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Prediction of academic manpower system of a Polytechnic institution in Nigeria

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Abstract: This study is on makovian approach in studying the behaviour of the academic staff grade transition of a Polytechnic institution in Nigeria. The objective of this study is to determine the proportion of staff recruited, promoted and withdrawn from the various grade levels in the institution over the years and also forecast the expected manpower structure of the institution for 2014/2015 session. Secondary data obtained from the Personnel Department of Delta State Polytechnic, Oghara for 2006/07 – 2011/12 sessions was used to evaluate the method. The findings from the analysis showed that the academic staff grade transition flow is stationary over the observed time period. Also, it was predicted that at the beginning of the 2014/15 session, that the expected staff structure of Delta State Polytechnic Otefe-Oghara will consist of 2 Assistant Lecturer's, 15 Lecturer's III, 11 Lecturer's II, 12 Lecturer's I, 9 Senior Lecturer's, 7 Principal Lecturer's and 7 Chief Lecturer's; if the current recruitment and promotion policies in the institution remain unchanged. The predicted distributed structure of academic staff of Delta state Polytechnic for 2014/15 session was observed to be approximately normally distributed.

Keywords: Promoted, Grade, Staff, Lecturer, Session, Recruitment

1. Introduction

Efficient manpower planning is a crucial task of managing large organizations such as industrial corporations, the state administration or academic systems. All of these systems comprise many segments of employees with specific roles and job descriptions. Skills needed to perform assigned tasks are usually acquired through special training or long work experience. [1], recognized that 'shortages' of persons with critical skills and knowledge required for effective national development is a serious problem in most developing nations. Hence, either a shortfall or a surplus of skilled staff can be costly and very inefficient in any organization. To prevent such difficulties, the future needs of personnel have to be predicted well in advance, while corresponding strategies to achieve the desired structure must be adopted [2]. Knowledge on the behavior of the system is important for predicting the future development of the manpower structure in complex organizations. In large systems, such predictions are usually based on previous experience. However, knowledge gained from such experience is often difficult to apply without appropriate mathematical or statistical models and corresponding computational tools. The most basic information that can be used to model manpower dynamics is the rate of transitions between different segments of the system, i.e. the transition probability. Transitions are usually consequences of either promotion, transfers between assignments or wastage and input into the system. Often transitions are controlled by certain rules that govern the system and cannot be arbitrarily changed. If this is the case, planning has to be especially careful since slight changes in policies can have considerable consequences on the future development of the manpower structure [2]. In several cases, the models used to predict the future structure of a dynamic system are based on Markov chains and their derivatives, such as semi-Markov chains. Both are based on the assumption that the rules governing the system's manpower dynamics do not change very often and that future dynamics will follow patterns observed in the past. While classical Markov chains view segments as homogeneous, semi-Markov chains additionally involve the time a person has spent in a segment, of course at the cost of the model's simplicity and therefore the possibility to reliably estimate its parameters. Speaking on the application of the Markovian approach on studying treatment programs, [3], reported that discrete-time Markov chains have been successfully used to investigate treatment programs and health care protocols for chronic diseases. The transition matrix, which describes the natural progression of the disease, is often estimated from a cohort observed at common intervals. Estimation of the matrix, however, is often complicated by the complex relationship among transition probabilities. In their study they summarizes methods to obtain the maximum likelihood estimate of the transition matrix when the cycle length of the model coincides with the observation interval, the cycle length does not coincide with the observation interval, and when the observation intervals are unequal in length. They noted that a subject's disease history can then be described by the movement through designed states over time. [4], noted that the outcome of a Markov chain model depends on the probabilities within the transition matrix, and on whether the transition matrix is time independent (stationary) or time dependent (non-stationary). They explained further that while a stationary assumption allows the straight forward calculation of the long run equilibrium distribution of the amounts in different states, changes in the transition probabilities over time may be a concern for researchers. [5], carried out a study on maintainability of departmentalized manpower structures in Markov chain model. They considered the condition for maintainability with an aspect of manpower planning and control that gives the management a desirable and acceptable free hand to efficiently manage wastage. This is concerned with the maintainability of a graded manpower system mode up of sub-unit or department. In addition, assumed these departments are alike in terms of grade structure, and the grades are the actual promotion cadres of units of system. In this system, the factor of interest on which condition for maintainability is placed then becomes transfer of units across the departments. This study was motivated out of difficulty of the management Board of Delta State Polytechnic Otefe-oghara in effective management of the institution due to inadequate knowledge and information on the behavior of the system. [6], in his study observed that his result revealed that the career prospect progressing through the hierarchy is stable and orderly, the total expected duration varied between 26 and 59 years and the wastage experience in the college average 2.78% of the total academic staff strength of the College of Applied Natural and Social Sciences of Anambra State University of Technology. Hence, there exists little or no literature on the application of the Markovian approach in determining the behavior and forecasting the academic grade transition in a Polytechnic institution. The objective of this study is to determine the proportion of staff recruited, promoted and withdrawn from the various grade levels in Delta State Polytechnic Oghara over the years and also forecast the expected manpower structure in Delta State Polytechnic Oghara for 2014/2015 session.

