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ACADEMIC STAFF FLOW MODELING IN A MANPOWER PLANNING SYSTEM INTEGRATED WITH SUSTAINABILITY PRACTICES

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ABSTRACT: Manpower is the human skills, expertise and intelligence in business organization which is responsible for the production of goods and services. Assigning employees to different jobs at the right time, into right positions and in right quantity involves using correct data in planning. Unfortunately, this has remained a huge challenge to human resource personnel in many of our educational institutions. The method of Markov's transition matrix probabilities is used to model manpower-flow in this article. This research explores the intersection of academic staff flow modeling and sustainable environmental management practices within a manpower planning system. Although, some researchers have made some attempts in modeling manpower planning with data applicable to higher institutions, much has not been said about academic staff-flow in Colleges of Education. In this study, an expansion of the concept of manpower-flow in some existing models is derived by formulating a Markov Model of Academic Staff-flow in Colleges of Education. From the results obtained in the numerical illustration, it is observed that the transient-state is a better parameter than the steady-state in determining the efficiency of the manpower planning system in the first few periods. In the first few periods, the total number of staff decreases with few departments in operation but as time goes on, more academic staffs are being recruited and many departments are usually approved by regulatory bodies such as National Commission for Colleges of Education (NCCE) and National University Commission (NUC) respectively. This gives rise to slow convergence; another phenomenon observed in the probability matrix is the fact that P_{ij} is an upper triangle matrix such that the eigen values form the diagonal elements. The highest eigenvalue is 0.90 which is approximately 1. The model offers practical utility for human resource personnel and policymakers in higher institutions to forecast and optimize staffing structures while supporting sustainability initiatives.

Keywords: Markov Model, integration, academic staff, promotion, recruitment, sustainability

Introduction

The Markov Chain theory was initially introduced in 1907 by Andrei Markov, a Russian mathematician, as documented in the work of Ezugwu and Ologun (2017). A later development of the Markov Chain theory was attributed to A. Kolmogorov, as Feller (1968) documents. The Markov process is classified as a stochastic operation in which elements of sets are transferred from one state to another. The manner in which this occurs is specified in a probability matrix, which may utilize discrete or continuous time parameters (Meng-Chuan et al., 2014). In recent years, the Markov Chain has undergone significant development and has been implemented in numerous fields of study, including the natural and social sciences. Managers utilise Markov Chain in the field of operations research to formulate policies pertaining to attrition, promotion, and recruitment (Hamed et al., 2013). Critical success factors and participatory approaches are essential for the success of sustainability initiatives in universities (Disterheft et al., 2015). It is imperative to comprehend the functions, obstacles, and difficulties associated with sustainability in institutions of higher education (Aleixo et al., 2018). The facilitation of sustainability practice implementation within universities can be achieved through the development of a conceptual model for sustainable building (Olteanu & Kifor, 2021).

The integration of environmental management principles into the process of academic staff planning is of paramount importance in educational institutions as it serves to promote environmentally favourable practices and mitigate environmental impact. Krizek et al. (2012) highlight the significance of implementing sustainability initiatives across an entire university by identifying key impediments and motivations for a synchronized approach to sustainability on campus. A phased approach is delineated, comprising executive endorsement of the business case for sustainability, grassroots initiatives, visionary leadership, and the implementation of fully integrated sustainability practices throughout the campus. The aforementioned incremental strategy underscores the progression of sustainability endeavours implemented in academic establishments. The involvement of academic personnel in the development of sustainability efforts within institutions of higher education is crucial. Through the incorporation of sustainability principles into the process of planning academic staff, institutions can successfully foster environmental stewardship and resource efficiency. The importance of higher education institutions in spearheading sustainability initiatives is underscored in numerous studies. Stephens et al. (2008) emphasize the distinct capacity of higher education to expedite shifts in society in the direction of sustainability. The implementation of sustainable development in higher education institutions is examined by Ramos et al. (2015), who highlight the significance of environmental management for the establishment of sustainable universities. In addition, Filho et al. (2018) emphasize the significance of strategic planning in the execution of sustainability initiatives in institutions of higher education. Moreover, Jusuf et al. (2020) posit that the integration of sustainability principles into diverse spheres, including operations, community service, education, and research, is what enables institutions of higher education to attain sustainability. The comprehensive incorporation of sustainability principles across various facets of the organization is imperative in cultivating a climate that prioritizes environmental stewardship and sustainability.

