J. Univ. Kuwait (Sci.) **6**, 1979

Forecasting development of Kuwait University

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ABSTRACT

The aim of this paper is to present the latest trends and results to be included in the research study of forecasting Kuwait University development. The total number of students (Y) in the successive years is considered as a measure of the dynamic development of the University. It is assumed that (Y) can be expressed as a function of: budget, scholarships, staff members, demonstrators, manpower and libraries. Development of the whole University environment can be expressed by the six-factor Cobb–Douglas function. This function gives a very close fitting to the empirical time series. It gives also a very good smoothing of the series. The models were realized in the form of two programs named CD1 and TS1. Both programs are written in FORTRAN IV language.

The final results of the study will be a set of specialized programs suited to Kuwait University. However, the logic and the described processes will be applicable to many institutions. Every institution has unique specifications for information and would necessarily tailor the ideas of this study to its particular needs.

INTRODUCTION

The proper methodology of planning and designing the future development of a modern university assumes that one should be familiar with the conditions and principles of its evolution. Also, this requires one to compose suitable mathematical models of its activities. These models can be helpful in undertaking the decisions concerning the improvement of the present university activities. In addition, they can be useful in selecting the best strategy for its future development and also in undertaking the decisions regarding the establishment of a new university. Mathematical models of the past activities and development of the present-day university can be used too to formulate some hypotheses on the evolution and growth limits of the university and its faculties. In order to attain this, it is necessary to construct a system of forecasts concerning the whole university, its individual faculties, etc.

In the process of forecasting the university's future development one can distinguish two basic steps:

(i) Constructing the system of forecasts for the whole university, treated as an entity.

(ii) Constructing the forecasts of the development of its individual faculties.

The problem is very difficult because the forecasts are not independent, but form a

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set of interacting mathematical models. The university can be treated as a complex system. The problems of its everyday activities and development can be, then, investigated only on the basis of systems analysis. This is a dynamic, nonlinear and stochastic system. Consequently, an adequate mathematical model should possess the same properties (Huang 1971). This implies that the models of the forecasts should be nonlinear and stochastic, too. On the other hand, according to the general methodology of mathematical modelling, the model should be as simple as possible. First of all, it should reflect the most fundamental properties of the university system and include the essential interactions between its faculties. Choosing the linear model, one should keep in mind that it is nothing more than an approximation of the nonlinear reality.

Before beginning to make the forecasts for the university's future development, one needs to construct the mathematical model for its actual status. This model should connect all the essential factors characterising the development of the university in relation to time.

The main aim of a university is graduating highly educated specialists; seeing that the total number of students enrolled in the university in successive years can be considered as an index of its development. This index will be treated as a function of the following factors: (X_1) budget, (X_2) scholarships, (X_3) staff members, (X_4) resident demonstrators, (X_5) manpower, (X_6) university libraries.

As a model of the dependence between these factors, the generalised Cobb–Douglas function will be considered. Each of these factors is assumed to be a time function. The value of the Cobb–Douglas function corresponding to an arbitrary year characterises the state of the university system in that year. Then it is possible to use this function to forecast the future growth and development of the university. To do this, it is necessary to know the most reliable tendencies of the future development for the factors, $X_1, X_2, \ldots X_6$. The next step in constructing the system of forecasts should be the preparation of some mathematical models for each faculty separately. This problem is not investigated in this study.

METHODOLOGY

Beside the theoretical methods based on investigating the nature and mechanisms of the real processes and phenomena, it is often desirable to describe them by using methods of mathematical statistics. These methods give us the ability to analyse the relation between the studied quantities. In particular, the regression analysis and correlation methods can be very useful. They can be applied to identify the unknown relations between the number of students in the university and the volume of the budget, between the number of books, scientific periodicals in the library and the total number of staff members, etc.

In the regression and correlation methods, the polynomial models are of great importance. They give the ability to express the relations between the investigated quantity Y and some other factors in the form of polynomials of an appropriate order. The advantage of polynomial models constantly increases because of the increasing abilities and uses of computers (Anderson 1970; Theil 1971). There are two kinds of polynomial models: linear and nonlinear. The first are simpler and easier for mathematical treatment. Therefore, they are more popular and widely used. Only in cases where they do not give good results should nonlinear models be used (Kendall and Stuart 1968).