1.1. Manpower Models

Traditionally, manpower models were thought as mathematical representations of a manpower system. The representations are usually in the form of mathematical equations, which expresses the manpower process. [7], explained that manpower systems are normally considered as complex systems in which their counter parts interacts with each other in order to accomplish the desired outcome. Subsystems can be identified which makes it necessary to distinguish between the system by age, length of services or by department and section. Manpower planning is the process of ensuring that the correct number of human resources is available at the right time at the right place. In order to do that they need appropriate analytical tools, much effort has been devoted to developing tools and techniques to assist managers with their planning. Many of these were based on the theory of stochastic processes and more specifically the concept of Markov chains [8]. Defining Human resources [9], stated that human resources constitute the ultimate basis for wealth of nations, capital and natural resources are passive factors of production; human beings are the active agents who accumulate capital, exploit natural resources, build social, economic and political organizations, and carry forward national development. Clearly, a country which is unable to develop the skills and knowledge of its people and to utilize them effectively in the national economy will be unable to develop anything else. [10], carried out a study on the theoretical markov chain model for evaluating correctional methods applied to people with criminal tendencies. He used markov chain approach which uses past history to predict the state of a system in the future and came out with a model which comprises the effect of different correctional practices on people with criminal tendencies. [11], focused on tandem queues. They considered a discrete-time tandem queue with blocking. In general, computing the response time in this type of queues requires setting up Markov chain, finding its stationary values and then the response time. In their study they directly based the Markov chain regarding to the age of the leading job in the first queue which led them to calculate the response time easily from the stationary values of this Markov chain. [12], in their study developed a model for manpower management. Their model explicitly considered the fact that managers classify employees into good and poor performers, that certain sources of new employees are more likely to produce good performers than others and that there is a period of learning before a person reaches his full potential in a job. Numerical examples of the use of the model were presented, first to determine the pattern of recruitment from various sources, given manning requirements, that maximizes a measure of performance of the department considered in their study. Next, some of the parameters of the model were varied to determine the effect of changes in turnover rate and rate of promotion to higher job levels. The model presented is descriptive of the movement of individuals through an organization. It does not attempt to explain why people leave an organization or why they join it in the first place.

