{P_L}}$ and $\overline{P_L}$ are the estimated value, measured value, mean of the estimated value and mean of the measured value.

3. Result & Discussion

The required data for annual peak demand, number of consumers, price per kWh, system loss, load factor etc, have been collected from annual report of Nepal Electricity Authority whereas population, GDP have been collected from world bank data retrieved from its site.

The relevant data have been analyzed using Microsoft Excel-2007 with its data analysis tool and solver. The analysis has been done for 28-year data (1986-2013).

3.1 Result

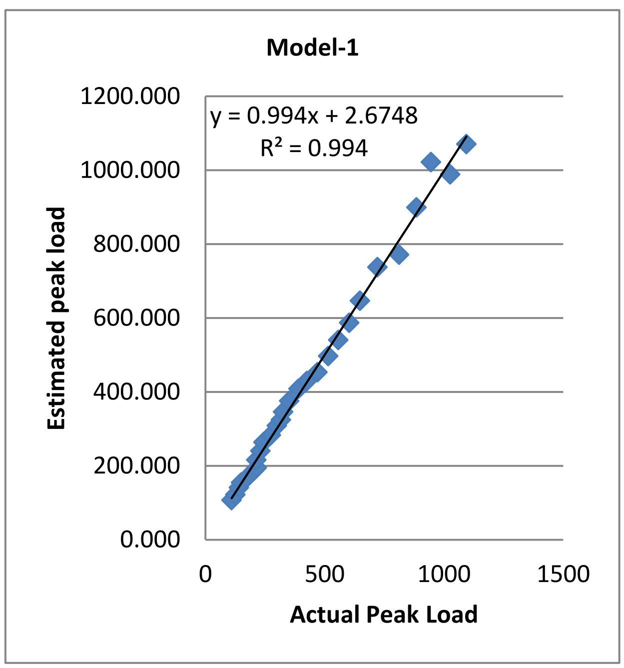


Figure 2: Scatter plot between actual and estimated value for model-1

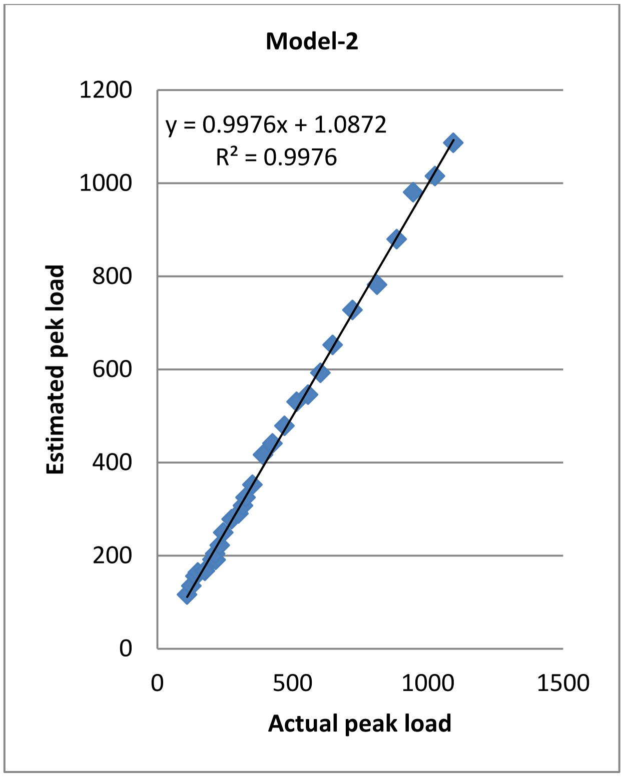
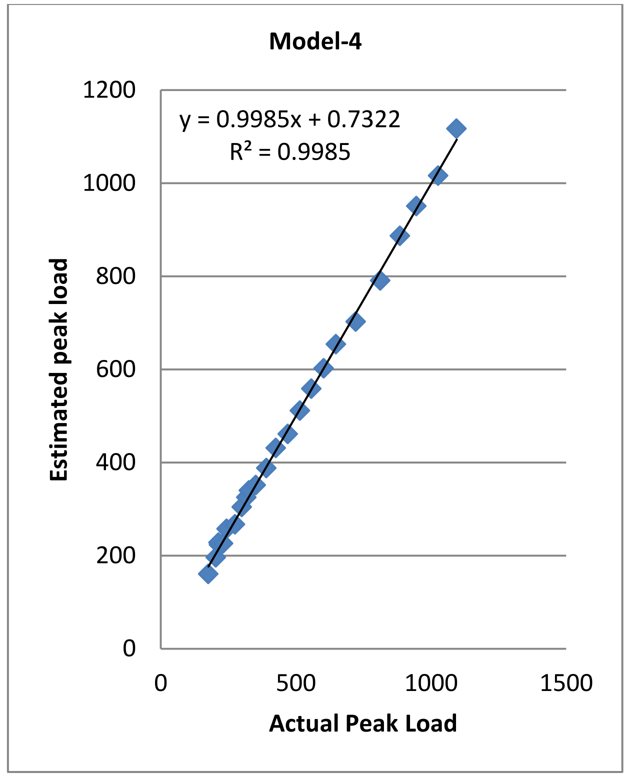


