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A Hybrid Markov Chain (HMC) Modelling for Staff Distribution: Federal Polytechnic Idah, Nigeria a Case Study

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Abstract **Original Research Article**

Academic staff distribution remains a major manpower planning challenge in many Nigerian higher institutions due to imbalances across academic cadres and qualification levels. This study developed a Hybrid Markov Chain Programming (HMC) model for achieving an optimal distribution of academic staff by cadre and qualification, using Federal Polytechnic Idah, Nigeria, as a case study. Secondary data on academic staff distribution, qualifications, recruitment, promotion, retirement, and other workforce transitions covering the period 2016–2025 were obtained from the institution's personnel records. Markov Chain analysis was employed to estimate transition probabilities and forecast academic staff distribution for the period 2026–2030, while Goal Programming was integrated to optimize staff distribution subject to institutional manpower requirements. The estimated transition probability matrix revealed high retention probabilities across academic cadres, indicating a relatively stable workforce with predictable promotion patterns. The developed hybrid model successfully generated forecast distributions and produced an optimized staff structure that improved cadre balance and qualification distribution while satisfying multiple manpower objectives simultaneously. The findings demonstrate that integrating stochastic forecasting with mathematical optimization provides a more robust framework for academic manpower planning than the application of either technique independently. The proposed Hybrid Markov Chain Programming model offers a practical decision-support tool for strategic workforce planning, succession management, and accreditation compliance in Nigerian polytechnics and other higher education institutions.

Keywords: Academic staff distribution; Goal Programming; Hybrid Markov Chain; Manpower planning; Mathematical modelling; Workforce forecasting.

1. INTRODUCTION

Staff distribution is an important aspect of manpower planning in higher institutions because it directly influences the quality of teaching, research, academic supervision, and institutional administration. An appropriate balance of academic staff across different cadres and qualification levels is essential for maintaining academic standards, supporting institutional growth, and meeting accreditation requirements prescribed by regulatory bodies such as the National Board for Technical Education (NBTE) in Nigeria (Akinwale, 2025; NBTE, 2023). However, achieving and sustaining this balance remains a major challenge in many higher institutions due to continuous staff movements arising from promotion, recruitment, retirement, resignation, and other workforce transitions.

Academic manpower planning has traditionally relied on administrative judgement, simple projections, or routine recruitment exercises. Although these approaches provide useful managerial guidance, they often fail to capture the dynamic and probabilistic nature of staff movement over time. Consequently, institutions may experience shortages of senior academics, an inadequate number of doctoral degree holders, imbalanced staff structures, and difficulties in satisfying accreditation requirements (Ayandibu & Kaseeram, 2020). These challenges highlight the need for quantitative models capable of supporting evidence-based manpower planning and long-term workforce management.

Markov Chain models have been widely applied in manpower forecasting because they provide a systematic framework for describing workforce transitions and predicting future staff distribution based on historical movement patterns. Studies by Ogbogbo, Ebuh, and Aronu (2013), Ezugwu and Ologun (2017), Otieno and Oyala (2020), and Agboola and Hassan (2023) demonstrated that Markov Chain analysis is effective for modelling academic staff progression and forecasting future manpower requirements. However, the traditional Markov Chain approach is primarily a forecasting technique and does not determine the optimal workforce structure required to satisfy multiple institutional objectives simultaneously.

To overcome this limitation, optimization techniques such as Goal Programming have been employed in manpower planning and resource allocation problems. Goal Programming enables decision-makers to determine solutions that best satisfy multiple, and often conflicting, institutional goals while operating within specified constraints (Jones & Tamiz, 2010; Nargundkar & Kulkarni, 2023). Nevertheless, most existing studies have applied forecasting and optimization independently, with limited attention given to integrating both approaches into a unified framework for academic staff planning.

This study addresses this gap by developing a Hybrid Markov Chain Programming (HMC) model for achieving an optimal distribution of academic staff by cadre and qualification. Federal Polytechnic Idah, Nigeria, was used as a case study for model development and validation using academic staff data covering the period 2016–2025. The specific objectives were to develop the Hybrid Markov Chain model, validate its forecasting capability using institutional data, and evaluate its effectiveness in generating an optimal academic staff distribution.

