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Estimation of Expected Academic Staff Structure of Universities in South East, Nigeria: A Stationary Markov Chain Approach

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Abstract:-**Due to the high unpredictable human behaviour and social environment where the manpower system functions, there is need to study the manpower structure of any organization to avoid challenges such as short fall and surplus of skilled staff in the organization which has the potential of leading to costly staff capacity problem. This study examined the expected academic staff structure of selected Universities in South East Nigeria. The transition probability of the University grade levels were found to be stationary over the observed period and positive recurrent or strongly ergodic. The result of the prediction equation model found that at the beginning of the 2020/21 session (t=11), it is expected that the staff structure of the University Institution will consist of 336 Assistant Lecturers, 921 Lecturers II, 835 Lecturers I, 1654 Senior Lecturers, 460 Readers and 62 Professors; if the current recruitment and promotion policies in the institutions remains unchanged.**

Keywords: **Ergodic, Staff Capacity, Staff Structure, Stationarity, Recruitment**

I. INTRODUCTION

In recent time, manpower development has been identified as an accepted phenomenon in many global organizations. In tertiary institutions for instance, lecturers' development programmes are considered very important to the productivity of the institution. These developmental programmes are planned activities that focus on increasing the capabilities, improving the technical and conceptual skills of lecturers so that they can possess the necessary and required abilities to handle complex situations and better perform their job. Through renewal activities, lecturers avoid becoming unsophisticated (Peretomode and Chukwuma, 2016).

The important of studying the career pattern in any organization cannot be overemphasized this is because it helps policy makers and planners for effectively implement policies and manage the system properly. Hence, the aim of this study is to determine the expected academic staff structure of selected South East Universities in Nigeria.

II. LITERATURE REVIEW

Dessler (2005) opined that staffing as management function determines the type of people that should be hired, recruiting prospective employees; selecting employees setting performance standards; compensating employees; evaluating performances; counselling employee; training and developing employees. This concept of staffing is central to both management and human resource management which involves the process of acquiring, training, appraising and compensating employees, and attending their labour task, health and safety, and fairness concern.

Ekankumo *et al*. (2011) examined the human resource management skills required for the administration of tertiary institution the Niger Delta region in Nigeria. The findings of their study showed that the opinion of the respondent vary significantly in some of items in the research instrument. The study revealed that all the major skills of human resource management need to be emphasized in time of management, while government should provide all resources needed for the practical training of students for the achievement of the aims and objectives of the institution.

Anyebe (2014) examined the performance of the Nigerian university system with regards to manpower development. The study focused on identifying areas that require urgent attention in order to reposition the university system to be highly productive in terms of quality of manpower. The study reveals that the expansion in the university system is characterized by a collective bag of limited success and continued challenges such as short fall of staff at some certain grades. It was recommended that for Nigerian university system to live up to its objective effectively, the university system needs to be evidence based planned in order to produce graduates that are versatile enough to acquire competitive positions as well as generate their own employment.

III. METHODS AND MATERIAL

3.1 Method of Data collection

Secondary source of data collection was adopted for this study with data obtained from the Personnel Department of Nnamdi Azikiwe University, Awka, Chukwuemeka Odumegwu Ojukwu University, Imo State University, Owerri, and Federal University of Technology (FUTO), Owerri between

2006/07 – 2016/17 sessions. The selection criteria for these institution is on availability of the required data for this study.

3.2 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 $u < t$. This implies that the probability of any particular future behaviour of the process, when its current state is known exactly, is not altered by any additional knowledge concerning its past behaviour (Taylor and Klarlin, 1998).