Ezugwu and Ologun (2017) define a Markov chain as a probabilistic or stochastic model in which the likelihood of each state occurring is solely determined by the state immediately preceding it. Markov chain applications include (i) forecasting future labour needs, including recruitment, promotion, and attrition; (ii) managing inventory and congestion issues; and (iii) facilitating the production of products and services. Vijaya and Jaikar (2019) stipulate that for a problem to be modelled as a Markov process, there must be a finite number of states that are mutually and collectively exclusive, with the probability of transitioning depending on the current state.

According to Bulla and Scott (1994), the workforce within an organization consists of manpower, which is tasked with the production of products and services. Furthermore, in their 2016 article, Vaughter et al. examine the governance frameworks that are essential for fostering sustainability in institutions of higher education. They emphasize the significance of contributing to the institutionalization of sustainability practices and devising and implementing policies that support sustainability objectives. The establishment of governance structures that are effective is crucial in promoting sustainability initiatives and guaranteeing their enduring prosperity. The oversight and control of academic personnel are critical for maintaining and improving the standard of instruction and investigation in institutions of higher learning. Efficient management practices are crucial for enabling institutions to accomplish their educational objectives, cultivate an atmosphere that encourages research and innovation, and advance academic excellence. Manpower planning entails the evaluation of present and prospective labour needs with the intention of devising strategies to guarantee the presence of a sufficient workforce and maximize their effectiveness, as stated by Ogumeyo and Okogun (2023). Sethare (2007) asserts that human beings are vital, capricious, and uncertain elements within any business organization. They exhibit volatility and unpredictability by virtue of the fact that their employment and termination are contingent upon the state of affairs. Personnel might also be compelled to leave their positions at times due to untimely demise, poor health, or more lucrative employment opportunities elsewhere.

Active participation of academic personnel is imperative in order to attain sustainability objectives. Staff engagement is emphasized in Ceulemans et al.'s (2015) examination of the relationship between sustainability reporting and organizational change management in higher education. Furthermore, Amaral et al. (2015) emphasize the criticality of universities engaging in sustainability initiatives, resource management, environmental stewardship, and social accountability. Furthermore, Park (2024) emphasizes the significance of higher education establishments in advancing sustainable development by cultivating an atmosphere that values ethical judgement and environmental stewardship. Academic institutions, being centres of knowledge and innovation, are in a unique position to promote sustainability initiatives and inculcate in faculty and students a sense of environmental stewardship.

Consequently, it is occasionally necessary to establish strategies for staff availability, retention, and utilization through the application of forecasting models like Markov Chain. An illustration of such models can be found in the literature, where Rachid and Mohamed (2013) propose a Markov chain model that forecasts the movement of personnel across various grade levels due to recruitment, promotion, demotion, or attrition. In contrast to the manpower planning model devised by Touama (2015), which utilized a Markov transition probability matrix to illustrate the movement of personnel between grades within a business organization, Pharm et al. (2013) developed a Markov model to assess the transition probability of personnel recruitment and promotion. The model was implemented within a private organization engaged in the manufacturing of products.

The accurate allocation of personnel to various tasks in a timely manner, suitable positions, and adequate quantities necessitates the utilization of accurate data during the planning phase. Sadly, this does not appear to be the case in the majority of our educational institutions. The involvement of academic personnel in promoting campus sustainability is crucial owing to their expertise and established networks within academic institutions (Juhari & Yusoff, 2022). Hence, it is critical to incorporate sustainability competencies into the curriculum of mathematics education teachers (Moreno-Pino et al., 2021).