The general form of a linear regression model is:

$$\mathbf{Y}=\beta_0\mathbf{Z}_0+\beta_1\mathbf{Z}_1+\ \dots\ +\beta_\rho\mathbf{Z}_\rho+\boldsymbol{\varepsilon} \tag{1}$$

where: $\mathbf{Z}_0$ is a fictitious variable, always equal to **l**; $\mathbf{Z}_i$ is a function of the variable X_1; β_i is an unknown parameter whose value should be estimated from the statistical data; $\boldsymbol{\varepsilon}$ is a remainder which reflects the influction of the unknown factors and random errors on the variable Y. The variables $\mathbf{Z}_i$ are called independent and the variable **Y** is called dependent.

The coefficients β_i of equation (1) illustrate the increase of the variable **Y** in respect to the changes of the variables $\mathbf{Z}_i$ when the values of the other independent variables are fixed. For example the coefficient β_i expresses the regression of the variable **Y** in respect to $\mathbf{Z}_i$ when the other variables are fixed. For this reason the coefficients β_i are called the pure-regression coefficients.

The variables $\mathbf{Z}_i$ may be random or fixed. The random variables are investigated by the methods of correlation analysis. Relationship between the fixed variables are studied in the frame of the regression analysis.

If the number of variables in equation (1) is more than one, it is called a multi-regression equation. One has to keep in mind that the linearity of equation (1) is testified by the linearity of its coefficients β_i.

By putting $\rho=1$, $\mathbf{Z}_1=\mathbf{X}_1$ into equation (1) we obtain the linear regression equation of the first order with one independent variable in the form:

$$\mathbf{Y}=\beta_0\mathbf{l}+\beta_1\mathbf{X}_1+\boldsymbol{\varepsilon} \tag{2}$$

In equation (1), if we put $\rho=k$ and $\mathbf{Z}_j=\mathbf{X}_j$, then we obtain a multi-dimension linear regression equation in the form:

$$\mathbf{Y}=\beta_0\mathbf{l}+\beta_1\mathbf{X}_1+\beta_2\mathbf{X}_2+\dots+\beta_k\mathbf{X}_k+\boldsymbol{\varepsilon} \tag{3}$$

In equation (1), if we put $\rho=2$, $\mathbf{Z}_1=\mathbf{X}_1$, $\mathbf{Z}_2=X_1^2$ and $\beta_2=\beta_{11}$, then we get a linear model of the second order with one independent variable in the form:

$$\mathbf{Y}=\beta_0 1+\beta_1\mathbf{X}_1+\beta_{11}\mathbf{X}_1^2+\boldsymbol{\varepsilon} \tag{4}$$

This is the second order parabolic function. In the same way it is possible to construct parabolic models of higher orders.

There is a variety of nonlinear models which can be transformed into linear forms. The most important of them are mentioned in the following items.

One of the best-known nonlinear models is the multiplicative model

$$Y=\alpha_0 X_l^{\alpha_1}\, X_2^{\alpha_2}\ \dots\ X_k^{\alpha_k}\cdot\varepsilon \tag{5}$$

where α_0, α_1..., α_k are unknown parameters. By taking the logarithm of both sides of equation (5) we get:

$$\ln Y=\ln\alpha_0+\alpha_1\ln X_1+\dots+\ln\varepsilon \tag{6}$$

In the economic and prognostic literature the expression (5) is called the generalised Cobb–Douglas function. The particular case of (6) is an exponential function that has the form:

$$Y=\alpha_0 X_1^{\alpha_1} \tag{7}$$

It is sometimes called one-factor Cobb–Douglas function. In the forecasting theory and practice the two-factor Cobb–Douglas function is also of great importance. The analytical form of this function is:

$$Y=\alpha_0 X_1^{\alpha_1}\, X_2^{\alpha_2} \tag{8}$$

The nonlinear model of the following form:

$$Y = \alpha_0 \exp(\beta_0 + \beta 1 X_1 + \ldots + \beta_k X_k + \varepsilon) \tag{9}$$

is often used also.
By the logarithmation of both sides of this equation we get:

$$\ln Y = (\beta_0 + \beta_1 X_1 + \ldots + \beta_k X_k) + \varepsilon_1 \tag{10}$$

The particular case of the function (9) is the following model:

$$Y = \alpha_0 e^{\beta}{}_1 X_1 \tag{11}$$

which after logarithmation gives the linear equation

$$\ln Y = \ln \alpha_0 + \beta_1 X_1 \tag{12}$$

In case of linear models the most efficient tool for the estimation of their parameters is the least-square method.