A discrete-time Markov chain can be defined as a Markov process whose state space is finite and whose (time) index set is T = 0, 1, 2, ... Thus, the Markov property is that

$$\Pr\{X_{t+1} = j / X_0 = i_0, \ldots, X_{t-1} = i_{t-1}, X_t = i\} = \Pr\{X_{t+1} = j / X_t = i\} \tag{1}$$

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

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

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

$$p_{ij}^{t,t+1} = \Pr\{X_{t+1} = j | X_t = i\} \tag{2}$$

In the present study, the grade range will run from i= 1, 2, 3, 4, 5, 6 which represent the grade range from Assistant lecturer (1), Lecturer II (2), Lecturer I (3), Senior Lecturer (4), Reader (5) and Professor (6). Also, we shall consider, t= 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 to represent the academic sessions of the institution where 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, t=7 stand for 2012/2013 session, t=8 stand for 2013/2014 session, t=9 stand for 2014/2015 session, t=10 stand for 2015/2016 session, t=11 stand for 2016/2017.

3.3 Model Assumptions And Notations

The following assumptions were made about the recruitment and promotion flow and the Transition Probability Matrices (TPMS) which is denoted by $P = [p_{ij}]_{m \times m}$, where m denotes the grade level.

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

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

b. Promotions in the Institution depend on such factors as the qualification, experience and productivity of staff. Due to individual differences, the wastage flow w_i with the independent transition probability p_{ij} satisfy the condition (4)

$$\sum_{j=1}^{n} p_{ij} + w_i = 1, \text{ for } i = 1, 2, \cdots n \tag{4}$$

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.

d. Accelerated promotion is not allowed

The following notations are relevant in generating the manpower structure

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

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

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

iv. w_i = The wastage flow from i^{th} cadre within the t^{th} session

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

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

3.4 Transition Probabilities of the Manpower Structure

According to Bhat, (1971), the statistical inference procedure for the Markov chains uses the principle of maximum likelihood to exploit the multinomial distribution of $n_{ij}(t)$ given $n_i(t)$ for each period to obtain the estimates of p_{ij} as

$$\hat{p}_{ij} = \frac{n_{ij}(t)}{n_i(t)}, \quad \text{i= 1, 2,...,6, j=1, 2,...,7} \qquad (5)$$

If stationarity holds, the pooled estimate becomes

$$p_{ij} = \frac{\sum_{t=1}^{11} n_{ij}(t)}{\sum_{t=1}^{11} n_i(t)} \qquad \text{i, j=1, 2,...,7} \qquad (6)$$

3.5 Stationarity of the Transition Probabilities of the Manpower Structure

The transition probabilities may be constant over time (Uche, 1978). Hence, in stochastic processes, if the transition probabilities over the period of study are not constant, the procedure is to estimate a different transition probability matrix for each transition within the period (Golan and Vogel, 2000; Karantininis, 2001).

Assumption of constant transition probabilities over time implies that $p_{ij}(t) = p_{ij}$ for all $i, j = 1,2,\ldots,6(7)$

The test hypothesis is stated as;

H_0: Transition probabilities are constant over time

H_1: Transition probabilities are not constant over time

To test the stationarity of the seasonal TPM's p_i with elements $\hat{p}_{ij}(t)$ for $i = 1,2,\ldots,6(7)$, we use the following layout below.

The χ^2- test of Stationarity specify that transitions from row state i to state j are stationary at α- level of significance if

$$\chi^2 = \sum_{j(i)=1}^{n+1} \sum_{i=1}^{n} \sum_{t=1}^{T} n_i(t) \frac{\left(p_{ij}(t) - p_{ij}\right)^2}{p_{ij}} \times G < \chi^2_{(\alpha,(m-1))} \qquad (7)$$

Where m is the number of p_{ij} 's > 0 (Cochran, 1952) and G is a normalizing constant.

3.5.1 Ergodicity of a Transition Markov Chain

Spanos (2003) described a stochastic process $\{X_t, t \in T\}$ to be ergodic if any characteristic of the process can be obtained with probability one from a single realization (sample path) of the process.