Education for sustainability and reflective learning has the potential to augment the professional competence of educators (Alsina & Mulà, 2019).

By involving academic personnel in sustainability initiatives, the impact on students and the wider community can be exponential. The influence of staff members' adoption of environmentally responsible behaviour on students' attitudes towards sustainability is a topic of discussion in Juhari and Yusoff (2022). By integrating sustainability principles into the process of planning academic staff, institutions can foster a campus-wide promotion of sustainable practices and cultivate a sense of environmental accountability.

While certain scholars have attempted to model manpower planning using data relevant to higher education, there is still a dearth of information regarding the academic staff-flow in colleges of education. As an illustration, Rahela (2015) constructed a Markov chain model for personnel planning that predicts the staff recruitment process within a university system using data. A Markov model that forecasts staff recruitment in order to guarantee productivity and assure the availability of human resources is also described in the study by Wan-yin and Shou (2015). Ekhosuehi (2013) presents a Markov model that examines the attrition of personnel in a university system's faculty through means such as retirement, deadlock, and staff retrenchment. Several models in the literature have addressed the flow of manpower in university systems, with the exception of colleges of education systems. Therefore, it is necessary to design a model for manpower planning that accounts for the flux of personnel in the higher education system.

In an organization, staff movement, also referred to as manpower flow, can be categorized Academic staffs are employees saddled with the responsibility of teaching, research and community development in an academic institution. Ekhosuehi (2016) and Ezegwu and Ologun (2017) define academic staff as the human factor which consists of intelligence, skills and expertise that gives an academic institution its distinctive features and market worth. Manpower planning in an academic institution involves assessing future manpower needs in terms of number of academic and non-academic staffs including the types of skills and competence they possessed in order to formulate plans and meet those requirements. Setlhare (2007) stated the two major questions usually faced by human resource personnel in manpower planning as follows: (i) How many staffs are required? and (ii) what are their qualifications? As reported in Ogumeyo and Okogun (2023), the main objective of manpower planning is to take inventory of staff movement from one grade to another in terms of recruitment, promotion or retirement in discrete time.

Recruitment is the intake of employees into the workforce of an organization. There are two sources of manpower recruitment namely; external and internal recruitment. External recruitment occurs when employees are recruited from outside the organization while internal recruitment involves transfer and redeployment of staffs within the organization. Promotion is the movement of staffs from lower ranks to higher ranks, Ekhosuehi (2016). Wastage refers to exit of staffs from an organization as a result resignation, retrenchment, dismissal, retirement, death etc.

Academic staff-flow in an institution of higher learning having various ranks of staff can be categorized into the recruitment flow, promotion between ranks and the wastage-flow from the institution. According to Raghavendra (1991), manpower flow from one rank to another occurs according to a discrete time Markov chain. This involves the use of a transition matrix of stationary probabilities $q_{ij}(t)$ for a person in grade i to move to grade j $(i, j = 1, 2, \cdots, k)$ in period t.

Hall (2009), stated that Markov models can make use of the expected number of exit staff (wastage) annually including the cohort sizes to select optimal policies of all the decision variables at the same time. By using estimated number of exit staff (wastage) in the near term enable human resource personnel to have insightful information on retirements or resignations over a planning horizon, Hall (2009).

Hall (2009) argued that at a steady state, the number of exit staff (wastage) must be equal to the number of recruited, but the challenge is how to locate where the wastage should take place. Ogumeyo and Okogun (2023) remarked that the optimal solution of the manpower planning problem can be obtained by allowing the manpower model to allocate the exit of staff (wastage) above the first two periods of the model. The decision to allow a model to determine the exit of staff, facilitate the attainment of a steady-state solution in the course of looking for an optimal solution. staff (wastage) above the first two periods of the model. The decision to allow a model to determine the exit of staff, facilitate the attainment of a steady-state solution in the course of looking for an optimal solution.