Estimation of the regression function parameters can be realized only on the basis of the statistical observation of the variables $Y, X_1, \ldots X_n$. They are usually given in the form of time series. The series corresponding to these variables can be summarized in the data-matrix in Fig. 1. Columns of this matrix represent the time-evolution of the suitable variables. On the base of these time series, the interdependence of the particular variables and their time-evolution can be investigated.

t	Y	X_1	...	X_k
1	y_1	X_{11}		X_{1k}
2	y_2	X_{21}		X_{2k}
.	.			.
.	.			.
.	.			.
n	y_n	X_{n1}		X_{nk}

Fig. 1.

If the number of independent variables equals k, and the length of the time series is n, where $k < n+1$, then the model of linear regression can be written in the following matrix form:

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \tag{13}$$

where

$$\mathbf{Y} = \begin{bmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ \cdot \\ y_n \end{bmatrix}, \quad \mathbf{X} = \begin{bmatrix} 1 & X_{11} & \ldots & X_{lk} \\ 1 & X_{21} & \ldots & X_{2k} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ 1 & X_{nl} & \ldots & X_{nk} \end{bmatrix},$$

$$\boldsymbol{\beta} = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \beta_k \end{bmatrix}, \quad \boldsymbol{\varepsilon} = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \varepsilon_k \end{bmatrix}$$

To estimate the value of the parameters of the regression function, the least-squares method can be applied.
Estimation of the vector $\boldsymbol{\beta}$, obtained by this method, minimizes the following expression:

$$\boldsymbol{\varepsilon}^T\boldsymbol{\varepsilon}$$

Now, after replacing the vector $\boldsymbol{\beta}$ with the vector $\mathbf{b}$ in equation (13), and after realising simple transformation we get:

$$(\mathbf{X}^T\mathbf{X})\,\mathbf{b}=\mathbf{X}^T\mathbf{Y} \tag{14}$$

This relationship is called the matrix equation in the normal form. If the matrix (X^TX) is not singular, then there exists its inverse and there exists one and only one solution to this equation. This solution has the following form:

$$b=(X^TX)^{-1}\,X^TY \tag{15}$$

The main properties of the vector $\mathbf{b}$ are the following:

(i) It minimises the expression $\boldsymbol{\varepsilon}^T\boldsymbol{\varepsilon}$ independently of the character of the probability distribution of $\boldsymbol{\varepsilon}$.

(ii) Its components are linear functions of the components of the observation vector $\mathbf{Y}$. They are unbiassed estimators of the parameters β, i.e. their variances are minimal independently of the distribution of $\boldsymbol{\varepsilon}$.

The estimators obtained by the least-squares method allow us to obtain the forecasts $\hat{\mathbf{Y}}$ of the variable $\mathbf{Y}$ according to the following formula:

$$\mathbf{Y}=\mathbf{X}\mathbf{b} \tag{16}$$

The remaining vector $\boldsymbol{\varepsilon}$, can be calculated on the grounds of the formula

$$\boldsymbol{\varepsilon}=\mathbf{Y}-\hat{\mathbf{Y}} \tag{17}$$

As an index of fitting the regression functions to the empirical time series, the standard deviation $\mathbf{S}_{\boldsymbol{\varepsilon}}$ of the remainder $\boldsymbol{\varepsilon}$ can be used.

$$S_{\varepsilon}=\sqrt{\frac{\sum_{i=1}^{n}(y_i-\hat{y}_i)^2}{n-k}} \tag{18}$$

This estimator indicates the average deviation of the theoretical model from the empirical data. The smaller $S\varepsilon$ is, the better is the fitting of the regression function to the time series. The standard deviation should be estimated only when the time series is long enough.

