

Regression Analysis based Effective Manpower Planning Methodology: A Case Study.

ABSTRACT

Forecasting manpower requirement has been useful for economic planners and even the academic sector. In other to avoid imbalance, the manpower requirement is very vital in determining the desired output in a system. This study is aimed at predicting the adequate manpower required in a unit of an academic institution. Manpower related data of Mechanical Engineering Department, Federal University of Technology, Akure Nigeria were collected. The data analysed includes manpower capacity and students population over a period of thirteen consecutive years. Regression analysis based model was formulated from the outcomes of the analyzed data. The developed model was implemented in a computer software using Visual Basic programming language to facilitate the solution procedure. The outcome of this study will aid the management of the institution in effective manpower determination and students number projection in future years.

Keywords: Forecasting, Manpower, Academic, Regression Analysis, Mathematical Model, Computer Software.

1. INTRODUCTION

Manpower is an important factor that determines the level at which production facilities are being utilized to achieve the desired objectives of an organization. Manpower requirement of any organization have to be planned for, just as we budget for the amount of money to be spent [1]. It is important to note that an organization would suffer a huge setback if the manpower structure is not properly settled. The rate at which the production facilities are being transformed into goods and services depends greatly on the manpower structure. In this sense, low performance manpower operates at low productivity rate as a result of some factors like ability, age, capacity, health status etc., while high performance manpower can operate at high productivity rate.

Moreover, it is expected that a high performing worker should be more efficient than a low performing one, in terms of transforming resources into good and/or services [2]. But, this will be done at a higher cost as well. It is also worthy to note that, not all duties require highly skilled workers. Some duties can be done effectively by low performing staff, especially when they are subjected to proper training and re-training. Hence, to minimize cost, appropriate manpower should be employed based on the available production capacity, time and skill of operation required.

In an academic institution, where there are various duties requiring different skills, such as research, lecturing, administrative and technical duties, it is imperative to schedule personnel to duties based on skill and requirement. However, in developing nations like Nigeria, the manpower structure is in a way such that personnel are either over-worked or under-worked. This problem can therefore be solved by proper manpower requirement determination.

However, many quantitative techniques have been applied to determine effective size of manpower to be engaged at a particular time. The most common among them include the Workload method [3-7], Maintenance times analysis [8], Dynamic programming [9], Multiple Activities Process Chart [10], Queuing System [11-13]. Moreover, different models have been developed and applied in this line of study. Among them are: descriptive-predictive model [14] and normative model [15-16].

This study aims at establishing models to determine the number of students and respective level of manpower requirements in a technical department of an institution. The models were

implemented using computer software. Mechanical Engineering Department of the Federal University of Technology, Akure, Nigeria was used as a case study.

2. METHODOLOGY

In achieving the objective of the study, data were collected, classified, analysed and regression model was formulated based on the data analysed. The academic unit whose data was studied is the Mechanical Engineering Department of the Federal University of Technology, Akure, Nigeria. The data were collected through the use of questionnaire and oral interviews. The data that were collected include the numbers of students, lecturers and technical staff in the department for a period of thirteen (2005/2006 to 2017/2018) consecutive academic years.

The regression method of least squares was applied in estimating the trend from the collected data. The trend of the number of manpower required (lecturers and technical staff) depends on the number of students which serves as the economic indicator.

The data of thirteen years of the students' population was used to determine the projected number of students for the next seven years. The projected trend of the number of students was then determined as in Equation (1), in which the economic indicator is the serial number of each year

$$y_s = a + bx_s \quad (1)$$

y_s is projected trend of the number of students, x_s is economic indicator being used for the prediction and a, b are parameters of regression equation.

The economic indicator used in Equation (1) is the serial number of each year in order. To determine the values of constants a and b , Equations (2) and (3) were solved simultaneously.

$$\sum y_s = na + b \sum x_s \quad (2)$$

$$\sum x_s y_s = a \sum x_s + b \sum x_s^2 \quad (3)$$

Similarly, the data of thirteen years of the number of different classes of manpower, which include academic and technical staff, were used to determine the respective numbers of academic and technical staff required for the next seven years. The projected trend of each of these classes of manpower can be determined using Equation (4). The trend equation, in each case, is a measure of the staff-students equation/relationship, in which the economic indicator is the number of students (independent variable).

$$Y = A + BX \quad (4)$$

Y is number of manpower, X is economic indicator (number of students) and A, B are parameters of the regression equation.

The regression parameters can be determined by solving Equations (5) and (6) simultaneously.

$$\sum Y = NA + B \sum X \quad (5)$$

$$\sum XY = A \sum X + B \sum X^2 \quad (6)$$

N is the number of observed data.