In his study, Touama (2015) constructed a Markovian model that incorporated a transition probabilities matrix in order to examine the staff mobility within a corporate entity. In contrast, Rachid and Mohamed (2013) present a Markovian model for predicting the supply of labour. Hamed et al. (2013) also examine a Markovian model that utilizes Markov Chain to predict demand in the trading industry. In their 1991 paper, Uche and Ezepue presented a Markovian model that was utilized to examine the movement of academic staff in tertiary institutions. Verbeken and Guerry (2021) posit that Markov models operate under the assumption that the duration of time spent in state i prior to transitioning to state j is solely determined by state i, and that the waiting time distribution demonstrates the property of memory-less.

Markov personnel flow models have been the subject of investigation and implementation by numerous researchers across various domains of human resource management in both public and private organisations. The literature has not addressed the topic of manpower migration in our higher education institutions, particularly the polytechnics and colleges of education that train the middle manpower cadre employed in our industries and educational establishments.

The purpose of this study is to build upon the research conducted by Ezugwu and Ologun (2017) as well as Vijaya and Jaikar (2019), which focused on the migration of personnel within a university system. As a result, we implement the Markov model utilized in their models to analyze the recruitment, promotion, and attrition movement of academic staff in colleges of education that have a graded personnel structure. In this study, we develop a Markov model with a probabilities' matrix for the length-of-service-dependent movement of academic staff from a lower grade to a higher one. The procedure entails manipulating the probabilities of promotion within the system structure until a specified quantity of personnel is accumulated. As we recollect, the personnel structure of any given organization is hierarchical, and personnel advance or regress from one grade to the next via promotion or demotion. Rather than demotion of personnel, this article centres on staff recruitment (inflow), staff promotion (migration from a lower grade to a higher grade), and staff outflow from the manpower system, also referred to as wastage.

Significance of Research

This study introduces a comprehensive manpower planning framework tailored for Colleges of Education, leveraging a Markov model to analyze academic staff flow. It bridges a critical gap in existing literature by addressing staff recruitment, promotion, and wastage in this underexplored sector of higher education. The integration of sustainability principles in the proposed model aligns institutional growth with environmental stewardship, reflecting the broader goals of sustainable development in academia. By focusing on transient states, the research provides actionable insights for early-stage manpower planning, ensuring effective resource allocation and minimizing disruptions. The model offers practical utility for human resource professionals and policymakers in higher education to forecast and optimize staffing structures while supporting sustainability initiatives.

2.0 Methodology and Materials

Model Description: Description of the Model: The Colleges of Education currently have a total of seven academic faculty vacancies. The senior levels are as follows: lecturer II (L2), lecturer I (L1), lecturer III (L3), assistant lecturer (AL), lecturer (PL), and chief lecturer (CL). The phases of the personnel system in which academic staff members advance from one lower grade to a higher one are represented by these grades. It is a prevalent occurrence that upon the retirement, resignation, retrenchment, or dismissal of academic staff, each grade level recruits or promotes new personnel to occupy the positions vacated by their departures. The term for this phenomenon is "manpower flow." This investigation examines Delta State College of Education, Mosogar as a case study. In order to forecast the institution's future personnel structure, the objective of this study is to ascertain the academic staff members who will be hired, promoted, or let go using the Markov chain method.