In case of smoothing the empirical time series by a simple regression function

$$\mathbf{Y}=\beta_0\mathbf{I}+\beta_1\mathbf{X}+\boldsymbol{\varepsilon} \tag{19}$$

the estimators b_0,b_1 of the parameters β_0,β_1 obtained by the least-squares method, are the following

$$b_1=\frac{n\sum_{i=1}^{n}X_iy_i-\sum_{i=1}^{n}X_i\sum_{i=1}^{n}y_i}{n\sum_{i=1}^{n}X_i^2-\left(\sum_{i=1}^{n}X_i\right)^2} \tag{20}$$

$$b_0=\frac{\sum_{i=1}^{n}y_i-b_i\sum_{i=1}^{n}X_i}{n} \tag{21}$$

The process of time series forecasting with the aid of regression analysis methods consists of the following steps:

(i) Building of model regression function.
(ii) Estimation of the model parameters.
(iii) Statistical verification of the model.
(iv) Computing the values of the independent variables.

The steps (i), (ii) and (iv) were discussed in the previous pages. However, there was no possibility in this work to realise step (iii). This is due to the fact that the empirical time series under consideration are too short. In order to execute this step it is necessary to have at least two further observations (1976/77, 1977/78).

From a theoretical point of view, the regression model can be used to get forecasts only after performing its statistical verification.

The forecasts of the future trends of time series under consideration can be obtained by extrapolation of their regression functions. In order to do this, it is necessary to assume the stationarity of the environmental conditions in the whole prognostic period. For example, in the case of linear regression function one has to assume that for the whole prognostic period the following formula holds:

$$\mathbf{Y}(T)=\beta_0\mathbf{l}+\beta_1\mathbf{X}_{1T}+\ldots+\beta_k\mathbf{X}_{kT}+\boldsymbol{\varepsilon}_T \qquad (22)$$

where $\mathbf{X}_{iT}=\mathbf{X}_i(T)$

Let $\mathbf{X}(T)$ be the vector

$$\mathbf{X}(T)=\begin{bmatrix}1\\ X_{iT}\\ X_{2T}\\ X_{kT}\end{bmatrix}$$

where T is the point in time for which we want to formulate the forecast. Unbiassed forecast of the variable $\mathbf{Y}$ at the time T is:

$$\hat{\mathbf{Y}}_T=\mathbf{X}^T(T)\cdot\mathbf{b} \qquad (23)$$

where $\mathbf{b}$ is given by (15).

Variance of the forecast $\hat{Y}_T$ can be calculated according to the following formula:

$$D^2(\hat{Y}_T)=S^2[1+\mathbf{X}^T{}_{(T)}\,(\mathbf{X}^T\mathbf{X})^{-1}\,\mathbf{X}_{(T)}]$$

where S^2 is as follows:

$$S^2(\hat{\mathbf{Y}}_T)=\frac{\sum_{i=1}^{n}(y_{iT}-\hat{y}_{iT})^2}{n-K} \qquad (24)$$

The standard deviation of the forecast $\hat{\mathbf{Y}}_T$ is the following:

$$S(\hat{\mathbf{Y}}_T)=\sqrt{S^2(\hat{\mathbf{Y}}_T)} \qquad (25)$$

By considering the confidence coefficient $1-\alpha$, it is possible to build the confidence interval for the vector $\mathbf{Y}_T$ according to the formula:

$$P\{\hat{\mathbf{Y}}_T-t_\alpha S(\hat{\mathbf{Y}}_T)<\mathbf{Y}_T<\hat{\mathbf{Y}}_T+t_\alpha S(\hat{\mathbf{Y}}_T)\}=1-\alpha \qquad (26)$$

where: $\mathbf{Y}_T$ is the value of the forecast indicated by formula (23), $S(\hat{\mathbf{T}}_T)$ is the standard deviation of the forecast indicated by formula (24), t_α is the value of the t-student variable taken from the statistical tables for $n-k-1$ degrees freedom and for confidence coefficient $1-\alpha$.

Because of the very short time series of the empirical data, neither measures of fitting the regression function to the given series, nor the band of confidence intervals could be calculated (Hannan 1970).

EMPIRICAL DATA

All calculations in this work are based on the statistical data given in the Statistical Review of Kuwait University for the ten years from 1966/67 to 1975/76.

