

# Determining the Expected Length of Stay of Academic Staff in Various Grade Levels in a Polytechnic Institution in Nigeria Using a Markov Chain Approach

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**Abstract** This study examined the transition into various grade levels of academic staff at Delta State Polytechnic, Otefe-Oghara using a markov chain approach. The staff transition for the various grade levels were found to be stationarity, since the  $\chi^2$  (computed) was obtained as 16.12 with a corresponding p-value = 0.1925 which fall on the acceptance region using  $\alpha=0.05$ . It was found that an entrant on grade 1 (Assistant lecturer grade) is expected to stay for a period of 2 years and seven months in grade 1; an entrant on grade 2 (Lecturer III) is expected to stay for a period of 4 years and a month in grade 2; an entrant on grade 3 (Lecturer II) is expected to stay for a period of 3 years and 2 months in grade 3; an entrant on grade 4 (Lecturer I) is expected to stay for a period of 3 years and 4 months; an entrant on grade 5 (Senior Lecturer) is expected to stay for a period of 2 years and 11 months; an entrant on grade 6 (Principal Lecturer) is expected to stay for a period of 2 years and six months in grade 6; an entrant on grade 7 (Chief Lecturer) is expected to stay for a period of 4 years and 3 months in grade 7. It was concluded that staff in Principal Lecturer (grade 6) and Assistant Lecturer (grade 1) has less expected length of stay and also has greater chance of promotion than other grade level, hence, potential applicants are advised to apply for Principal Lecturer and Assistant Lecturer positions if vacancies exist in the Institution.

**Keywords** Lecturer, Transition, Academic Staff, Stationarity, Carer Prospect, Matrix

## 1. Introduction

Organisations tend to be hierarchical with finite number of levels (ranks). Humans are considered as the most crucial and potentially unpredicted resource which an organisation utilises to achieve it set goals. If an organisation fails to place and direct human resources in the right areas of business, at the right time, and at the right cost, serious inefficiencies are likely to occur creating considerable operational difficulties or even business failure. In order to achieve efficiency in managing human resources in an organisation, the coordination of demand and supply is required, together with the monitoring and assessment of productivity and technological changes. Career pattern is concerned with the passage of individuals through an organizational system. That is, the duration of individuals progress through the grades in an organization. It is clear that it is difficult to track and monitor this progress of the individuals through the organizations grades without the complexity of qualitative factors and the projection of resource mismatches[1].[2],

recognised that ‘shortages’ of persons with critical skills and knowledge required for effective national development is a serious problem in most developing nations. This problem is further compounded by some derogatory and discriminatory policies (in Nigeria for instance) like “state of origin”, “federal character”, etcetera.[3] in his study stressed that analysis of manpower systems have become very important component of planned economic development of any organisation or nation. However, manpower planning depends on the highly unpredictable human behaviour and uncertain social environment in which the system functions. He added that this implies that probabilistic or stochastic models of manpower systems are very much essential in management of any organisation. The present study was motivated out of curiosity and arguments by most academic staff of Delta State Polytechnic Otefe-Oghara who claims that promotion has been overlooked by the management of the Institution. Therefore the need to determine the length of stay of academic staff in various grade levels of the Institution and ascertaining the chances of promotion in various grade levels a sine qua non.

### 1.1. Manpower Models

Traditionally, manpower models were thought as mathematical representations of a manpower system. The

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representations are usually in the form of mathematical equations, which expresses the manpower process.[4], 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[5]. Defining Human resources[6], 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.[7], 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.[8], 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.[9], 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 organisation; 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 organisation are determined not so much by the number required in that level of the organisation 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. Materials 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 behaviour of the process, when its current state is known exactly, is not altered by additional knowledge concerning its past behaviour[10]. A discrete-time Markov chain is a Markov process whose state space is a finite or countable set,

and whose (time) index set is  $T = (0, 1, 2, \dots)$ . In formal terms, the Markov property is that

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

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

It is frequently convenient to label the state space of the Markov chain by the nonnegative integers  $\{0, 1, 2, \dots\}$ , which will be 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  $i, j = 1, 2, \dots, 7$

