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SHORT COMMUNICATION
MODELLING OF ELECTRICAL ENERGY CONSUMPTION: A CASE STUDY

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***RINGKASAN**: Tenaga elektrik dianggap sebagai tenaga yang terpenting bagi sesebuah negara. Kertas ini mempersembahkan model komputer untuk meramal penggunaan jumlah tenaga elektrik bagi sebuah negara dengan menggunakan analisis regresi (regression). Bangladesh, sebuah negara membangun, telah dipilih sebagai satu kes. Perwakilan graf untuk model yang dicadangkan boleh memberitahu secara jelas tentang status penggunaan tenaga elektrik pada tahun-tahun yang lepas dan akan datang kepada penggubal polisi bagi sesebuah negara dan dengan itu ianya membantu dalam mengambil langkah-langkah yang perlu untuk memenuhi keperluan tenaga masa depan secara cekap dan berkesan. Teknik ini boleh diaplikasikan kepada sektor-sektor tenaga yang lain bagi sesebuah negara.*

ABSTRACT: Electrical energy is considered one of the most important energy sectors of a country. This paper presents a computer model for prediction of total electrical energy consumption of a country using regression analysis. Bangladesh, a developing country, was taken as a case study. Graphical representation of the proposed model can give a vivid picture of the status of the electrical energy consumption for the past and future years to the policy makers of a country. This therefore helps in taking necessary measures to meet the future demands of energy efficiently and effectively. The technique is applicable to other sectors of energy consumption of a country.

KEYWORDS: Electrical energy, modeling, regression

INTRODUCTION

Bangladesh is a small country in Asia situated between 20^0 to 27^0 latitude (north) and 88^0 to 93^0 longitude (East). The area of Bangladesh is about 144000 sq. km and its population is about 130 million (GPRB, 1990). Population density is high and the country is not rich in natural resources. Its socio-economic condition is also miserable. So it is important to take necessary steps for the development of this country.

From the very early days human beings need energy. It is a crucial resource for the development of a country. The rate of energy consumption in a country indicates its level of development. The higher energy consumption per capita GDP (Gross Domestic Product) is a broad indicator of higher economic development (APDC, 1990). For the development of a country, proper emphasis should be given to the energy sector and this requires an appropriate and efficient energy consumption model.

Modelling of energy consumption has the following advantages (GPRB, 1994):

- To meet the increased demand of energy in the most economical way
- To reduce the use of imported energy and to optimise the use of indigenous energy resources
- To remove the imbalances of energy demand and supply in rural and urban areas
- To reduce environmental and atmospheric pollution in generation and consumption of energy
- To forecast future technical changes, population growth and subsequent requirement of energy considering industrial and agricultural development
- To accelerate research on development of non-conventional energy technology for future conservation of energy

Since energy plays an important role in the development of a country, it is essential to measure the energy consumption status of a country to steer towards proper development. An attempt has been made in this paper to predict the electrical energy consumption in Bangladesh. However, the same approach can be used for any other sectors of energy, of any country.

MATHEMATICAL MODEL

Multiple regression analysis based on least squares method (Frederick *et al.*,1970, Lukacs and Eugene, 1972) has been applied to find out the mathematical model for energy consumption in Bangladesh.

Lets assume the regression line is of the form $Y = b_0 + b_1 X$. Then the linear first order model can be written as : $Y = \beta_0 + \beta_1 X + \epsilon$ where ϵ is the increment by which any individual Y may fall off the regression line. β_0 and β_1 are called the parameters of the model. If there are n sets of observation then sum of the squares of deviation from the true line is:

$$S = \Sigma \epsilon^2 = \Sigma (Y_i - \beta_0 - \beta_1 X_i)^2 \text{———————————} \quad \text{(i)}$$

For sum of the squares to be minimum, we differentiate equation (i) with respect to β_0 and β_1 and equating to zero we get the following equation: $\delta S/\delta\beta_0 = -2 \Sigma (Y_i - \beta_0 - \beta_1 X_i) = 0$

i.e. $n \beta_0 + \beta_1 \Sigma X_i = \Sigma Y_i$ ——————————— (ii)