The development of the university is characterized by the following factors:

1. Development in student numbers
2. Postgraduate students
3. Scholarships
4. Graduates
5. University missions
6. Staff members
7. Manpower
8. Visiting professors
9. University libraries
10. Youth welfare
11. Financial activity.

These factors are given in the form of time series, contingency tables, diagrams and plots. The form in which these factors are expressed leads us to the appropriate mathematical tools. No doubt, mathematical tools are time series analysis and regression and correlation calculus. In order to apply the statistical methods, it is important to have a long enough time series data. However, the available data concerning Kuwait University are limited by ten years as a maximum. Data for the whole university are complete for ten years whereas for the individual faculties e.g. the Faculty of Law and Sharià, Faculty of Commerce and Economics and the Faculty of Engineering and Petroleum, data are not complete. It is clear that the data of these faculties cannot be used for constructing the statistical models.

In this work all the studied examples are of ten element time series. As a horizon of forecasts the academic year 1985/86 is considered.

From the factors characterising the development of the university mentioned above, we choose the following which are most essential:

1. Total number of students ($Y=X_0$)
2. Budget (X_1)
3. Scholarships (X_2)
4. Staff members (X_3)
5. Resident demonstrators (X_4)
6. Manpower (X_5)
7. University libraries (X_6)
8. Total number of new students (X_7)

The time series which represent these factors are summarized in Table 1.

Table 1. Time series of the analysed factors

No.	Year	$Y=X_0$	X_1	X_2	X_3	X_4	X_5	X_6	X_7
1	1966/67	418	1334264	22	31	13	170	20000	418
2	1967/68	874	2138125	55	74	38	332	97701	516
3	1968/69	1337	3083390	130	119	60	430	134902	557
4	1969/70	1713	3836461	164	158	66	565	165640	564
5	1970/71	1988	4799310	210	175	65	600	183227	654
6	1971/72	2453	5126080	234	189	83	734	189876	1018
7	1972/73	3286	6636900	222	211	100	887	196476	1271
8	1973/74	3836	7234600	282	244	100	1006	227842	1245
9	1974/75	4445	9071670	313	289	83	1206	240515	1552
10	1975/76	3832	19877126	379	341	87	1492	289442	1658

$Y=X_0$=Total number of students; X_1=Budget, X_2=Scholarships, X_3=Academic staff, X_4=Demonstrators, X_5=Manpower, X_6=Libraries, X_7=New students.

DISCUSSION OF RESULTS

The statistical methods described before are realized in the form of two programs named CD1 and TS1. Both programs are written in FORTRAN IV language.

Program CD1 estimates the parameters of the following functions:

(1) $$Y=\alpha_0 X_i^{\alpha_1} \text{ for } i=1, 2,..., 6 \quad (27)$$

(2) $$Y=\alpha_0 X_i^{\alpha_1} X_j^{\alpha_2} \text{ for } i=1, 2,..., 6;\ j=i+1,..., 6 \quad (28)$$

(3) $$Y=\alpha_0 X_1^{\alpha_1} X_2^{\alpha_2} \dots X_6^{\alpha_6} \quad (29)$$

The input data for CD1 program are the time series of the variables $Y, X_1,..., X_6$. By this program the estimated values of the parameters α_i are obtained. Also, this program calculates the theoretical value of the variable Y obtained from its mathematical model.

Program TS1 calculates the parameters of the regression function of time. It calculates the theoretical value of the variables $X_i=X_i(t)$ and its forecast. Moreover, it plots the calculated results. For each one of the variables $X_i=X_0, X_1, X_2,..., X_6, X_7$ the following four models are considered:

(1) $$X(t)=\alpha_0\alpha_1 t \quad (30)$$
(2) $$X(t)=\alpha_0+\alpha_1 t \quad (31)$$
(3) $$X(t)=\alpha_0+\alpha_1 t+\alpha_2 t^2 \quad (32)$$
(4) $$X(t)=\alpha_0 e^{\alpha_1 t} \quad (33)$$

Input data for the program TS1 are time series for each variable. The output data of this program are the estimators of the parameters α_i, and also the theoretical value of the variable X_i and its forecast. The value of the variable X_i and its forecasts are plotted by computer.