1.2. Markov and Renewal Manpower Models

Markov models start with a given group of employees that exist in a level of the organization; given the flows in and out of each level (i.e. recruitment and promotions from outside the system together with wastage) they estimate the population of the level in the future. This type of model is particularly useful when the knowledge of existing employees are available together with the probabilities of flows between succeeding years and the required future manpower is not known. Markov models are based on the assumption that future employees in any level of the organization are determined not so much by the number required in that level of the organization but by the promotions and recruitment encouraging the movement up through the system. Because of this characteristic of "pushing" Markov models are often called "push" models. Renewal models concentrate on the basic assumption that requirements are met by changes in promotions and recruitment rates. Knowing the manpower requirements what is required is knowledge of how much recruitment and how many promotions should take place to satisfy them. In this way employees are "pulled" through the system to meet predetermined requirements of the system. Equally, because of this, renewal models are often called "pull" models. Applying the manpower method in an organisation with grades, a staff member can join the grades with equal probability and the entry into the system at the grade is independent of what happens at lower grades within the system, a staff member can be promoted to the next higher grade, stay in the present grade or leave the system by dismissal, retirement, death or for whatever reason each year. These modes of withdrawal will be pooled together. Manpower systems are hierarchical in structure. In a polytechnic institution where the cadre ranges from assistant lecturer to chief lecturer; every staff aspires to reach the top but not all get to the top. The career progress of staff depends mostly on qualification, years of experience and academic productivity in terms of proof of continued research and additional publication.

2. Material and Methodology

2.1. Markov Chain

A Markov process $\{X_t\}$ is a stochastic process with the property that, given the value of X_t the values of X_s, for $s>t$ are not influenced by the values of X_u for $u<t$. In other words, the probability of any particular future behavior of the process, when its current state is known exactly, is not altered by additional knowledge concerning its past behavior [13]. A discrete-time Markov chain is a Markov process whose state space is a finite or countable set, and whose (time) index set is T = (0, 1, 2, ...). In formal terms, the Markov property is that

$$\Pr\{X_{n+1}=j/X_0=i_0,\ldots,X_{n-1}=i_{n-1},X_n=i\}=\Pr\{X_{n+1}=j/X_n=i\} \quad (1)$$

For all time points n and all states $i_0,\ldots,i_{n-1},i,j.$

It is frequently convenient to label the state space of the Markov chain by the nonnegative integers {0, 1, 2, ...}, which will is often used unless the contrary is explicitly stated. It is customary to speak of X_n as being in state i if $X_n=i$.

The probability of the system X_{n+1} being in state j given that X_n is in state i is called the one – step transition probability and is denoted by $p_{ij}^{n,n+1}$. That is

$$p_{ij}^{n,n+1}=pr\{X_{n+1}=j|X_n=i\} \quad (2)$$

Let i= 1, 2, 3, 4, 6, 7; represent the cadre ranging from Assistant lecturer (1), Lecturer III (2), Lecturer II (3), Lecturer I (4), Senior Lecturer (5), Principal Lecturer (6) and chief lecturer (7).

Where t= 1, 2, 3, 4, 5, 6 represent the academic sessions of the Institution; t =1 stands for 2006/07 session, t =2 stands for 2007/08 session, t =3 stands for 2008/09 session, t =4 stands for 2009/10 session, t =5 stands for 2010/11 and t =6 stand for 2011/2012 session.

The following notations and assumptions are relevant;

$n_i(t)=$ Number of staff in cadre i at the beginning of the t^{th} session

$N(t)=\sum_{i=1}^{7} n_i(t)$ the total size of staff at the beginning of the t^{th} session

$n_{ij}(t)=$ Number of persons who move from grade i to j at t^{th} session

$n_{ij}=$ The wastage flow from i^{th} cadre within the t^{th} session

$n_{0j}(t)=$ The recruitment flow to grade j at the beginning of the t^{th} session

$P_{ij}(t)=$ The transition probability of a person in grade i moving to grade j within the t^{th} session $i,j=1,2,\ldots,7$

2.2. Model Assumption

The following assumptions are made about the recruitment and promotion flow and the transition Probability Matrices (TPMS) denoted by $P=[p_{ij}]_{m\times m}$;

where m denotes the cadres.