Figure 3: Scatter plot between actual and estimated value for model-2



Figrue 5: Scatter plot between actual and estimated value for model-4

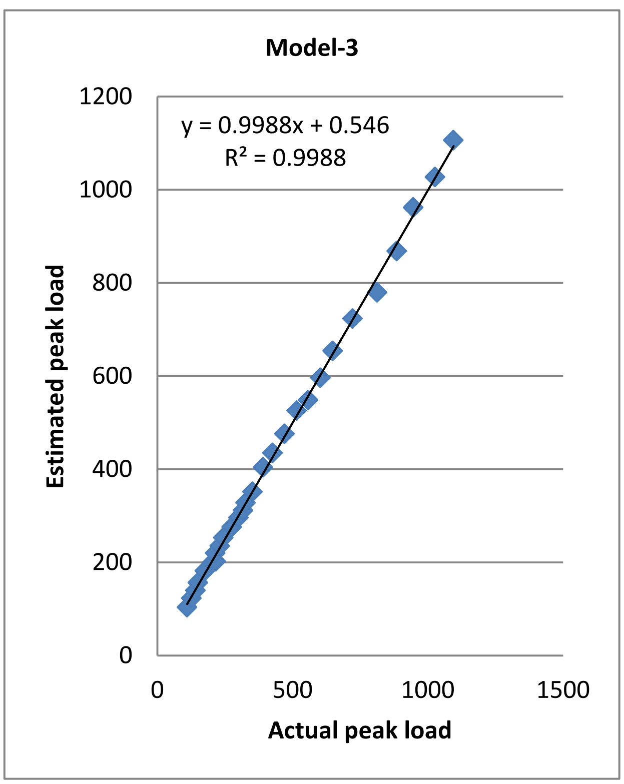


Figure 4: Scatter plot between actual and estimated value for model-3

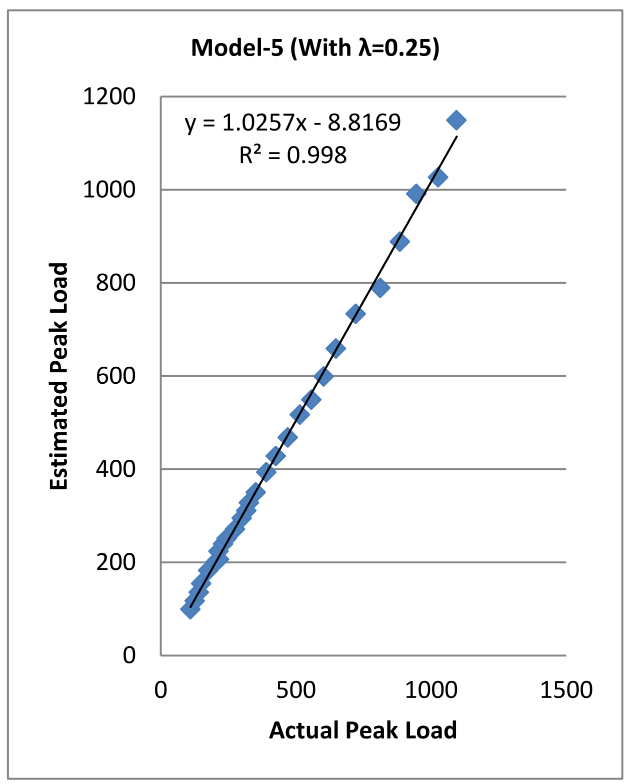


Figure 6: Scatter plot between actual and estimated value for model-5(λ=0.25)