COMPUTING RESULTS

The total number Y of students in successive years is considered as a measure of the

dynamic development of the university. It is assumed that Y can be expressed as a function of the following six factors:
(X_1) budget, (X_2) scholarships, (X_3) staff members, (X_4) resident demonstrators, (X_5) manpower, (X_6) university libraries.

Exponential model. The simplest model of the university dynamics is that which assigns changes in student population at the university according to the formula

$$Y = \alpha_0 X_i^{\alpha_1} \tag{34}$$

where $i = 1, 2, \ldots, 6$ and the α_0 and α_1 are the model parameters. They have to be estimated from statistical data. The model was implemented on computer as:

Model 1. Its parameters were identified for each of variables X_i ($i = 1, 2, \ldots, 6$). The resulting values of α_0 and α_1 are summarized in Table 2.

Table 2. Relation between the values of α_0 and α_1

No.	X_i	α_0	α_1
1	X_1	0·002	0·909
2	X_2	29·637	0·829
3	X_3	10·747	1·035
4	X_4	17·896	1·142
5	X_5	1·286	1·138
6	X_6	0·039	0·911

Each of the above models can be used to forecast the total number of students in the successive years. This number changes with variations of factors $X_1, \ldots, X_6$.

Two-factor Cobb–Douglas model. Another interesting growth model of the total number of students at the university can be obtained by assuming that the size of student population can be expressed as a two-factor Cobb–Douglas function of any of the variables $X_1, \ldots, X_6$. The model has the representation

$$Y = \alpha_0 X_i^{\alpha_1} \; X_i^{\alpha_2} \tag{35}$$

where α_0, α_1 and α_2 are the unknown parameters. They must be calculated from the time series of the variables Y, X_i and x_j. Table 3 summarizes the esimated values of the parameters α_0, α_1, α_2. The four models under consideration include the time series *YE*, *XI*, *XJ* corresponding to the variables Y, X_i and X_j respectively. Moreover, in the second column the theoretical values *YT* of the variable Y, calculated from the appropriate model, are presented. From the mathematical statistics point of view all the models considered can be accepted in practice.

Six-factor Cobb–Douglas model: Suppose that the total number of students at the university is considered to be nonlinear function of all variables $X_1, \ldots, X_6$, and that it is represented by product of the variables X_i raised to the α_ith power, i.e.

$$Y = \alpha_0 X_1^{\alpha_1} \; X_2^{\alpha_2} \; X_3^{\alpha_3} \; X_4^{\alpha_4} \; X_5^{\alpha_5} \; X_6^{\alpha_6} \tag{36}$$

Table 3. The estimated values of the parameters α_0, α_1, α_2.

No.	X_i	X	α_0	α_1	α_2
1	X_1	X_2	2·412	0·220	0·665
2	X_1	X_3	8·815	0·019	1·016
3	X_1	X_4	0·092	0·467	0·673
4	X_1	X_5	156·000	−0·596	1·816
5	X_1	X_6	0·003	0·479	0·504
6	X_2	X_3	7·876	−0·280	1·379
7	X_2	X_4	26·736	0·734	0·142
8	X_2	X_5	2·975	0·252	0·810
9	X_2	X_6	73·073	0·928	−0·118
10	X_3	X_4	10·763	0·987	0·059
11	X_3	X_5	2·775	0·402	0·705
12	X_3	X_6	117·907	1·408	−0·359
13	X_4	X_5	1·980	0·303	0·877
14	X_4	X_6	2·889	0·825	0·263
15	X_5	X_6	0·730	1·013	0·115

The values of the unknown parameters α_1, α_2, α_3, α_4, α_5 and α_6 are to be estimated from statistical data. The model was implemented on a computer as model 3. The resulting values of the parameters are as follows:

$$\alpha_0 = 3195{\cdot}044 \qquad (37)$$
$$\alpha_1 = -0{\cdot}554 \qquad (38)$$
$$\alpha_2 = 0{\cdot}147 \qquad (39)$$
$$\alpha_3 = 0{\cdot}272 \qquad (40)$$
$$\alpha_4 = 0{\cdot}225 \qquad (41)$$
$$\alpha_5 = 1{\cdot}537 \qquad (42)$$
$$\alpha_6 = -0{\cdot}412 \qquad (43)$$