A Markov chain with N states is said to be ergodic if there exist $\pi = (\pi_1, \pi_2, \ldots, \pi_N)$ such that;

(a) $\pi_i > 0$, i = 1, 2, ..., N

(b) $\sum_{i=1}^{N} \pi_i = 1$

Furthermore, Taylor and Karlin (1998) opined that the higher transition matrix can be computed by raising the transition probability matrix to a high order.

Let P be a regular transition probability matrix on the states 0, 1, ..., N. Then the limiting distribution $\pi = (\pi_0, \pi_1, \ldots, \pi_N)$ is the unique nonnegative solution of Equation (8).

$$\pi_j = \sum_{i=0}^{N} \pi_i p_{ij} \quad \text{for j= 1,..., N} \qquad (8)$$

and $$\sum_{i=0}^{N} \pi_i = 1 \qquad (9)$$

3.5.2 The Prediction Equation For Expected Staff Structures

Let $n(t) = (n_1(t), n_2(t), \cdots, n_7(t))$ be the vector of cadre sizes at the beginning of the t^{th} session. It can be shown that

$$n(t+1) = n(t)Q \qquad (10)$$

and

$$Q = P + w^T r \qquad (11)$$

Where $q_{ij} = p_{ij} + w_i r_j$, i, j=1, 2, ..., 7 are elements of the matrix Q,

P = n X n, overall transition probability matrix (TPM)

w = 1 X n, row vector of wastage probabilities

r = 1 X n, row vector of average recruitment probabilities

3.6 Data Presentation

The manpower data of the Academic Staff of University is presented in table 1, where the university grade levels of staff are classified into Grade1 – Assistant Lecturer, Grade2 – Lecturer II, Grade3 – Lecturer I, Grade4 – Senior Lecturer, Grade5 – Reader, Grade6 – Professor.

Table 1: Distribution of Manpower Structure Of Academic Staff Of University

	AL			LII				LI			
SESSION	R(AL)	AL	W(AL)	R(LII)	LII	P(AL)	W(LII)	R(LI)	L(I)	P(LII)	W(LI)
2006/2007	7	472	0	172	1182	49	0	92	1137	224	63
2007/2008	48	408	0	71	1044	64	20	76	1043	116	92
2009/2010	89	332	20	20	969	89	16	49	997	68	44
2011/2012	39	368	12	8	941	56	0	40	1002	49	68
2013/2014	104	288	0	24	885	68	0	37	926	56	44
2014/2015	44	304	16	16	914	89	12	16	885	44	32
2015/2016	101	285	2	44	869	49	8	8	813	49	16
2016/2017	112	317	16	37	845	68	12	20	775	60	8

SL				READER				PROF			
R(SL)	SL	P(LI)	W(SL)	R(RD)	RD	P(SL)	W(RD)	R(PROF)	PROF	P(RD)	W(PROF)
0	412	135	37	0	268	49	49	0	180	24	60
40	329	89	49	27	180	83	56	0	209	89	12
16	276	52	20	12	236	61	24	32	168	24	27
8	261	44	12	0	244	32	4	0	172	20	12
27	209	76	20	8	192	44	8	8	153	49	8
32	192	83	24	19	164	27	12	12	145	27	4
16	233	44	20	0	135	20	8	8	159	44	1
27	168	37	8	8	124	37	12	12	212	24	13

Key: Al = Assistant lecturer, LII = Lecturer 2, LI = lecturer 1, SL = Senior Lecturer, R = Reader, PROF = Professor, R = Recruitment, P = Promoted and W= Wastage.

IV. DATA ANALYSIS AND RESULTS

4.1 Testing for Stationarity Analysis

The test for stationarity of the transition probabilities was performed to determine the transition probabilities of the manpower structure. The application of the Markov model was applied to the manpower developments of the staff collected from 2006/07 – 2016/17 session for which t= 0, 1, 2, 3, 4, 5, 6, 7. The hypothesis for testing for stationarity which was mentioned earlier in the previous section, have a test statistic for the manpower structure expressed in equation (7)**.** The decision rule is to reject the null hypothesis at significant level, if computed χ^2 is greater than the critical value of χ^2 or when the p-value is less than the critical value of 5%.