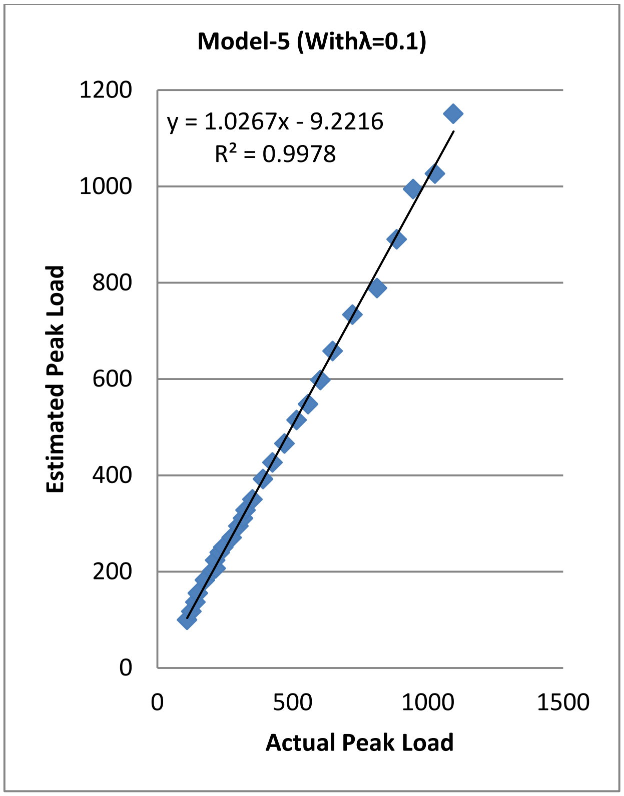


Figure 7: Scatter plot between actual and estimated value for model-5(λ=0.1)