The accuracy of the model is worthy of notice. The six-factor Cobb–Douglas regression function gives the best fitting to empirical time series of the variable Y. Model (36) assumes that the development of the university can be designed to accommodate varying proportions of factors X_i and that it can be combined with these factors in various ratios. It should be noticed that model (36) allows one to investigate the interactions between all the variables Y, X_1, X_2,...,X_6. Also, it is self-evident that if Y, X_1,...,X_6 should be functions of time it would be possible to use model 3 to predict the most probable trends of the development of the university. In order to attain it, it would be necessary to find the mathematical models of variations of the variables Y, X_1,...,X_6 treated as a function of time. Then, we obtain the following formula:

$$Y(t) = \alpha_0 X_1(t)^{\alpha_1} \; X_2(t)^{\alpha_2} \ldots X_6(t)^{\alpha_6} \qquad (44)$$

Variations of individual factors with time. In order to find the appropriate mathematical models of the variation of factors X_0, X_1,...,X_7, four different functions were investigated:

$$X_i = \alpha_0 \alpha_1 t$$
$$X_i = \alpha_0 + \alpha_1^t$$

$$X_i = \alpha_0 + \alpha_1 t + \alpha_2 t^2$$
$$X_i = \alpha_0 e^{\alpha_1^t} \qquad (45)$$

The factor X_7 denotes the total number of new students at the university in the successive years. All the functions (45) were studied as models of the variables X_0, $X_1,\ldots,X_7$, in order to show their respective abilities to represent the changes of these variables. For each model, the empirical values $X(T)$ of the suitable variable X_i and the values $XT(T)$ obtained from the appropriate theoretical formula, as well as the differences $X(T) - XT(T)$ were given. The forecasts were obtained by the extrapolation of the theoretical curves. The results were presented numerically and graphically.

The closeness of the fitting of the models to the empirical data is worthy of notice. However, not each of them gives reasonable forecasts. The prognostic usefulness of the models is symbolically presented in Table 4.

Table 4. The prognostic usefulness of the models

	Variable							
Model	X_0	X_1	X_2	X_3	X_4	X_5	X_6	X_7
1	−	−	−	−	−	−	−	−
2	+	+	+	+	+	+	+	+
3	+	−	+	+	−	−	−	+
4	−	−	−	−	−	−	−	−

+, Admissible forecast
−, Inadmissible forecast

CONCLUSIONS AND REMARKS

From the above-mentioned considerations one can conclude that each of the models (i.e., linear, exponential and parabolic) can be accepted as a model of time series X_0, $X_1,\ldots,X_7$ in the period 1966/67–1975/76. However, not each of them may be used to make forecasts. This property belongs, above all, to the linear model and, in some particular cases, to the parabolic one. Development of the whole university can be, formally, expressed by the six-factor Cobb–Douglas function. This function gives a very close fitting to the empirical time series. It gives, also, a very good smoothing of the series. All the forecasts of the factors X_0, $X_1,\ldots,X_7$ presented in this study are point forecasts. Because the empirical time series are very short, it is inadvisable to calculate the confidence intervals for these point forecasts. It is impossible too to construct the confidence bands of the prognostic curves.

From the mathematical–statistical point of view, each of the considered empirical time series constitutes a small-size statistical population which is too small to apply the suitable statistical methods. From the prognostic theory one knows that when the empirical time series are short, the most effective tool for forecasting is the adaptive models. They possess the ability to adapt to the varying conditions of the environment. It seems that it could be useful to build the system of the adaptive prognostic models for the development of the university.

The models presented in this study can be helpful not only for forecasting but also as a tool in the process of university managing. They will be useful too in constructing computer-aided systems for forecasting the development and the activities of the university.

The object of this study was the whole university considered as a system. In the course of subsequent studies it seems necessary to investigate, in a similar manner, its individual faculties.

The computer outputs obtained in this study showing the Cobb–Douglas functions, time series graphs and the algorithms could not be included in this paper for shortage of publishing space. Any further information concerning them can be requested from the author.