Table 2: Summary result of Test of stationarity of Transition probabilities

Cadre(i)	χ_i^2	df	$\chi^2_{(0.05,df)}$	p-value
1	0.0145	4	9.49	0.9999
2	0.0104	4	9.49	0.9999
3	0.0125	4	9.49	0.9999
4	0.0159	4	9.49	0.9999
5	0.0089	4	9.49	0.9999
6	0.0051	4	9.49	0.9999
7	0.0061	2	5.99	0.9999
Total	0.0734	26	62.93	1.0000

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

$$= \sum_{j(i)=1}^{8} \sum_{i=1}^{7} \sum_{t=1}^{7} n_i(t) \frac{\left(p_{ij}(t) - p_{ij}\right)^2}{p_{ij}} \times G = 0.0734$$

Since, the p-value = 1.00 is greater than the $\alpha = 0.05$, we accept the null hypothesis of stationarity of the grade transition.

4.2 Testing for Ergodicity of the Transition Probability Matrix

The probability matrix for the manpower structure was obtained as;

$$P = \begin{pmatrix} 0.8227 & 0.1578 & 0 & 0 & 0 & 0 \\ 0 & 0.9124 & 0.0795 & 0 & 0 & 0 \\ 0 & 0 & 0.8910 & 0.6580 & 0 & 0 \\ 0 & 0 & 0 & 0.7930 & 0.1492 & 0 \\ 0 & 0 & 0 & 0 & 0.7650 & 0.1492 \\ 0 & 0 & 0 & 0 & 0 & 0.1495 \end{pmatrix}$$

$$\pi_{ju} = \begin{bmatrix} 0.2325 & 0.2614 & 0.2879 & 0.0477 & 0.0662 & 0.1042 \end{bmatrix}$$

$p_{11}(1)=0.8227>0$, $p_{22}(1)=0.9124>0$, $p_{33}(1)=0.8910>0$, $p_{44}(1)=0.7930>0$, $p_{55}(1)=0.7650>0$, $p_{66}(1)=0.1495>0$

$$P^2 = \begin{pmatrix} 0.6768 & 0.0249 & 0 & 0 & 0 & 0 \\ 0 & 0.8325 & 0.0063 & 0 & 0 & 0 \\ 0 & 0 & 0.7939 & 0.4330 & 0 & 0 \\ 0 & 0 & 0 & 0.6289 & 0.0223 & 0 \\ 0 & 0 & 0 & 0 & 0.5853 & 0.0223 \\ 0 & 0 & 0 & 0 & 0 & 0.0224 \end{pmatrix}$$

$p_{11}(2)=0.6768>0$, $p_{22}(2)=0.8325>0$, $p_{33}(2)=0.7939>0$, $p_{44}(2)=0.6289>0$, $p_{55}(2)=0.5853>0$, $p_{66}(2)=0.0224>0$

$$P^3 = \begin{pmatrix} 0.5568 & 0.004 & 0 & 0 & 0 & 0 \\ 0 & 0.7595 & 0.0005 & 0 & 0 & 0 \\ 0 & 0 & 0.7073 & 0.2849 & 0 & 0 \\ 0 & 0 & 0 & 0.4987 & 0.0033 & 0 \\ 0 & 0 & 0 & 0 & 0.4477 & 0.0033 \\ 0 & 0 & 0 & 0 & 0 & 0.0033 \end{pmatrix}$$

$p_{11}(3)=0.5568>0$, $p_{22}(3)=0.7595>0$, $p_{33}(3)=0.7073>0$, $p_{44}(3)=0.4987>0$, $p_{55}(3)=0.4477>0$, $p_{66}(2)=0.0033>0$

In this way we obtain

$$p_{ii}(1d) => 0 \text{ ff for d=1, 2, 3, 4 ...}$$

Where the greatest common denominator is 1; P is said to be aperiodic and $\pi_j > 0$, hence P is positive recurrent or strongly ergodic.