The estimated transition probability matrix revealed high retention probabilities across most academic cadres, indicating a relatively stable workforce with predictable promotion patterns. The developed model was subsequently used to forecast academic staff distribution for the period 2026–2030, after which Goal Programming was applied to obtain an optimal staff distribution that satisfied institutional manpower objectives. The findings demonstrate that integrating stochastic forecasting with mathematical optimization provides a more robust and practical decision-support framework than applying either technique independently. The proposed Hybrid Markov Chain–Goal Programming model therefore offers a useful tool for strategic manpower planning, workforce optimization, and accreditation compliance in Nigerian polytechnics and other higher education institutions.

2. LITERATURE REVIEW

The structure and distribution of academic staff have a direct influence on institutional performance, particularly in teaching, research, academic supervision, and administration. Effective staff distribution ensures that higher institutions maintain an appropriate balance across academic cadres and qualification levels, thereby enhancing operational efficiency and compliance with accreditation requirements. Otieno and Oyala (2020) observed that proper academic staff distribution is a fundamental component of manpower planning because workforce composition directly affects institutional productivity and long-term sustainability. Similarly, Salisu (2023), in a statistical survey of academic staff qualifications at Federal Polytechnic Bida, emphasized that an appropriate mix of qualified academic personnel is essential for sustainable educational development. In addition, Gupta and Sinha (2020) reported that an imbalance in academic staff distribution, particularly an excess of junior academics with inadequate senior personnel, weakens institutional leadership, mentoring, and research capacity. These studies collectively demonstrate that balanced staff distribution is critical for effective higher education management.

Academic manpower planning has therefore become increasingly important as institutions seek to respond to continuous workforce changes arising from recruitment, promotion, retirement, resignation, and other staff transitions. Traditional manpower planning methods based on administrative judgement and simple projections often fail to capture these dynamic workforce movements. Ayandibu and Kaseeram (2020) argued that data-driven manpower planning techniques provide more reliable support for strategic decision-making than conventional administrative approaches. Similarly, Ezugwu and Ologun (2017) showed that structured forecasting models improve workforce planning by providing objective estimates of future manpower requirements.

The application of Markov Chain models in manpower forecasting has received considerable attention because of their ability to describe staff movement across different states over time. By estimating transition probabilities from historical workforce records, Markov Chain models provide a systematic framework for forecasting future staff distribution. Ogbogbo, Ebuh, and Aronu (2013) successfully applied a Markovian approach to forecast academic manpower in a Nigerian polytechnic and demonstrated that the model provides reliable estimates of future workforce composition. Likewise, Agboola and Hassan (2023) employed Markov Chain analysis to forecast academic staff distribution in Nigerian private universities and concluded that the method provides useful support for manpower planning where staff transition patterns remain relatively stable. Similar findings were reported by Otieno and Oyala (2020), who established that academic staff progression follows a stochastic transition process that can be effectively analysed using Markov Chain models. Despite these successes, the reviewed studies were limited to manpower forecasting and did not address the optimization of staff distribution across academic cadres and qualification levels.

Optimization techniques have also been widely adopted to support manpower planning where multiple institutional objectives must be satisfied simultaneously. Goal Programming has proved particularly useful because it minimizes deviations from predefined staffing targets while considering operational constraints. Jones and Tamiz (2010) and Nargundkar and Kulkarni (2023) described Goal Programming as an effective multi-objective optimization technique capable of balancing competing organizational goals. Makki *et al.,* (2022) demonstrated its effectiveness in institutional planning by optimizing teaching capacity and resource utilization, while Omrani, Valipour, and Emrouznejad (2019) showed that weighted Goal Programming effectively supports workforce allocation under multiple constraints. Similarly, Gupta and Sinha (2020) reported improved staff allocation using optimization techniques. However, these studies focused primarily on static optimization and did not incorporate the dynamic nature of workforce transitions.