The degree of agreement of the formula with real data was determined by the coefficient of correlation r which is given as in Equation (7)

$$r = \sqrt{1 - \frac{\sum(Y_a - Y_c)^2}{\sum(Y_a - \bar{Y})^2}} \quad (7)$$

Y_a is actual value of the dependent variables (i.e. manpower), Y_c is calculated value found from the trend line and $\bar{Y}$ is average of the actual values of the dependent variables. The rule of thumb for interpreting coefficient of correlation r is as given in Table 1.

Table 1. Interpretation of correlation coefficient r

Value of r	Interpretation
0.90 – 1.00	Very high correlation
0.70 – 0.90	High correlation
0.40 – 0.70	Moderate correlation
0.20 – 0.40	Low correlation
0.00 – 0.20	Slight correlation

Source: [9]

2.1 Data Analysis

The trend equations of the number of students and manpower requirements were determined by analysing the data collected on the students and staff population over the thirteen years under review. These were done respectively as in Tables 2, 4 and 6. The trend equation in each case was then used to respectively determine the projected number of students, and staff requirements in the next seven years, as presented in Tables 3, 5 and 7. The trend equations developed (mathematical models) was implemented in computer software developed using Visual Basic programming language.

Table 2. Analysis of data of students' population

Year	No of students (y_s)	x_s	x_s^2	$x_s y_s$
2005/2006	222	1	1	222
2006/2007	220	2	4	440
2007/2008	271	3	9	813
2008/2009	291	4	16	1164
2009/2010	307	5	25	1535
2010/2011	342	6	36	2052
2011/2012	306	7	49	2142
2012/2013	480	8	64	3840
2013/2014	495	9	81	4455
2014/2015	513	10	100	5130
2015/2016	505	11	121	5555
2016/2017	524	12	144	6288
2017/2018	555	13	169	7215
$n = 13$	$\sum y_s = 5031$	$\sum x_s = 91$	$\sum x_s^2 = 819$	$\sum x_s y_s = 40851$

Substituting these values in Equations (5) and (6) gives

$$5031 = 13a + 91b$$

$$40851 = 91a + 819b$$

By solving the above equations simultaneously, the regression parameters were obtained as

$$a = 170.31, b = 30.96$$

Therefore the trend equation for the student population was determined by substituting the values of a and b in Equation (4). That is,

$$y_s = 170.31 + 30.96x_s$$

Hence, the trend values for the thirteen years, and the projected trend values for the students' population in the next seven years are presented in Table 3.

Table 3. Students' population trend values for the thirteen years and projected values for the next seven years

Year	Students population $y_s = 170.31 + 30.96x_s$	y_s
2005/2006	$= 170.31 + 30.96(1)$	201.27
2006/2007	$= 170.31 + 30.96(2)$	232.23
2007/2008	$= 170.31 + 30.96(3)$	263.19
2008/2009	$= 170.31 + 30.96(4)$	294.15
2009/2010	$= 170.31 + 30.96(5)$	325.11
2010/2011	$= 170.31 + 30.96(6)$	356.07
2011/2012	$= 170.31 + 30.96(7)$	387.03
2012/2013	$= 170.31 + 30.96(8)$	417.99
2013/2014	$= 170.31 + 30.96(9)$	448.95
2014/2015	$= 170.31 + 30.96(10)$	479.91
2015/2016	$= 170.31 + 30.96(11)$	510.87
2016/2017	$= 170.31 + 30.96(12)$	541.83
2017/2018	$= 170.31 + 30.96(13)$	572.79
The projected trend values of students' population for the next seven years:		
2018/2019	$= 170.31 + 30.96(14)$	603.75
2019/2020	$= 170.31 + 30.96(15)$	634.71
2020/2021	$= 170.31 + 30.96(16)$	665.67
2021/2022	$= 170.31 + 30.96(17)$	696.63
2022/2023	$= 170.31 + 30.96(18)$	727.59
2023/2024	$= 170.31 + 30.96(19)$	758.55
2024/2025	$= 170.31 + 30.96(20)$	789.51