$\delta S/\delta\beta_1 = -2 \Sigma X_i (Y_i - \beta_0 - \beta_1 X_i) = 0$

i.e. $\beta_0 \Sigma X_i + \beta_1 \Sigma X_i^2 = \Sigma X_i Y_i$ ——————————— (iii)

Equations (i) and (ii) can be written in the matrix form as below:

$$[\beta_0 \ \beta_1] \begin{bmatrix} n & \Sigma X_i \\ \Sigma X_i & \Sigma X_i^2 \end{bmatrix} = \begin{bmatrix} \Sigma Y_i \\ \Sigma X_i Y_i \end{bmatrix} \text{———————} \quad \text{(iv)}$$

Following the above procedure, it can be written for n independent variables:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n + \epsilon$ ——————————— (v)

In matrix form:

$$[\beta_0 \beta_1 .... \beta_n] \begin{bmatrix} n & \Sigma X_1 & \Sigma X_2 & ..... & \Sigma X_n \\ \Sigma X_1 & \Sigma X_1^2 & \Sigma X_1 X^2 & ..... & \Sigma X_1 X_n \\ ..... & ..... & ..... & ..... & ..... \\ ..... & ..... & ..... & ..... & ..... \\ \Sigma X_n & ..... & ..... & ..... & \Sigma X_n \end{bmatrix} = \begin{bmatrix} \Sigma Y \\ \Sigma X_1 Y \\ ..... \\ ..... \\ \Sigma X_n Y \end{bmatrix} \text{———————} \quad \text{(vi)}$$

Solving the above matrix equation, the values of $\beta_0 \beta_1 \beta_2 \beta_3 .... \beta_n$ can be found.

SOFTWARE DEVELOPMENT

Computer software has been developed to solve matrix equation with multiple variables using FOTRAN 77 language (Cliffs, 1989). The user-friendly software can be used for modelling energy consumption in sectors such as oil and gas of a country. In accordance with user's instruction, it can read data files from past years and can predict the data for future years. Flow chart of the programme is shown in Figure 1.

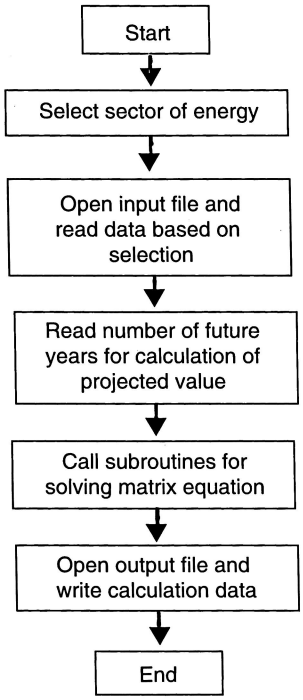


Figure 1. *Flowchart of software operation*

ELECTRICAL ENERGY CONSUMPTION MODEL

The variables used for electricity energy consumption model are as below (BSB, 1990 to 2000):

X_1 = Dummy variable
X_2 = Population in 10^7
X_3 = Per capita electricity consumption in KWh
X_4 = Number of consumers in 10^5
X_5 = Number of villages electrified in 10^2
X_6 = Length of distribution line in thousand miles
Y = Electricity consumption in 10^8 KWh

The data of electrical energy consumption for past and future years are shown in Table 1 and Table 2 respectively. Since the study was conducted in the year 2000, the data from 2001 onwards were considered as future values. Data for past years was collected from the Bureau of Statistics of Bangladesh and the data for the future years was predicted from the proposed software model.

Table 1. Data on electrical energy consumption for past years (BSB, 1990 to 2000)