a. Recruitment can be made into any of the grades and at the beginning of any session where n_{0j} represents the recruitment flow and p_{0j} the probability of recruitment such that

$$\sum_{j=1}^{7} p_{0j} = 1 \tag{3}$$

b. Promotions in the institution depends on such factors as the qualification experience and productivity of staff but due to individual differences, the promotion flow n_{ij} is a random variable with independent transition probability p_{ij} for which summing over j^{th} rows will give ;

$$\sum_{j=1}^{7} p_{ij} + w_i = 1 \tag{4}$$

c. The assumption of an orderly and stable flow would imply that the initial transition probability (p_i) as well as the overall TPM (Transition Probability Matrix) (P) is stationary overtime which implies that the probability matrix is independent of time.

2.3. Determination of Transition Probabilities

The statistical inference procedures for markov chains following the (see [14]) and using the principle of maximum likelihood to exploit the multinomial distribution of $n_{ij}(t)$ given $n_i(t)$ for each period with probabilities $p_{ij}(t)$ gives the estimates of p_{ij} as

$$\hat{p}_{ij} = \frac{n_{ij}}{n_i} \quad i = 1,2,...,7 \; j = 1,2,...,7 \tag{5}$$

If stationarity holds, the pooled estimate becomes

$$p_{ij} = \frac{\sum_{t=1}^{6} n_{ij}(t)}{\sum_{t=1}^{6} n_i(t)} \quad ij = 1,2,...,7 \tag{6}$$

Speaking on the substochastic nature of the transition probability matrix, [2] using the markov chain to model the manpower of Solvenian Armed Forces explained that the actual model used in their study was based on the model described in ([15]), where a vector of recruit's *r* was added. The model allows wastage w; which accounts for those people who leave the system. They argued that in their model, the transition matrix *P* need not be stochastic but only substochastic, which implies that the sum of rows of the transition matrix may be less than 1, where the difference is wastage ***w***, thus,

$$w_i = 1 - \sum_{i=1}^{m} p_{ij} \cdot$$

2.4. Stationarity of Transition Probabilities

[16], stated that the transition probabilities may or may not be constant over time. Hence, in stochastic process, if the transition probabilities over the period of study are not constant, the procedure will be to estimate a different transition probability matrix for each transition ([17]; [18]).

Assumption of constant transition probabilities overtime implies that $p_{ij}(t) = p_{ij}$ for all $j = 1,2,...,7$

Our test hypothesis is stated as;

H_0: Transition probabilities are constant overtime

H_1: Transition probabilities are not constant overtime

To test the stationarity of the seasonal TPM's p_i with elements $\hat{p}_{ij}(t)$ we use the following layout below, $i = 1,2,...,7$.

The π^2 - test of stationarity specify that

1. Transitions from row state i to state j are stationary at α - level of significance if

$$\chi_i^2 = \sum_{j(i)=1}^{7} \sum_{t=1}^{6} n_i(t) \frac{[p_{ij}(t) - p_{ij}]^2}{p_{ij}} < \chi^2_{(\alpha,2(m-1))} \tag{7}$$

Where m is the number of p_{ij} 's > 0

2. The entire TPM, P is constant overtime if

$$\sum_{i=1}^{7} \sum_{j(i)=1}^{7} \sum_{t=1}^{6} n_i(t) \frac{[p_{ij}(t) - p_{ij}]^2}{p_{ij}} < \chi^2_{(\alpha,2(m-1))} \tag{8}$$

Where m is the number of p_{ij} 's > 0.