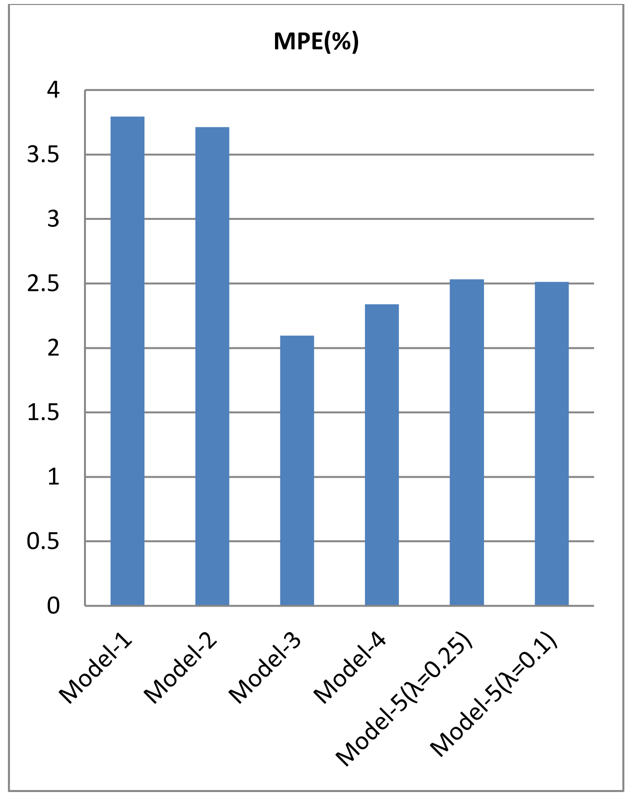


Figure 9: Comparison of MPE

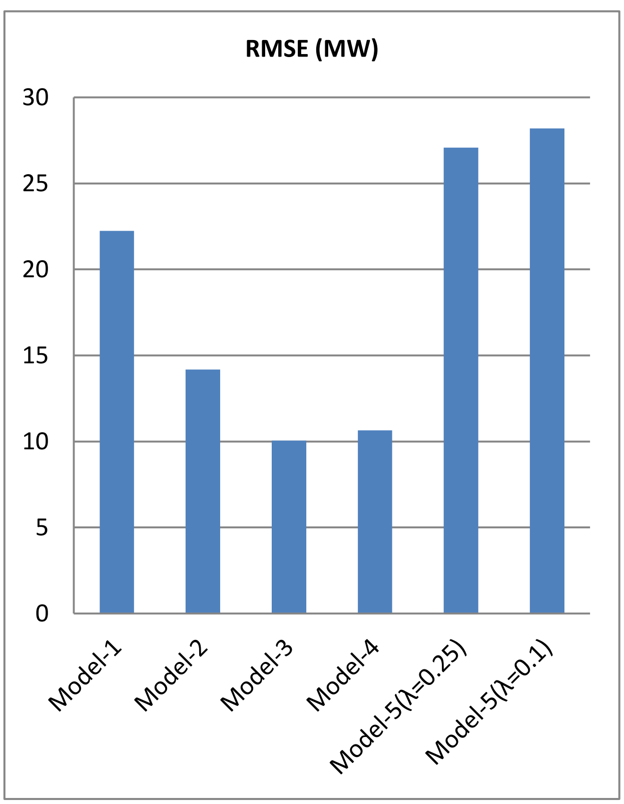


Figure 8: Comparison of RMSE

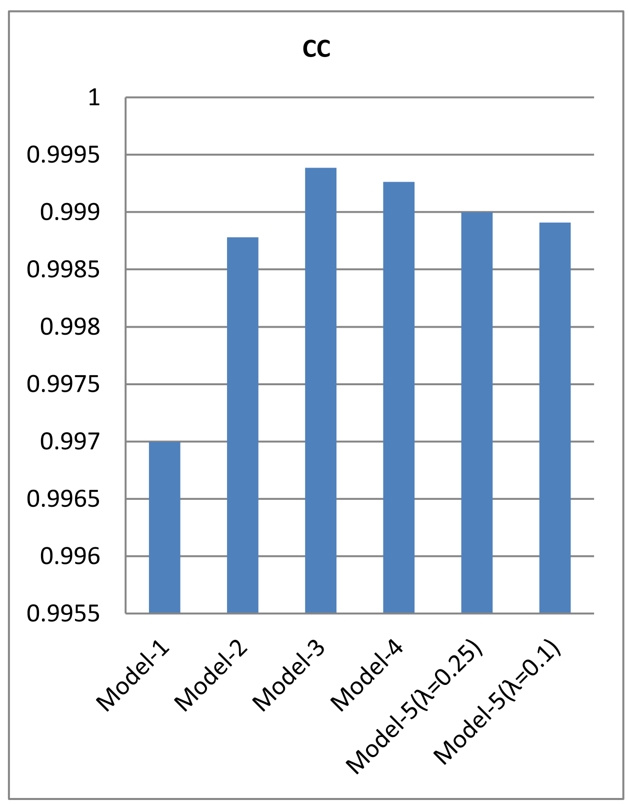


Figure 10: Comparison of CC

3.2 Discussion

Scatter plot between actual peak load and estimated peak load corresponding to each proposed model have been plotted in figure 2 through figure 7. In figure 2, we have R^2=0.994 and y=0.994x+2.674. In figure 3, we have R^2=0.997 and y=0.997x+1.087; in figure 4 we have R^2=0.998 and y=0.998x+0.546; in figure 5 we have R^2=0.998 and y=0.998x+0.732; in figure 6 we have R^2=0.998 and y=1.025x-8.816 and in figure7 we have R^2=0.997 and y=1.026x-9.221. Even though model -3, model-4 and model-5 have equal and highest co-efficient of determination, each model has R^2 nearly equal to unity. Hence each model has its output linearly fit with its actual. Model-3 and model-4 has equal slope but different intercept. However the difference in intercept is negligible. So, model-3 and model-4 can be equally good for estimation.

The comparative study between errors and correlation coefficient has been done in figure 8 through 10. As far as RMSE is concerned, figure 8 depicts that minimum RMSE of 10.05 is exhibited by Model-3. But Model-4 also shows nearly equally minimum RMSE of 10.64. The highest RMSE of 28.2 is exhibited by model-5(λ=0.1).

As far as mean percent error is concerned, the acceptable value is below 10% when there is uncertainty associated with input parameters. In our case GDP and Population growth has uncertainty. So MPE should be below 10%. If we see figure 9, model-3 has minimum MPE of 2.095% whereas model-1 has greatest MPE of 3.795%. Usually fuzzy based linear programming yields minimum MPE. But in our case, Model-5 which is based on fuzzy LP has a little bit higher MPE than model-3. Noticeably, there is no significant change in MPE (from 2.53 to 2.51) as we change degree of fuzziness from λ=0.25 to λ=0.1.

As far as Correlation co-efficient is concerned, figure 10 shows that model-3 has highest CC of 0.0.999 which is close to 1.Model-1 has lowest CC of 0.997. Model-4 depicts as equal CC as that of model-3.

4. Conclusion

Since Model-3 has minimum RMSE and MPE, as well as highest CC, it can be considered as the best estimator for the peak load demand of NEA. This is based upon 28 year data analysis. This model can be used to predict next 20 to 30 years peak demand. For this model the input parameters are GDP, Population growth. The trend of its growth has been predicted Nepal Rastra Bank as well as census report. The growth rate of sale rate per unit has been declared by NEA. So with the basis of these data, the input parameters can be predicted and corresponding input in to the model-3 yields the predicted value of peak load demand for desired upcoming years.

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