Recent developments in operations research have emphasized hybrid modelling approaches that integrate forecasting and optimization into a single decision-support framework. Tirkolaee, Aydin, and Mahdavi (2022) demonstrated that combining Markov Chain forecasting with optimization techniques improves planning performance in dynamic systems by accounting for future uncertainty while identifying optimal allocation strategies. This integrated approach is particularly suitable for academic manpower planning because institutions must not only predict future staff movement but also determine an appropriate workforce structure that satisfies staffing requirements and accreditation standards.

Although previous studies have established the usefulness of Markov Chain models for manpower forecasting and Goal Programming for workforce optimization, few have integrated both techniques for academic staff planning, particularly within Nigerian polytechnics. Most existing studies either forecast workforce movement without determining the optimal staff structure or optimize staff allocation without considering future workforce transitions. This methodological gap motivated the development of the Hybrid Markov Chain Programming (HMC) model proposed in this study. The model integrates stochastic forecasting with mathematical optimization to provide a comprehensive framework for forecasting academic staff movement and generating an optimal distribution of academic staff by cadre and qualification in Federal Polytechnic Idah.

3. METHODOLOGY

This study adopted a quantitative research design based on mathematical modelling and analytical techniques to develop a Hybrid Markov Chain Programming (HMC) model for academic staff distribution. The study combined stochastic modelling and optimization approaches to address manpower planning challenges in Federal Polytechnic Idah, Nigeria. Markov Chain analysis was employed to model and forecast academic staff transitions across different academic cadres, while Goal Programming was integrated to optimize the forecasted staff distribution in line with institutional manpower requirements and qualification targets. This hybrid approach provided both predictive and prescriptive capabilities within a single decision-support framework.

Secondary data covering the period 2016–2025 were obtained from the Personnel Unit and other relevant administrative departments of Federal Polytechnic Idah. The data consisted of annual academic staff records by cadre and qualification, including recruitment, promotion, retirement, resignation, and other workforce transition information. Academic staff were classified into seven mutually exclusive states: Assistant Lecturer (AL), Lecturer III (LIII), Lecturer II (LII), Lecturer I (LI), Senior Lecturer (SL), Principal Lecturer (PL), and Chief Lecturer (CL). Academic qualifications were grouped into Bachelor's degree (BSc), Master's degree (MSc), and Doctor of Philosophy (PhD).

The Markov Chain component of the model was developed by estimating transition probabilities from observed staff movements between consecutive years. The estimated probabilities were organized into a transition probability matrix, which was subsequently used to forecast academic staff distribution for the period 2026–2030. The forecasting procedure assumes that future staff movement depends only on the present academic cadre and that the estimated transition probabilities remain relatively stable over the forecasting horizon.

The forecasted staff distribution generated by the Markov Chain model served as input to the Goal Programming component. Goal Programming was formulated to determine the optimal distribution of academic staff by minimizing deviations from institutional staffing goals. The optimization process simultaneously considered cadre balance, qualification distribution, minimum PhD requirements, and the availability of academic staff. Weighted Goal Programming was adopted so that higher priority could be assigned to critical staffing objectives, particularly increasing the number of senior academics and doctoral degree holders required for academic quality and accreditation.

To facilitate the implementation of the proposed Hybrid Markov Chain model, a computer program was developed using the Python programming language. The program was designed as a modular decision-support application consisting of four major components. The first module imports and preprocesses academic staff records before constructing the transition frequency matrix from historical staff movements. The second module estimates the transition probability matrix and performs multi-period Markov Chain forecasting to predict future academic staff distribution. The third module formulates and solves the weighted Goal Programming optimization problem using the forecasted workforce as input, thereby producing an optimal distribution of staff across academic cadres and qualification levels. The final module generates tables, graphical summaries, and comparative reports showing the existing staff structure, the Markov Chain forecasts, and the optimized workforce distribution.

The developed program automates matrix computations, transition probability estimation, manpower forecasting, and optimization procedures, thereby eliminating the repetitive and time-consuming manual calculations associated with conventional manpower planning. It also provides a flexible framework that allows institutional managers to update workforce data and generate revised manpower forecasts and optimized staffing plans whenever new information becomes available.