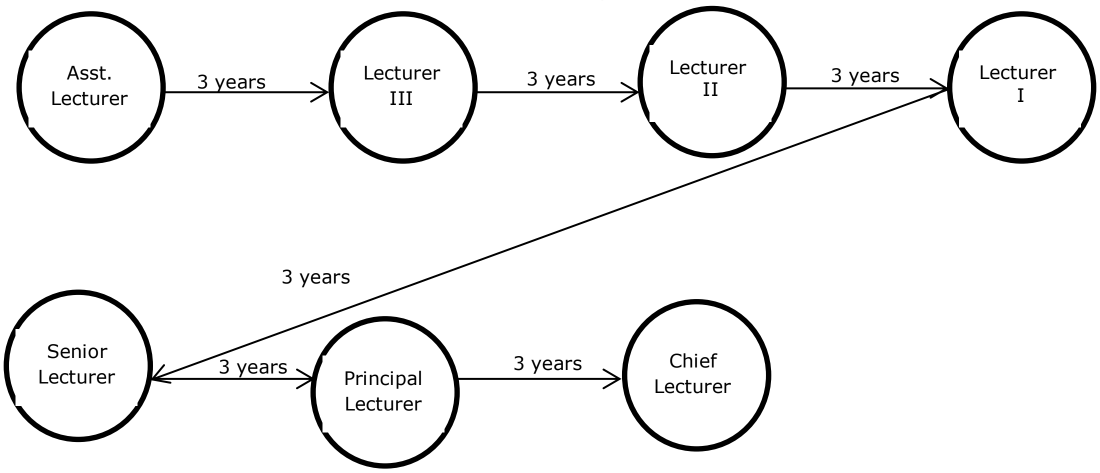

Fig 1: Academic staff flows

The grades or positions that academic personnel in colleges of education can achieve as they advance in their service are illustrated in Figure 1. The seven-tiered structure commences with the Assistant Lecturer level and culminates in the Chief Lecturer rank. The direction of the flow is denoted by the arrows. The three-year interval between ranks signifies that promotion exercises are conducted every three years for personnel who continue to fulfill the necessary criteria. It is postulated that the movement of personnel transpires in accordance with a discrete time Markov chain, with transition matrix probabilities being utilized.

2.0 METHODOLOGY AND MATERIAL

Model Assumptions

(a) There are k ranks arranged in ascending order.

(b) Every staff has an equal opportunity off being promoted from grade i to grade j provided the criteria for promotion are satisfied.

(c) Promotion takes place at the end of every three years.

(d) Recruitment and wastage can occur at any grade.

(e) Part-time staff or demotion is not considered.

Mathematical Notations

i = Various grades of academic staff of the college where $i = 1, 2, \dots k$
t = Time horizon being considered for planning where $t = 1, 2 \dots .T$
h_{ij} = number of staff who migrate from grade i to grade j.
$h_i(t)$ = number of staff in grade i at time t.
$s_j(t)$ = number of staff recruited into grade j at time t.
$v_i(t)$ = number of staff on wastage at grade i in time t.
$q_{ij}(t)$ =Probability of a recruit moving from grade i to grade j at time t.

3.0 MODEL FORMULATION

The total number of staff in the manpower system at any given time t is:

$$h_j(t) = \sum h_j\,(t-1)q_{ij}(t) + s_j(t),\ where\ t \geq 1 \quad (1)$$

Equation (1) states that the number of staff in the system at any period is sum total of staff from the previous periods multiplied by their various probabilities at each grade plus the number of recruited staff in period j. While the number of wastage staff in grade i at time $\mathrm{t}-1$ is given in equation (2).

$$\mathrm{v_{ij}(t) = 1 - \sum q_{ij}\,(t)} \quad (2)$$

If the initial number of staff $h_j(t)$ is known, then the number of staff to be recruited or promoted can be determined at time t from the number of staff in the previous period, $\mathrm{t}-1$. This makes the model a Markov chain. The model in this study is derived by making use of the concept of embedded discrete time Markov chain where any future state of the process depends only on the current state and is independent of the past history of the process.

Equation (2) can be rewritten as:

$$h(t) = h(t-1)q + s,\ \ t \geq 1 \quad (3)$$

The s and q are row vectors and they are independent of time. That is the number of staff recruited and their various probabilities are independent of time. The q is a matrix whose elements are q_{ij}.