2.5. The Prediction Equation for Expected Staff Structures

Let $\underline{\overline{n}}(t) = (\overline{n}_1(t), \overline{n}_2(t), \cdots, \overline{n}_7(t))$ be the vector of cadre sizes at the beginning of the t^{th} session, where the top and bottom bar notation denote expectation and vector respectively. It can be shown that

$$\underline{n}(t+1) = \underline{n}(t)Q \quad (9)$$

Where,

$$Q = P + W^{\tau} r = (q_{ij} = p_{ij} + w_i r_j) \quad (10)$$

Where P = 7 X 7, overall transition probability matrix (TPM)

w^T = 7 X 1, vector of wastage probabilities

r = 1 X 7, vector of average recruitment probabilities

2.6. Data Collection

The data used in this study is secondary data obtained from the Personnel Department of Delta State Polytechnic, Oghara for 2006/07 – 2011/12 sessions. The manpower data of the academic staff of Delta state polytechnic, Oghara is presented in Table 1; where the grade level of staff is classified into Grade1 – Assistant lecturer, Grade2 – lecturer III, Grade3 – lecturer II, Grade4 – lecturer I, Grade5 – senior lecturer, Grade6 – principal lecturer, Grade7 – chief lecturer.

Table 1. *Distribution of Manpower Structure of Delta State Polytechnic Otefe-Oghara*

	AL			LIII				LII				LI			
SESSION	R(AL)	AL	W(AL)	R(LIII)	LIII	P(AL)	W(LIII)	R(LII)	L(II)	P(LIII)	W(LII)	R(LI)	L(I)	P(LII)	W(LI)
2006/07	0	10	0	10	12	9	1	2	10	1	0	4	9	4	4
07/08	1	9	0	8	15	6	4	2	8	2	2	2	13	2	1
08/09	2	8	0	2	19	4	4	1	12	4	3	1	11	2	6
09/10	1	5	0	2	16	2	0	3	10	3	2	3	13	4	2
10/11	0	4	0	3	12	3	1	2	12	5	3	2	12	2	4
11/12	1	5	0	2	10	2	0	2	10	2	3	2	13	2	2

SL				PL				CL			
R(SL)	SL	P(LI)	W(SL)	R(PL)	PL	P(SL)	W(PL)	R(CL)	CL	P(PL)	W(CL)
6	6	3	0	2	4	3	1	2	2	1	1
3	7	2	0	2	3	2	0	2	2	1	0
8	6	0	2	1	6	4	2	1	2	3	1
2	8	3	2	1	4	3	2	1	3	2	1
1	6	2	1	1	6	2	3	1	2	1	1
1	5	1	0	1	4	1	1	2	2	1	0

Key: AL = Assistant lecturer, LIII = Lecturer 3, LII = Lecturer 2, LI = lecturer 1, SL = Senior Lecturer, PL = Principal lecturer, CL = Chief Lecturer, R = Recruitment, P = Promoted and W= Wastage (Retirement, Resignation, Sack or termination, death and ill health).

3. Analysis and Result

Using the collected data as presented in Table 1 the transition probability of the academic staff of Delta State polytechnic was summarized for the seven grade levels below (see Table 2 at the Appendix)

From Table 2, the transition probability matrix for the staff transition was extracted as given

$$p = \begin{bmatrix} 0.6119 & 0.3881 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.7560 & 0.1532 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.6813 & 0.1758 & 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 & 0.7030 & 0.1089 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.6552 & 0.2586 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.6000 & 0.2000 \\ 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.7647 \end{bmatrix}$$

3.1. Stationarity of the Transition Probabilities

The transition probabilities for the various grade levels presented in Table 2 was tested for stationarity using the procedure discussed in section 2.4 (see Equation 7 and Equation 8).

Table 3. *Summary Result of Test of stationarity of Transition probabilities*

Cadre(i)	χ_i^2	df	$\chi^2_{(0.05,df)}$	p-value
1	1.42	5	11.07	0.92
2	4.16	5	11.07	0.53
3	2.41	5	11.07	0.79
4	4.78	5	11.07	0.44
5	1.75	5	11.07	0.88
6	1.20	5	11.07	0.94
7	0.40	5	11.07	0.99
Total	16.12	35	43.77	0.99

Recall that the Chi-square used as the test statistics for TPM is

$$\sum_{i=1}^{7} \sum_{j(i)=1}^{7} \sum_{t=1}^{6} n_i(t) \frac{[p_{ij}(t) - p_{ij}]^2}{p_{ij}} = 16.12$$

Since, the p-value = 0.99 is greater than the $\alpha = 0.05$, we accept the null hypothesis of stationarity of the cadre transition.