The degree of agreement of the calculated data, using the trend equation, with the real data is determined by the coefficient of correlation r which is given in Equation (7). The correlation analysis parameters are determined and presented as thus

$$\sum(y_a - y_c)^2 = 15471.66$$

$$\sum(y_a - \bar{y})^2 = 189878$$

$$r = \sqrt{1 - \frac{15471.66}{189878}}$$

$$= 0.958$$

Table 4. Analysis of data of Lecturers' population

Year	No of students (X)	No of Lecturers (Y)	X^2	XY
2005/2006	222	16	49284	3552
2006/2007	220	16	48400	3520
2007/2008	271	16	73441	4336
2008/2009	291	20	84681	5820
2009/2010	307	20	94249	6140
2010/2011	342	21	116964	7182
2011/2012	306	21	93636	6426
2012/2013	480	21	230400	10080
2013/2014	495	25	245025	12375
2014/2015	513	27	263169	13851
2015/2016	505	28	255025	14140
2016/2017	524	29	274576	15196
2017/2018	555	31	308025	17205
$N = 13$	$\sum X = 5031$	$\sum Y = 291$	$\sum X^2 = 2136875$	$\sum XY = 119823$

Substituting these values in Equations (5) and (6) gives

$$291 = 13a + 5031b$$

$$119823 = 5031a + 2136875b$$

Solving the resulting expressions simultaneously gives

$$a = 7.70, b = 0.04$$

Therefore, the trend Equation for the lecturers' population was determined by substituting the values of a and b in Equation (4). That is

$$Y = 7.70 + 0.04X$$

Hence, the trend values for the thirteen years, and the projected trend values for the lecturers' population in the next seven years are presented in Table 5.

Table 5 Lecturers' population trend values for the thirteen years and projected values for the next seven years

Year	Lecturers population $Y = 7.70 + 0.04X$	Y
2005/2006	$= 7.70 + 0.04(222)$	16.58
2006/2007	$= 7.70 + 0.04(220)$	16.50
2007/2008	$= 7.70 + 0.04(271)$	18.54
2008/2009	$= 7.70 + 0.04(291)$	19.34
2009/2010	$= 7.70 + 0.04(307)$	19.98
2010/2011	$= 7.70 + 0.04(342)$	21.38
2011/2012	$= 7.70 + 0.04(306)$	19.94
2012/2013	$= 7.70 + 0.04(480)$	26.90
2013/2014	$= 7.70 + 0.04(495)$	27.50

2014/2015	= 7.70 + 0.04(513)	28.22
2015/2016	= 7.70 + 0.04(505)	27.90
2016/2017	= 7.70 + 0.04(524)	28.66
2017/2018	= 7.70 + 0.04(555)	29.90
The projected trend values of lecturers' population for the next seven years:		
2018/2019	= 7.70 + 0.04(603.75)	31.85
2019/2020	= 7.70 + 0.04(634.71)	33.09
2020/2021	= 7.70 + 0.04(665.67)	34.33
2021/2022	= 7.70 + 0.04(696.63)	35.57
2022/2023	= 7.70 + 0.04(727.59)	36.80
2023/2024	= 7.70 + 0.04(758.55)	38.04
2024/2025	= 7.70 + 0.04(789.51)	39.28

The degree of agreement of the calculated data, using the trend equation, with the real data is determined by the coefficient of correlation r which is given in Equation (7). The correlation analysis parameters are determined and presented as thus

$$\sum(Y_a - Y_c)^2 = 52.63$$

$$\sum(Y_a - \bar{Y})^2 = 317.08$$

$$r = \sqrt{1 - \frac{52.63}{317.08}}$$

$$= 0.913$$

Table 6 Analysis of data of technicians' population

Year	No of students (X)	No of technicians (Y)	X^2	XY
2005/2006	222	13	49284	2886
2006/2007	220	12	48400	2640
2007/2008	271	13	73441	3523
2008/2009	291	14	84681	4074
2009/2010	307	16	94249	4912
2010/2011	342	15	116964	5130
2011/2012	306	15	93636	4590
2012/2013	480	18	230400	8640
2013/2014	495	18	245025	8910
2014/2015	513	18	263169	9234
2015/2016	505	18	255025	9090
2016/2017	524	19	274576	9956
2017/2018	555	19	308025	10545
N = 13	$\sum X = 5031$	$\sum Y = 208$	$\sum X^2 = 2136875$	$\sum XY = 84130$

Substituting these values in equations (5) and (6) gives

$$208 = 13a + 5031b$$

$$84130 = 5031a + 2136875b$$

By solving the above equations simultaneously gives

$$a = 8.59, b = 0.02$$

Therefore the trend equation for the technicians' population is determined by substituting the values of a and b in Equation (4). That is,

$$Y = 8.59 + 0.02X$$

Hence, the trend values for the thirteen years, and the projected trend values for the technicians' population in the next seven years are presented in Table 7.