The solution of equation (3) can be determined by rearranging it as:

$$h(t) = h(0)q^t + s\sum_{k=0}^{t-1} q^k \quad (4)$$

For the row sums, $q < 1$. Hence, the solution to equation (4) tends to a steady-state as $t \to \infty$. That is:

$$\lim_{t\to\infty} h_j(t) = s(1-q)^{-1} \quad (5)$$

We define:

$$q_{ij}{}^{(n-m)} = q\left\{x^{(n)} = \frac{j}{x^{(m)}} = i\right\} \quad (6)$$

as time-homogeneous transition probability where $\mathrm{q_{ij}{}^{(n-m)} = q_{ij}\,(m,n)}$ and that

$x^{(m)} = i$ describes the state of the manpower system that the value of the random variable can take at each time t. Thus, our proposed model is a one-step transition probability which could be defined as:

$$q_{ij} = q_{ij}(n, n+1) = q\left\{x^{(n+1)} = \frac{j}{x^{(n)}} = i\right\} \quad (7)$$

Equation (7) could be more conveniently arranged in a matrix form as follows:

$$Q = \begin{bmatrix} q_{00} & q_{01} & q_{02} & q_{03} \cdots \\ q_{10} & q_{11} & q_{12} & q_{13} \dots \\ q_{20} & q_{21} & q_{22} & q_{23} \cdots \\ q_{30} & q_{31} & q_{32} & q_{33} \cdots \\ \cdots & \cdots & \cdots & \cdots \end{bmatrix} \quad (8)$$

Equation (8) is the transition matrix where probability P_{ij} must satisfy the conditions:

$$\textstyle\sum_j q_{ij} = 1, \quad \forall\, i \quad (9)$$

Equation (9) implies that the sum of the matrix probabilities must be equal to 1 while each probability element must be greater than or equal to zero as stated in Equation (10).

$$q_{ij} \geq 0 \quad \forall\, i \text{ and } j \quad (10)$$

3.0 NUMERICAL ILLUSTRATION

Let q_{ij} be the proportion of staff at grade i at time $t-1$ to bepromoted to grade j at time t. The transition matrix in Table 2 is formulated from equation (8) for numerical illustration.

Table 1: Transition Matrix

$Q =$	AL	$L3$	$L2$	$L1$	SL	PL	CL	$Wastage$
AL	0.55	0.30	0	0	0	0	0	0.15
$L3$	0	0.65	0.25	0	0	0	0	0.10
$L2$	0	0	0.7	0.15	0	0	0	0.15
$L1$	0	0	0	0.75	0.10	0	0	0.15
SL	0	0	0	0	0.80	0.15	0	0.05
PL	0	0	0	0	0	0.85	0.5	0.10
CL	0	0	0	0	0	0	0.90	0.10

The symbols in Table 1 are used as follows:

AL = Assistant

Lecturer, L3 = Lecturer III, L2 =Lecturer II, L1 =Lecturer I, SL =Senior Lecturer, PL=Principal Lecturer and CL =Chief Lecturer. Given that the constant recruitment policy requires 10 Assistant Lecturers and 5 Lecturer III to be recruited each year, use Markov model to determine the number of academic staff at each grade in the next three years.

Table 1, row 2 implies that, each year 70% of academic staff will remain in the rank of Lecturer 2, 15% of the lecturers will be promoted to Lecturer 1. The remaining 15% will be on wastage which could be in form of resignation, retirement or death. In row 3, 75% of the lecturers remain in the rank of Lecturer 1, 10% of the lecturers will be promoted to the rank of Senior Lecturer, while 15% of the lecturers will be on wastage. Similar procedure is used for obtaining the entries of the other rows.