3.2. Prediction of Future Structure

From the Table 3 the vector of recruitment and wastage probabilities respectively were calculated as given

$r = \lfloor 0.05 \quad 0.28 \quad 0.13 \quad 0.15 \quad 0.22 \quad 0.08 \quad 0.09 \rfloor$ and

$w = \lfloor 0 \quad 0.0900 \quad 0.1429 \quad 0.1881 \quad 0.0862 \quad 0.2000 \quad 0.2353 \rfloor$ respectively.

$$p = \begin{bmatrix} 0.6119 & 0.3881 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.7560 & 0.1532 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.6813 & 0.1758 & 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 & 0.7030 & 0.1089 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.6552 & 0.2586 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.6000 & 0.2000 \\ 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.7647 \end{bmatrix}$$

So that $Q = P + w^T r$ is computed as

$$Q = \begin{bmatrix} 0.6119 & 0.3881 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ 0.0045 & 0.7812 & 0.1649 & 0.0135 & 0.0198 & 0.0072 & 0.0081 \\ 0.0071 & 0.0400 & 0.6999 & 0.1972 & 0.0314 & 0.0114 & 0.0129 \\ 0.0094 & 0.0527 & 0.0245 & 0.7312 & 0.1503 & 0.0150 & 0.0169 \\ 0.0043 & 0.0241 & 0.0112 & 0.0129 & 0.6742 & 0.2655 & 0.0078 \\ 0.0100 & 0.0560 & 0.0260 & 0.0300 & 0.0440 & 0.6160 & 0.2180 \\ 0.0118 & 0.0659 & 0.0306 & 0.0353 & 0.0518 & 0.0188 & 0.7859 \end{bmatrix}$$

To predict the manpower structure of Delta state Polytechnic using Equation (9) and (10), Table 4 below was obtained;

Table 4. *Observed Expected manpower Structure* $\bar{n}(t)$ *for t= 0, 1, 2, 3, 4, 5, 6, 7, 8, 9*

SESSION	t	1	2	3	4	5	6	7	N(t)
2006/07	1	10	30	13	13	15	8	2	91
2007/08	2	10	25	9	16	12	7	3	82
2008/09	3	10	21	15	8	12	9	5	80
2009/10	4	6	20	14	18	11	6	5	80
2010/11	5	4	17	15	12	8	6	2	64
2011/12	6	6	14	11	15	7	5	5	63
2012/13	7	4	15	11	14	8	5	6	63
2013/14	8	3	15	11	13	9	6	6	63
2014/15	9	2	15	11	12	9	7	7	63

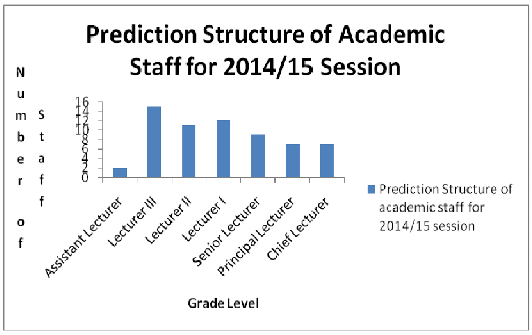

Figure 1. *Prediction Structure of Academic Staff for 2014/15 Session*

4. Discussion

The result of the stationarity test, showed that the grade transition flows from one grade to the other is stationary, since, the p-value = 0.99 is greater than the $\alpha = 0.05$, we accept the null hypothesis of stationarity of the grade transition (see Table 3).