Year	X_2	X_3	X_4	X_5	X_6	Y
1981	89.90	17.73	5.68	7.06	17.67	15.94
1982	92.10	22.02	6.45	8.31	13.56	20.28
1983	94.30	25.44	6.69	11.79	15.10	23.99
1984	96.50	28.02	7.27	8.78	10.62	27.04
1985	98.70	28.64	8.03	7.32	17.40	28.41
1986	100.80	32.52	8.88	9.45	30.26	33.07
1987	103.10	34.33	9.63	16.11	24.20	34.85
1988	105.30	36.48	10.38	14.68	45.90	37.72
1989	107.60	44.50	11.51	14.43	34.59	46.94
1990	110.00	43.77	11.76	13.85	40.89	47.05
1991	111.98	46.99	12.51	15.92	43.80	64.84
1992	114.19	49.84	13.22	16.78	47.22	70.91
1993	116.19	52.69	13.92	17.65	50.64	76.99
1994	118.61	55.53	14.63	18.51	54.05	83.07
1995	120.82	58.38	15.34	19.37	57.47	89.15
1996	123.03	61.22	16.04	20.24	60.89	95.23
1997	125.24	64.07	16.75	21.10	64.30	101.30
1998	127.45	66.92	17.46	21.96	67.72	107.38
1999	129.66	69.76	18.16	22.83	71.14	113.46
2000	131.87	72.61	18.87	23.69	74.55	119.54

Table 2. Predicted data for future years (using the developed software)

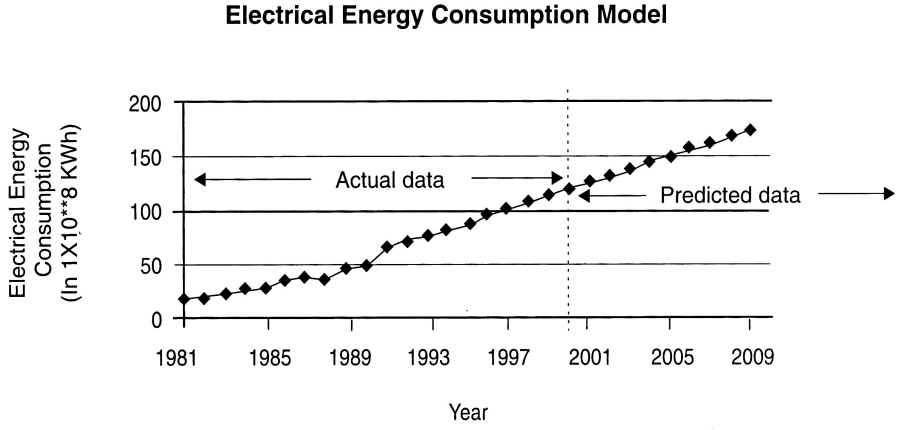
Year	X_2	X_3	X_4	X_5	X_6	Y
2001	134.08	75.45	19.57	24.55	77.97	125.61
2002	136.29	78.30	20.28	25.41	81.38	131.69
2003	138.50	81.15	20.99	26.28	84.80	137.77
2004	140.71	83.99	21.69	27.14	88.22	143.85
2005	142.92	86.84	22.40	28.00	91.63	149.93
2006	145.13	89.68	23.11	28.87	95.05	156.00
2007	147.34	92.53	23.81	29.73	98.47	162.08
2008	149.55	95.38	24.52	30.59	101.88	168.16
2009	151.76	98.22	25.23	31.46	105.30	174.24

Considering all the variables mentioned above, the resulting equation for electricity consumption is:

$$Y = 33980 - 344.122X_2 + 1547.935X_3 - 6213.741X_4 + 6.4767X_5 + 217.87X_6$$

Electrical energy consumption model was prepared based on the actual data from 1981-2000 and a projection was made for the period of 2001-2010, with the assumption that the present trend in economic activity remains the same for the predicted years. Graphical representation of the energy consumption model was developed using the data in Table 1 and Table 2.

Figure 2 shows that the electrical energy consumption increases with respect to time. This is true because Bangladesh is a developing country. Population as well as economic activities is increasing every year and hence energy consumption is increasing. This trend will continue in the future. However, from 1987 to 1990 the electrical energy consumption is slightly lower than the remaining years. It is known from history that Bangladesh faced severe economic crisis during that period.



Electrical Energy Consumption Model

Figure 2. *Graphical representation of electrical energy consumption model*

CONCLUSION

Optimised use of electrical energy consumption is an important issue for the development of a country. The proper model is necessary so that the future electrical energy demand of a country can be predicted and necessary measures can be taken to meet the demand. Computer model of the electrical energy consumption presented in this paper gives a solution for this issue. The same method is applicable for any energy sector of a country. A more accurate model can be developed using polynomial regression technique.

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