4.3 The Prediction Equation For Expected Staff Structures

The wastage (w) and recruitment (r) probabilities for the university institution are given by

$$W = \begin{bmatrix} 0.0195 & 0.0081 & 0.0432 & 0.0724 & 0.0858 & 0.0893 \end{bmatrix}$$

$$r = \begin{bmatrix} 0.3430 & 0.2472 & 0.2131 & 0.1047 & 0.0467 & 0.0454 \end{bmatrix}$$

$$P = \begin{pmatrix} 0.8227 & 0.1578 & 0 & 0 & 0 & 0 \\ 0 & 0.9124 & 0.0795 & 0 & 0 & 0 \\ 0 & 0 & 0.8910 & 0.6580 & 0 & 0 \\ 0 & 0 & 0 & 0.7930 & 0.1492 & 0 \\ 0 & 0 & 0 & 0 & 0.7650 & 0.1492 \\ 0 & 0 & 0 & 0 & 0 & 0.1495 \end{pmatrix}$$

So that $Q = P + W^{\tau} r$ is computed as

$$Q = \begin{pmatrix} 0.8294 & 0.1626 & 0.0042 & 0.0020 & 0.0009 & 0.0009 \\ 0.0028 & 0.9144 & 0.0812 & 0.0008 & 0.0004 & 0.0004 \\ 0.0148 & 0.0107 & 0.9002 & 0.6625 & 0.0020 & 0.0020 \\ 0.0248 & 0.0179 & 0.0154 & 0.8006 & 0.1526 & 0.0033 \\ 0.0294 & 0.0212 & 0.0183 & 0.0090 & 0.7690 & 0.1531 \\ 0.0306 & 0.0221 & 0.0190 & 0.0093 & 0.0042 & 0.1536 \end{pmatrix}$$

Using Equation (10) and (11) the table of expected structure tagged table 3 was generated;

Table 3: Observed Expected manpower Structure for University $\underline{\overline{n}}(t)$ for t= 0, 1, 2, 3, 4, 5, 6,7

SESSION	t	1	2	3	4	5	6	N(t)
2006/07	0	479	1354	1166	375	219	120	3713
2007/08	1	438	1343	1193	1093	229	56	4352
2009/10	2	415	1100	1027	942	167	57	3708
2011/12	3	369	979	994	887	217	64	3510
2013/14	4	363	956	967	856	227	65	3434
2014/15	5	357	916	913	787	184	56	3213
2015/16	6	305	913	867	740	165	53	3043
2016/17	7	347	909	809	721	136	48	2970
2017/18	8	371	882	790	676	124	54	2897
2018/19	9	344	891	798	1068	201	32	3334
2019/20	10	333	903	813	1387	320	41	3797
2020/21	11	336	921	835	1654	460	62	4268

The result obtained in table 3 revealed that at the beginning of the 2020/21 session (t=11), we expect the staff structure to consist of 336 Assistant Lecturers, 921 Lecturers II, 835 Lecturers I, 1654 Senior Lecturers, 460 Readers and 62 Professors; if the current recruitment and promotion policies in the institutions remains unchanged.

V. CONCLUSION

One importance of studying manpower structure of any organization is because of high unpredictable human behaviour and uncertain social environment in which the system functions. Also, both a short fall and surplus of skilled staff in any organization especially tertiary institutions can lead to serious staff capacity problem both in quantity and quality. Issues as costly as this can lead to malfunction of the organization in terms of productivity.

This study examined the expected academic staff structure of selected Universities in South East Nigeria. The transition probability of the University grade levels were found to be stationary over the observed period and positive recurrent or strongly ergodic. The result of the prediction equation model found that at the beginning of the 2020/21 session (t=11), it is expected that the staff structure of the University Institution will consist of 336 Assistant Lecturers, 921 Lecturers II, 835 Lecturers I, 1654 Senior Lecturers, 460 Readers and 62 Professors; if the current recruitment and promotion policies in the institutions remains unchanged.