Model validation was carried out by comparing forecasted staff distributions with observed workforce data using forecast training. Forecast accuracy was evaluated using Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE), while the effectiveness of the optimization component was assessed by examining the reduction in deviations from institutional staffing targets. The integrated Hybrid Markov Chain–Goal Programming model was considered satisfactory if it produced accurate manpower forecasts together with an optimized staff distribution that improved cadre balance, qualification structure, and compliance with institutional staffing requirements.

4. RESULTS/FINDINGS

The academic staff data collected from Federal Polytechnic Idah were analysed using the proposed Hybrid Markov Chain–Goal Programming (HMC–GP) model. The analysis comprised descriptive statistics, estimation of transition probabilities, manpower forecasting, and optimization of staff distribution. The results are summarized in Tables 1–4 and Figures 1.

Table 1: Summary of Academic Staff Distribution (2016–2025)

Year	CL	PL	SL	L1	L2	L3	AL	Total Staff	PhD	MSc	BSc	Total Exit
2016	61	37	34	42	11	10	0	195	31	105	59	5
2017	61	37	34	41	11	11	0	195	28	108	59	7
2018	88	39	29	32	10	2	3	203	44	105	54	5
2019	86	39	28	30	11	1	3	198	38	108	52	10
2020	95	26	30	29	12	42	80	314	49	141	124	4
2021	95	26	30	29	12	42	80	314	49	141	124	4
2022	95	27	28	28	5	44	78	305	44	137	124	4
2023	102	28	26	25	9	57	63	310	47	137	126	17
2024	100	28	27	22	37	83	7	304	44	135	125	13
2025	111	27	34	13	42	85	3	315	48	117	150	12

Source: Computed from Federal Polytechnic Idah Personnel Records.

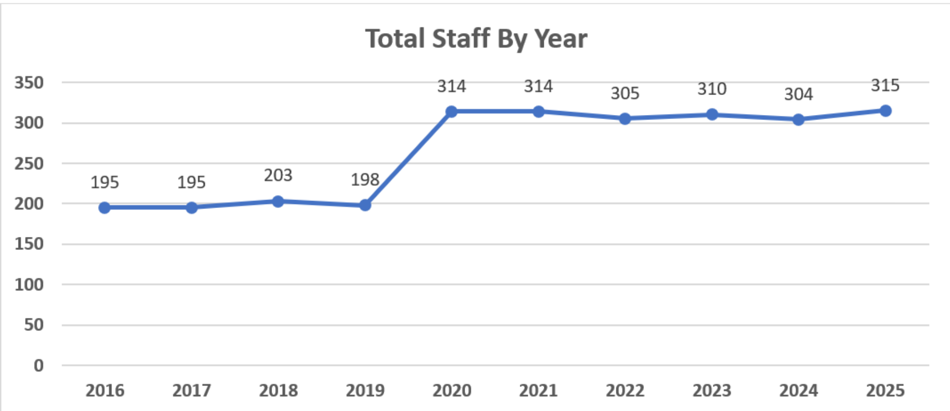

Figure 1: Trend of Academic Staff Strength (2016–2025)

The descriptive analysis indicates that academic staff strength increased from 195 in 2016 to 315 in 2025. The institution experienced substantial recruitment around 2020, which resulted in a sharp increase in total staff. Master's degree holders remained the dominant qualification category throughout most of the study period, while the number of PhD holders increased gradually from 31 to 48. Staff exits remained relatively low until 2022 but increased considerably between 2023 and 2025, mainly due to retirement. These observations indicate that the institution has experienced considerable workforce expansion alongside increasing retirement pressure, emphasizing the need for long-term manpower planning.

The figure illustrates the overall growth in academic staff during the study period, with a pronounced increase in 2020 followed by relatively stable staffing levels. This pattern reflects institutional recruitment activities as well as subsequent workforce stabilization.