Markov Model Promulgated for College of Education Academic Staff

Let *t* be discrete variable time in years. Then the manpower flow model of academic staff of a College of Education can be tabulated as follows: (Where
January first is assumed to be recruitment time for each year)

Table 2 Yearly Recruitment of Academic Staff

Date	01/01/2020	01/01/2021	01/01/2022	01/01/2023	
Year (t)	0	1	2	3	…..

By selecting a fixed recruitment policy of nine (9) Graduate Assistant Lecturers and three (3) Assistant Lecturers each year, equation (5) can be used to evaluate the number of staff in ranks in each year if any initial value is given. Examples of such computation is presented in Table 3 for a specified number of initial staff donated by *h(o)*.

Table 3: Markov Model of Academic Staff

	L2	L1	SL	PL	CL	TOTAL
R	9	3	0	0	0	12
h(0)	46	34	17	11	5	113
h(1)	39	36	17	12	6	110
h(2)	34	36	18	13	7	108
h(5)	27	32	20	15	10	104
h(10)	25	29	18	17	15	103
h(k)	25	26	15	15	32	113

5.0 DISCUSSION OF THE RESULTS

Based on the computational outcomes derived from equation (1) and displayed in Table 3, it was determined that the number of personnel hired and the initial staff count in the manpower planning system are equivalent. The final column of Table 3 displays the total number of personnel, which amounts to 113. Additionally, it is noted that the steady-state parameter is inadequate for predicting the transient-state during the initial phase of the manpower planning system. Early on, the total number of personnel will typically decline, as the institution typically approves a limited number of departments. Over time, however, regulatory bodies such as the National University Commission (NUC) and the National Commission for Colleges of Education (NCCE) increasingly accredit numerous departments. As a result, gradual convergence ensues. Therefore, it is more critical to have a sufficient number of academic staff on a transient basis rather than a steady-state basis, which is challenging to achieve (Hall, 2009). An additional phenomenon that is discernible in the probability matrix presented in Table 2 is that p_{ij} is an upper triangular matrix in which the diagonal elements are composed of eigenvalues. The maximum eigenvalue is 0.90, which is nearly equal to 1. The aforementioned factor accounts for the gradual convergence. The lower triangular matrix contains no entries due to the earlier stated model assumption that staff demotion is not permissible.

6.0 CONCLUSION

A Markov model was constructed in this research to depict the movement of academic personnel within the Colleges of Education. The various categories that academic staff members can earn as they advance in their professions are illustrated with the aid of a diagram. Senior Lecturer, Principal Lecturer, Chief Lecturer, Lecturer III, Lecturer II, and Lecturer I, in that order. In an effort to achieve sustainability, the purpose of this research is to expand upon existing manpower-flow models in order to characterize the movement of academic personnel from one grade level to another. In order to ensure productivity and sustainability in business organizations, it was necessary to investigate the gaps in overstaffing, understaffing, promotion, waste, and recruitment using a pertinent model and concrete data, from every angle of view. Human resource professionals could utilize the Markov model introduced in this article to forecast the movement of academic staff in colleges of education in the real world. Additionally, to guarantee that as personnel depart from the organization via retirement, resignation, or demise, promotions or hiring of new personnel occur to fill the resulting vacancies. To prevent unwarranted complexity, we opted to exclude the initial two ranks—Assistant Lecturer and Lecturer 111—from the calculation outlined in section 4.0 of the numerical illustration. This research developed a Markov model to simulate academic staff flow in Colleges of Education, providing insights into recruitment, promotion, and attrition. Unlike steady-state approaches, the focus on transient-state dynamics offers a more realistic framework for early manpower planning. Results highlight the importance of aligning staffing decisions with evolving institutional needs and sustainability goals. By addressing issues such as understaffing and overstaffing, the model enhances operational efficiency and supports the integration of environmental management practices into institutional planning. The proposed methodology serves as a robust tool for decision-makers to ensure balanced staff flow, enabling institutions to maintain academic excellence and promote sustainable development.

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