Table 7 Technicians' population trend values for the thirteen years and projected values for the next seven years

Year	Technicians population $Y = 8.59 + 0.02X$	Y
2005/2006	$= 8.59 + 0.02(222)$	13.03
2006/2007	$= 8.59 + 0.02(220)$	12.99
2007/2008	$= 8.59 + 0.02(271)$	14.01
2008/2009	$= 8.59 + 0.02(291)$	14.41
2009/2010	$= 8.59 + 0.02(307)$	14.73
2010/2011	$= 8.59 + 0.02(342)$	15.43
2011/2012	$= 8.59 + 0.02(306)$	14.71
2012/2013	$= 8.59 + 0.02(480)$	18.19
2013/2014	$= 8.59 + 0.02(495)$	18.49
2014/2015	$= 8.59 + 0.02(513)$	18.85
2015/2016	$= 8.59 + 0.02(505)$	18.69
2016/2017	$= 8.59 + 0.02(524)$	19.07
2017/2018	$= 8.59 + 0.02(555)$	19.69
The projected trend values of technicians' population for the next seven years:		
2018/2019	$= 8.59 + 0.02(603.75)$	20.67
2019/2020	$= 8.59 + 0.02(634.71)$	21.28
2020/2021	$= 8.59 + 0.02(665.67)$	21.90
2021/2022	$= 8.59 + 0.02(696.63)$	22.52
2022/2023	$= 8.59 + 0.02(727.59)$	23.14
2023/2024	$= 8.59 + 0.02(758.55)$	23.76
2024/2025	$= 8.59 + 0.02(789.51)$	24.38

The degree of agreement of the calculated data, using the trend equation, with the real data is determined by the coefficient of correlation r which is given in Equation (7). The correlation analysis parameters are determined and presented as thus

$$\sum(Y_a - Y_c)^2 = 6.007$$

$$\sum(Y_a - \bar{Y})^2 = 74$$

$$r = \sqrt{1 - \frac{6.007}{74}}$$

$$= 0.959$$

3. RESULTS AND DISCUSSION

The analyses of data obtained on the students and staff numbers for a period of thirteen years yield the trend equations of $y_s = 170.31 + 30.96x_s$, $Y = 7.70 + 0.04X$, and $Y = 8.59 + 0.02X$ respectively for the students population size, lecturers and technical staff requirements. As presented in Tables 3, 5 and 7, the trend equations were used to determine the respective trend

values for the thirteen years under study. The correlation coefficient analyses also yield correlation coefficients r of 0.958, 0.913 and 0.959 respectively for the relationship between the actual values and calculated trend values (using trend equation). This indicates very high correlation between actual data and calculated trend value in the cases of students and staff (manpower) data. Consequently, the trend equations are used to determine the projected number of students as well as the number of manpower required in the next seven years.

Fig. 1 presents the trend of students' population in the thirteen years under review, and the projected number of student in the next seven years as determined using the trend equation. Fig. 2 presents the graphical representation of the number of manpower trends in the thirteen years and the next seven years.