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Appendix

Table 4: Manpower Data for Selected Universities in South East Nigeria for t= 0, 1, 2, 3, 4, 5, 6, 7

t	1	2	3	4	5	6	8	
$N_{0j}(t)$ i								
								$n_i(t)$
1	472(0.1702)	49(0.0921)					0(0.0000)	521
	408(0.1471)	64(0.1203)					0(0.0000)	472
	332(0.1197)	89(0.1673)					20(0.3030)	441
	368(0.1327)	56(0.1053)					12(0.1818)	436
	288(0.1038)	68(0.1278)					0(0.0000)	356
	304(0.1096)	89(0.1673)					16(0.2424)	409
	285(0.1027)	49(0.0921)					2(0.0303)	336
	317(0.1143)	68(0.1278)					16(0.2424)	401
	2774(0.8227)	532(0.1578)					66(0.0195)	3372
2		1182(0.1545)	224(0.3363)				0(0.0000)	1406
		1044(0.1365)	116(0.1742)				20(0.2941)	1180
		969(0.1267)	68(0.1021)				16(0.2353)	1053
		941(0.1230)	49(0.0736)				0(0.0000)	990
		885(0.1157)	56(0.0841)				0(0.0000)	941
		914(0.1195)	44(0.0661)				12(0.1765)	970
		869(0.1136)	49(0.0736)				8(0.1176)	926
		845(0.1105)	60(0.0901)				12(0.1765)	917
		7649(0.9124)	666(0.0795)				68(0.0081)	8383
3			1137(0.1500)	135(0.2411)			63(0.1717)	1335
			1043(0.1376)	89(0.1589)			92(0.1589)	1224
			997(0.1316)	52(0.0929)			44(0.0929)	1093
			1002(0.1322)	44(0.0786)			68(0.0786)	1114
			926(0.1222)	76(0.1357)			44(0.1357)	1046
			885(0.1168)	83(0.1482)			32(0.1482)	1000
			813(0.1073)	44(0.0786)			16(0.0786)	873
			775(0.1023)	37(0.0661)			8(0.0661)	820
			7578(0.8910)	560(0.0658)			367(0.0432)	8505
4				412(0.1981)	49(0.1388)		37(0.1947)	498
				329(0.1582)	83(0.2351)		49(0.2579)	461
				276(0.1327)	61(0.1728)		20(0.0153)	357
				261(0.1255)	32(0.0907)		12(0.0632)	305
				209(0.1005)	44(0.1246)		20(0.0153)	273
				192(0.0923)	27(0.0765)		24(0.1263)	243
				233(0.1120)	20(0.0567)		20(0.0153)	273
				168(0.0808)	37(0.1048)		8(0.0421)	213
				2080(0.7930)	353(0.1346)		190(0.0724)	2623
5					268(0.1737)	24(0.0797)	49(0.2832)	341
					180(0.1167)	89(0.2957)	56(0.3237)	325
					236(0.1529)	24(0.0797)	24(0.1387)	284
					244(0.1581)	20(0.0664)	4(0.0231)	268
					192(0.1244)	49(0.1628)	8(0.0462)	249
					164(0.1063)	27(0.0897)	12(0.0694)	203
					135(0.0875)	44(0.1462)	8(0.0462)	187
					124(0.0804)	24(0.0797)	12(0.0694)	160
					1543(0.7650)	301(0.1492)	173(0.0858)	2017
6						180(0.1288)	60(0.4380)	240
						209(0.1495)	12(0.0876)	221
						168(0.1202)	27(0.1971)	195
						172(0.1230)	12(0.0876)	184
						153(0.1094)	8(0.0584)	161
						145(0.1037)	4(0.0292)	149
						159(0.1137)	1(0.0073)	160
						212(0.1516)	13(0.0949)	225
						1398(0.9107)	137(0.0893)	1535