## 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

$$\sum_{j=1}^7 P_{0j} = 1 \quad (3)$$

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 ;

$$\sum_{j=1}^7 P_{ij} + w_i = 1 \quad (4)$$

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[11]) 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

$$\hat{P}_{ij} = \frac{n_{ij}}{n_i} \quad i = 1, 2, \dots, 7 \quad j = 1, 2, \dots, 7 \quad (5)$$

If stationarity holds, the pooled estimate becomes

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

Speaking on the substochastic nature of the transition probability matrix, [12] 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 ([13]), 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,

$$w_i = 1 - \sum_{j=1}^m P_{ij}$$

## 2.4. Stationarity of Transition Probabilities

[14] 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 ([15];[16]).

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

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.  
 $i = 1, 2, \dots, 7$

The  $\pi^2$ -test of stationarity specify that

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

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

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

2. The entire TPM, P is constant overtime if

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

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

## 2.5. The Career Prospects of Staff

It should also be of interest to have an idea of the expected length of time a lecturer is likely to spend in a period and also the mean length of stay, which is the time spent in Delta State Polytechnic.[13] established that the mean length of time spent in grade  $i$  given entry in grade  $j$  is given by  $M$  and the probability of attainment of grade  $j$  from grade  $i$  is given by

$$\hat{w}_{ij} = \frac{\mu_{ij}}{\mu_{jj}} \quad (9)$$

Where  $\mu_{ij}$  and  $\mu_{jj}$  are element of the fundamental matrix

$$M = (I - P)^{-1} \quad (10)$$

Where P is the (7 X 7) TPM and I is the identity matrix.

## 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. Data Analysis

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).

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

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



$$M = (\hat{N}_{ij}) = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ 1 & 2.58 & 4.10 & 1.97 & 1.17 & 0.37 & 0.24 & 0.20 \\ 2 & 0.00 & 4.10 & 1.97 & 1.17 & 0.37 & 0.24 & 0.20 \\ 3 & 0.00 & 0.00 & 3.14 & 1.86 & 0.59 & 0.38 & 0.32 \\ 4 & 0.00 & 0.00 & 0.00 & 3.37 & 1.06 & 0.69 & 0.58 \\ 5 & 0.00 & 0.00 & 0.00 & 0.00 & 2.90 & 1.88 & 1.59 \\ 6 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 2.50 & 2.12 \\ 7 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 4.25 \end{bmatrix} \text{RowTotal}$$

$$(\hat{w}_{ij}) = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ 1 & 1 & 1 & 0.63 & 0.35 & 0.13 & 0.10 & 0.05 \\ 2 & & 1 & 0.63 & 0.35 & 0.13 & 0.10 & 0.05 \\ 3 & & & 1 & 0.55 & 0.20 & 0.15 & 0.08 \\ 4 & & & & 1 & 0.37 & 0.28 & 0.14 \\ 5 & & & & & 1 & 0.75 & 0.37 \\ 6 & & & & & & 1 & 0.50 \\ 7 & & & & & & & 1 \end{bmatrix}$$