ACKNOWLEDGEMENTS

The author is grateful to Dr Riyadh Al-Naqeeb, former Vice-Rector for Planning and Development of the University of Kuwait, and Dr Fahad Al-Rashed, for various facilities which made this work possible.

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(Received 17 December 1978)

التخطيط لنمو جامعة الكويت

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خلاصة

يقترح هذا البحث نماذج لتخطيط نمو جامعة ، كما يهدف بايجاز إلى عرض وتوضيح بعض الأساليب والنتائج الأخيرة التي أمكن تحقيقها ضمن الدراسات القائمة من أجل وضع الاستراتيجيات المتكاملة لتخطيط ونمو جامعة الكويت .

وغرضنا الأساسي هو ايجاد طرق جديدة أفضل لفهم وتخطيط الأنشطة والمباني والمعدات ، واستخدام الحاسب الرقمي والنماذج الرياضية لمحاكاة السلوك الحركي للنظام وتحليل الديناميكية والتركيب الداخلي للبيئة التعليمية ، فالتفاعلات المستمرة بين الأنشطة المختلفة في هيكلها الحركي بالبيئة التعليمية تفاعلات مركبة وعلى درجة بالغة من التعقيد ، ولن تصلح الأساليب التقليدية القديمة كسلاح لفهمها ووضع مقومات تخطيطها ، بل يجب ان نعد نماذج مبنية على هيكل متكامل للمعلومات يأخذ بعين الاعتبار جميع المتغيرات المؤثرة بالبيئة ويخضع لاحتياجات وامكانيات الجامعة والمجتمع .

وقد اتخذ النمو المستمر في اجمالي اعداد الطلاب بالسنوات المختلفة كمعيار للتطور الديناميكي للجامعة ، يتأثر ويؤثر في مجموعة من العوامل أهمها : اعداد الطلاب المستجدين سنويا ، وأعضاء هيئة التدريس والمعيدين ، وطلبة المنح الدراسية وطلاب الدراسات العليا ، وبعثات الجامعة ، والخريجين ، والقوى العاملة ، والأساتذة الزائرين وأنشطة رعاية الشباب ، والمكتبات ، والميزانية . ومثلت ستة من هذه العوامل عدديا في متواليات زمنية ، تحققت من خلال أربعة نماذج رياضية وبرنامجين قدما بلغة (فورتران ٤) .

وتتقيد النماذج المقترحة لتخطيط الأنشطة والمباني والمعدات بالاحتياجات والامكانيات المتاحة للجامعة ، كما أنها ديناميكية حتى تمكننا من تمثيل عامل الزمن وتأثيره على المتغيرات الأساسية بالبيئة . ويراعى في تصميمها وجود حلقة مستمرة من التغذية الارتدادية التي نحصل عليها من نتائج النموذج ، التي تقدم بدورها إلى مجموعة من الخبراء لتعديلها ومقارنتها بالواقع الفعلي للمعلومات قبل إعادة الدورة ، وبتكرار ذلك يمكننا تعديل أو تغيير بعض أجزاء النموذج . وبواسطة هذه العملية المستمرة ، يبقى النموذج متناسبا مع جميع التغيرات التي تحدث ، كما يجب ان ننظر اليه دائما ، كنموذج تجريبي قابل للتصحيح والمراجعة والتعديل الدوري المستمر .

وعلى الرغم من أن النتائج النهائية لهذا البحث عبارة عن مجموعة من النماذج والبرامج الرياضية المتخصصة التي تتناسب مع التركيب الداخلي للبيئة التعليمية بجامعة الكويت ، فإن الاسلوب التحليلي المتبع والطريقة النظامية المقترحة تصلح للتطبيق في أية مؤسسة أخرى ، طالما أخذ بعين الاعتبار ان النموذج وسيلة لا غاية ، وان ما يصلح في جامعة ما قد يفشل في جامعة اخرى أو تحت ظروف اخرى ، فالنموذج يؤخذ به حيث تتوفر مقوماته ، وتطبق نماذج اخرى معدلة ، أو صور نظامية مختلفة ، نابعة من صميم البيئة التعليمية ذاتها ، حيث تتوافر مقومات ومكونات تصميمية أنسب .