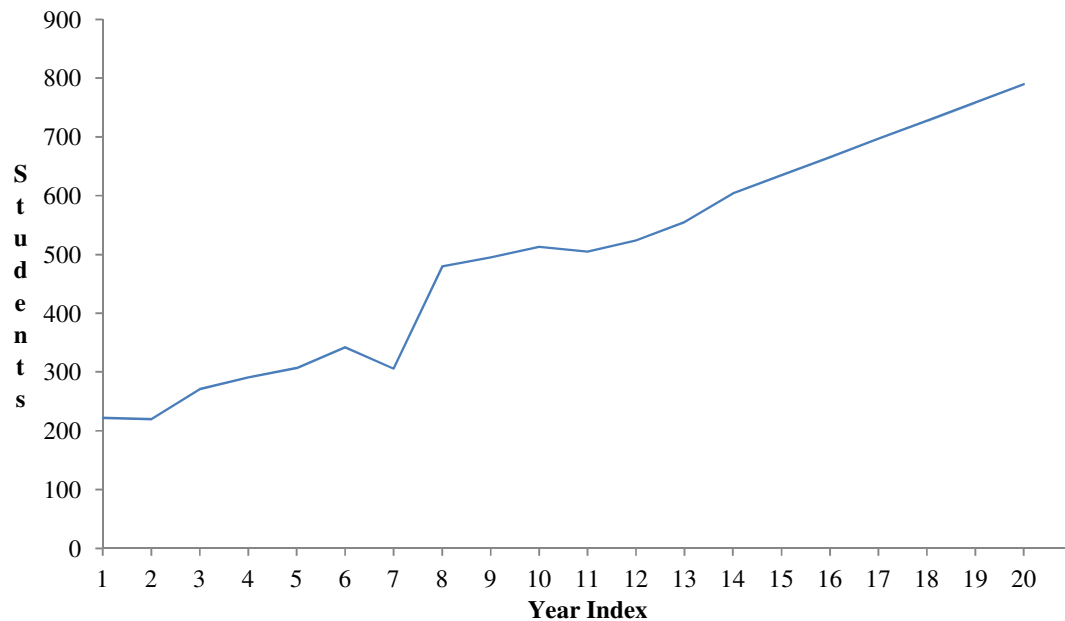


Figure 1. Students population in the thirteen years and next seven years

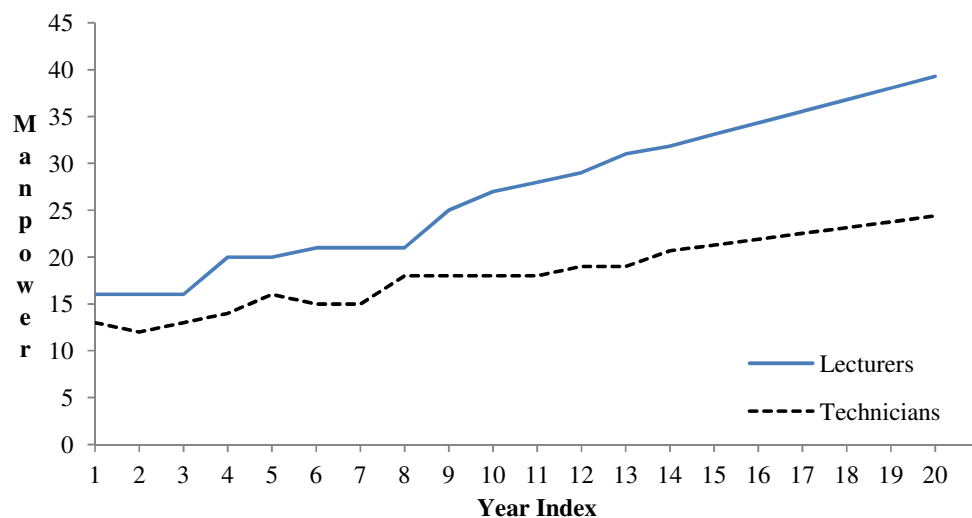


Figure 2. Manpower requirements in the thirteen years and next seven years

The data input and results interfaces of the computer software developed for the established mathematical models are presented in Figures 3 and 4. This software was validated by comparing its results with the manually calculated result and both give the same results.

Manpower Planning System.

Academics | Technologists | Administration

Professors:		No of Professors:	
Reader:		No of Reader:	
Senior Lecturer:		No of Senior Lecturer:	
Lecturer1:		No of Lecturer1:	
Lecturer2:		No of Lecturer2:	
Assistant Lecturer:		No of Assistant Lecturer:	
Research Assistant:		No of Research Assistant:	

(a)

Manpower Planning System.

Academics | Technologists | Administration

Chief Technologist:		No of Chief Technologist:	
Assistant Chief Technologist:		No of Assistant Chief Technologist:	
Senior Technologist:		No of Senior Technologist:	
Technologist 1:		No of Technologist 1:	
Technologist 2:		No of Technologist 2:	
Senior W/S Supervisor:		No of Senior W/S Supervisor:	
Headcraftman:		No of Headcraftman:	
Senior Lab Assistant:		No of Senior Lab Assistant:	

(b)

Figure 3 Data input interface of the computer software: (a) Academic staff, (b) Technical staff

Manpower Planning System.

Enter Values For Manpower Categories

Academics

Technologist

Administration

Values Processed Correctly.
Total Academics: 32
Total Technologists: 22
Total Administrators: 4

Department 2014

Figure 4 Results Interface for the Required Manpower

4. CONCLUSION

Data on the number of students and level of manpower of different type of staff, collected from the Mechanical Engineering Department, Federal University of Technology, Akure, Nigeria, have been analysed and mathematical models have been established, using the regression method, to determine the trend values of the number of students and manpower requirement over the period of years in view and to forecast the level of manpower required in any future year. The projected number of students and the respective level of manpower requirement determined through the established models will have high accuracy because it was also established that the mathematical models have very high correlation with the actual data.

Moreover, these mathematical models were also implemented in computer software to determine the projected number students and respective manpower requirements in certain future year. The study has given insight into how best manpower can be effectively planned in a technical department of an institution. The study is versatile and can be adapted to all sectors such as manufacturing, design, banking, refineries, insurance, etc, to effectively plan for manpower based on available capacity and operation time.

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