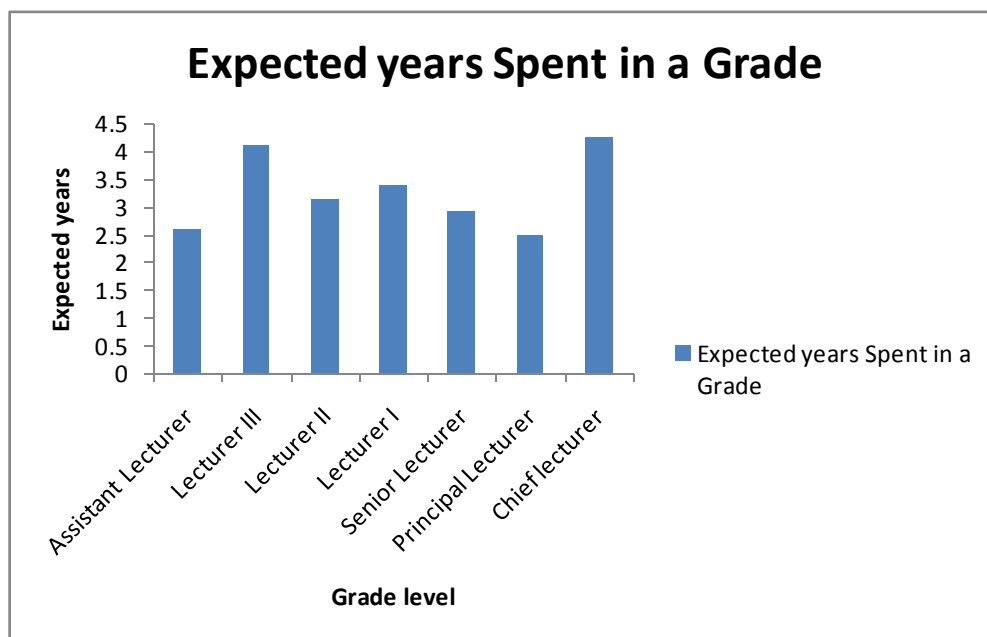


Figure 1. Distribution of Expected years Spent in a Grade

#### 4. Discussion

From the result of the stationarity test, it was observed 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).

We can denote from the result of the fundamental matrix (M) that an entrant on grade 1 (Assistant lecturer grade) is expected to stay for a period of 2 years and seven months in grade 1; an entrant on grade 2 (Lecturer III) is expected to stay for a period of 4 years and a month in grade 2; an entrant on grade 3 (Lecturer II) is expected to stay for a period of 3 years and 2 months in grade 3; an entrant on grade 4 (Lecturer I) is expected to stay for a period of 3 years and 4 months; an entrant on grade 5 (Senior Lecturer) is expected to stay for a period of 2 years and 11 months; an entrant on grade 6 (Principal Lecturer) is expected to stay for a period of 2 years and six months in grade 6; an entrant on grade 7 (Chief Lecturer) is expected to stay for a period of 4 years and 3 months in grade 7.

Also, the career prospect analysis, the matrix ( $\hat{W}_{ij}$ ) obtained showed that on the average potential entrants in grade 1 and 2 have 63% and 63% chances of being promoted to Lecturer II, entrant in grade 3 have 55% chances of being promoted to Lecturer I, entrant in grade 4 have about 37% chance of being promoted to Senior Lecturer while entrants in grade 5 have about 75% chance of being promoted to Principal Lecturer and entrants in grade 6 have about 50% chance of being promoted to Chief Lecturer.

From the graphical representation (see Figure 1) we observed that entrant into Principal Lecturer grade and Assistant Lecturer grade are expected to spend less years than the other grade levels with an expected length of 2 years and 6 months and 2 years and 7 months respectively.

## 5. Conclusions

In this study markovian approach was used to determine the transition of academic staff in the various grade levels in Delta state polytechnic Otefe – Oghara between 2006/07 and 2011/12 academic session. The findings showed that the grade transition flow is stationary over the observed time period and also found that staff in grade 6 (Principal Lecturer) have greater percentage chance (73%) of being promoted to grade 7 (Chief lecturer) followed by staff in grade 1 (Assistant Lecturer) and grade 2 (Lecturer III) with 60% chance of being promoted to grade 2 (Lecturer III) and grade 3 (Lecturer II) respectively. While staff in grade 3 (Lecturer II) have 58% chance of being promoted to grade 4 (Lecturer I) in the institution. Since it was obtained that staff in Principal Lecturer (grade 6) and Assistant Lecturer (grade 1) has less expected length of stay and also has greater chance of promotion than other grade level, hence, potential applicants are advised to apply for Principal Lecturer and Assistant Lecturer positions if vacancies exist in the Institution. However, this study presents the academic structure of Delta state Polytechnic Otefe–Oghara. We recommend for future research a manpower structure modelling for administrative staff of Delta state Polytechnic Otefe – Oghara from the inception of the institution to date.

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