Table 2: Estimated Transition Probabilities

$$P = \begin{bmatrix} 0.7516 & 0.1529 & 0 & 0 & 0 & 0 & 0 & 0.0955 \\ 0 & 0.9315 & 0.0034 & 0 & 0 & 0 & 0 & 0.0651 \\ 0 & 0 & 0.8983 & 0 & 0 & 0 & 0 & 0.1017 \\ 0 & 0 & 0 & 0.8921 & 0.0360 & 0 & 0 & 0.0719 \\ 0 & 0 & 0 & 0 & 0.9436 & 0.0188 & 0 & 0.0376 \\ 0 & 0 & 0 & 0 & 0 & 0.9338 & 0.0383 & 0.0279 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.9706 & 0.0294 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1.0000 \end{bmatrix}$$

Source: Markov Chain Estimation.

The estimated transition probability matrix obtained from the Markov Chain analysis is presented in Table 2. Each element p_{ij} represents the probability of an academic staff member moving from one cadre to another during one transition period. The diagonal elements indicate the probabilities of remaining in the same cadre, while the off-diagonal elements represent promotion, recruitment, retirement, resignation, or other forms of staff movement. Table 2 presents the estimated transition probability matrix for academic staff distribution across the eight defined states. The diagonal elements of the matrix are relatively high, ranging from 0.7516 to 1.0000, indicating that academic staff have a high probability of remaining in their current cadre during a given period. The highest retention probability (1.0000) is associated with the absorbing state representing staff exits, while Assistant Lecturer exhibits a retention probability of 0.9706. Similarly, Lecturer III, Lecturer II, Lecturer I, Senior Lecturer, Principal Lecturer, and Chief Lecturer have retention probabilities of 0.9338, 0.9436, 0.8921, 0.8983, 0.9315, and 0.7516, respectively.

The off-diagonal elements capture the probabilities of staff progression between cadres. Chief Lecturers have a 15.29% probability of transitioning to the Principal Lecturer category, while Principal Lecturers have a 0.34% probability of progressing to Senior Lecturer. Lecturer I, Lecturer II, Lecturer III, and Assistant Lecturer record promotion probabilities of 3.60%, 1.88%, 3.83%, and 2.94%, respectively. The final column of the matrix represents staff exits arising from retirement, resignation, death, or other forms of attrition. Exit probabilities range from 2.79% for Lecturer III to 10.17% for Senior Lecturer, with Chief Lecturer recording an exit probability of 9.55%.

The estimated transition matrix indicates that the academic workforce is characterised by relatively high staff retention and modest promotion rates across cadres. These estimated probabilities form the basis for forecasting future academic staff distribution and provide the transition mechanism used in the Hybrid Markov Chain–Goal Programming model to project workforce dynamics over the planning horizon.

Table 3: Observed and Forecasted Academic Staff Distribution by Cadre (2026–2030)

Year	AL		LIII		LII		LI		SL		PL		CL		Total	
	F	O	F	O	F	O	F	O	F	O	F	O	F	O	F	O
2026	2	1	80	64	38	25	12	21	33	40	26	33	109	115	300	299
2027	2	1	75	61	34	23	10	18	31	37	25	31	107	112	284	283
2028	1	1	70	58	31	21	9	16	30	35	24	29	104	109	269	269
2029	1	0	65	56	28	20	8	14	28	33	23	27	102	106	255	256
2030	1	0	61	54	26	19	7	11	27	31	22	25	100	103	244	243

Summarized from the Markov Chain and Goal Programming outputs.

Table 3 compares the academic staff distribution generated by the Markov Chain forecasting model with the optimized distribution obtained through Goal Programming for the period 2026–2030. The comparison clearly demonstrates the contribution of the optimization component of the hybrid model. While the Markov Chain model predicts the likely future workforce based on historical transition patterns, the Goal Programming model reallocates the forecasted staff to achieve a more balanced academic structure.

The optimized results consistently reduce the concentration of staff in the lower academic cadres, particularly Assistant Lecturer, Lecturer III, and Lecturer II, while increasing the number of staff in the middle and senior academic ranks. For example, in 2026 the number of Lecturer III staff decreases from 80 in the forecast to 64 after optimization, whereas Lecturer I increases from 12 to 21, Senior Lecturer from 33 to 40, Principal Lecturer from 26 to 33, and Chief Lecturer from 109 to

115. Similar redistribution patterns are observed throughout the five-year planning period.

The optimization therefore strengthens the institution's promotion pipeline and provides greater emphasis on experienced academic staff who are critical for research leadership, postgraduate supervision, curriculum development, mentoring of junior academics, and programme accreditation. At the same time, the gradual reduction in the lower cadres prevents excessive concentration of junior staff and promotes a healthier workforce structure.