Also, Table 4 shows that at the beginning of the 2014/15 session (t=9), the expected staff structure of Delta State Polytechnic Otefe-Oghara will consist of 2 Assistant Lecturer's, 15 Lecturer's III, 11 Lecturer's II, 12 Lecturer's I, 9 Senior Lecturer's, 7 Principal Lecturer's and 7 Chief Lecturer's; if the current recruitment and promotion policies in the institution remain unchanged.

From graphical representation of the prediction structure of academic staff of Delta state Polytechnic for 2014/15 session (see Figure 1) it was observed that the distribution of the structure was approximately normally distributed

5. Conclusions

This study employed the Markovian approach in studying the behavior of the academic staff grade transition for six academic sessions and forecasting the expected manpower structure in Delta State Polytechnic Oghara for 2014/15 session. The findings showed that the grade transition flow is stationary over the observed time period. Also, it was predicted that at the beginning of the 2014/15 session (t=9), the expected staff structure of Delta State Polytechnic Otefe-Oghara will consist of 2 Assistant Lecturer's, 15 Lecturer's III, 11 Lecturer's II, 12 Lecturer's I, 9 Senior Lecturer's, 7 Principal Lecturer's and 7 Chief Lecturer's; if the current recruitment and promotion policies in the institution remain unchanged. The predicted distributed structure of academic staff of Delta state Polytechnic for 2014/15 session was observed to be approximately normally distributed.

Appendix

Table 2. *Transition of Academic Staff into various Grades in Delta State Polytechnic for t =1, 2, 3, 4, 5, 6*

t	1	2	3	4	5	6	7	
$N_{0j}(t)$ i								$n_i(t)$
1	10(0.5263)	9(0.4737)						19
	9(0.6000)	6(0.4000)						15
	8(0.6667)	4(0.3333)						12
	5(0.7142)	2(0.2857)						7
	4(0.5714)	3(0.4286)						7
	5(0.7143)	2(0.2857)						
	41(0.6119)	26(0.3881)						67
2		12(0.8572)	1(0.0714)					14
		15(0.7143)	2(0.0952)					21
		19(0.7038)	4(0.1481)					27
		16(0.8421)	3(0.1579)					19
		12(0.6667)	5(0.2778)					18
		10(0.5882)	2(0.1176)					12
		84(0.7568)	17(0.1532)					111
3			10(0.7143)	4(0.2857)				14
			8(0.6667)	2(0.1667)				12
			12(0.7059)	2(0.1176)				17
			10(0.6250)	4(0.2500)				16
			12(0.7059)	2(0.1176)				17
			10(0.6667)	2(0.1333)				15
			62(0.6813)	16(0.1758)				91
4				9(0.5625)	3(0.1875)			16
				13(0.8125)	2(0.1250)			16
				11(0.6471)	0(0.0000)			17
				13(0.7222)	3(0.1667)			18
				12(0.6667)	2(0.1111)			18
				13(0.8125)	1(0.0625)			16
				71(0.7030)	11(0.1089)			101
5					6(0.6667)	3(0.3333)		9
					7(0.7778)	2(0.2222)		9
					6(0.5000)	4(0.3333)		12
					8(0.6154)	3(0.2308)		13
					6(0.6667)	2(0.2222)		9
					5(0.8333)	1(0.1667)		6
					38(0.6552)	15(0.2586)		58
6						4(0.6666)	1(0.1667)	6
						3(0.7500)	1(0.2500)	4
						6(0.5455)	3(0.2727)	11
						4(0.5000)	2(0.2500)	8
						6(0.6000)	1(0.1000)	10
						4(0.6666)	1(0.1667)	6
						27(0.6000)	9(0.2000)	45
7							2(0.6667)	3
							2(1.0000)	2
							2(0.6667)	3
							3(0.7500)	4
							2(0.6667)	3
							2(1.0000)	2
							13(0.7647)	17

Key: $n_i(t)$ = Number of staff in cadre i at the beginning of the t^{th} session

$N_{0j}(t)$ = Total recruitment flow to grade j at the beginning of the t^{th} session

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