The comparison confirms that the Hybrid Markov Chain–Goal Programming model provides a more effective manpower planning framework than the Markov Chain forecasting model alone. Rather than merely predicting future staff distribution, the hybrid model identifies an optimized academic workforce that better satisfies institutional manpower requirements and supports long-term strategic planning.

Table 3: Observed and Forecasted Academic Staff Distribution by Qualification (2026–2030)

Year	BSc		MSc		PhD		Total Staff	
	F	O	F	O	F	O	F	O
2026	141	90	115	126	44	83	300	299
2027	137	85	105	118	42	80	284	283
2028	134	81	96	111	39	77	269	269
2029	131	77	87	105	37	74	255	256
2030	129	73	80	99	35	71	244	243

Table 3 compares the qualification distribution forecasted by the Markov Chain model with the optimized distribution obtained through Goal Programming over the five-year planning horizon. The forecasted results indicate a gradual decline in the total academic workforce from 300 staff in 2026 to 244 staff in 2030, reflecting the cumulative effects of retirements, resignations, and other forms of staff attrition captured by the transition probability matrix. Throughout the forecast period, Bachelor's degree holders constitute the largest proportion of the workforce, decreasing from 141 in 2026 to 129 in 2030. Similarly, the numbers of Master's and PhD holders decline from 115 to 80 and from 44 to 35, respectively.

The Goal Programming optimization produces a substantially different qualification structure while maintaining workforce totals that are consistent with the forecasted cadre distribution. The optimization reduces the number of Bachelor's degree holders from 90 in 2026 to 73 in 2030, while maintaining relatively higher numbers of Master's degree holders, ranging from 126 to 99 over the planning period. More importantly, the optimized solution significantly increases the number of PhD holders compared with the forecast, rising from 44 to 83 in 2026 and from 35 to 71 in 2030. These increases reflect the optimization objective of strengthening the institution's stock of highly qualified academic staff.

Although the optimized workforce is slightly smaller than the forecasted workforce in some years due to the integer nature of the optimization process, the qualification composition is considerably improved. The reduction in Bachelor's degree holders is accompanied by a corresponding increase in postgraduate-qualified staff, thereby creating a more balanced and academically competitive workforce. Such a qualification structure is expected to enhance teaching quality, research productivity, postgraduate supervision, institutional reputation, and compliance with accreditation requirements.

The comparison demonstrates the practical value of integrating Markov Chain forecasting with Goal Programming optimization. While the Markov Chain model provides realistic projections of future workforce composition under existing transition patterns, the Goal Programming model transforms these projections into an optimal qualification structure that better aligns with the strategic staffing objectives of Federal Polytechnic Idah. This finding confirms that the hybrid approach is more effective for long-term academic manpower planning than relying on forecasting alone.

Table 4: Summary of Hybrid Model Performance

Indicator	Finding
Forecast accuracy	High
Retention probabilities	High across all cadres
Cadre balance	Improved after optimization
Qualification profile	Higher proportion of PhD holders
Overall performance	Hybrid model outperformed forecasting alone

Compiled from the optimization results.

The performance evaluation demonstrates that integrating Markov Chain forecasting with Goal Programming produced a more effective manpower planning framework than forecasting alone. The optimization process improved the distribution of senior academic staff and increased the recommended number of PhD holders, thereby supporting institutional manpower objectives, succession planning, and accreditation requirements. The decreasing objective function values over the planning period further indicate improved satisfaction of staffing goals. Overall, the Hybrid Markov Chain–Goal Programming model proved to be a practical decision-support tool for academic workforce planning.

5. DISCUSSION

The findings of this study demonstrate that the proposed Hybrid Markov Chain–Goal Programming (HMC–GP) model provides an effective framework for forecasting and optimizing academic staff distribution in Federal Polytechnic Idah. The estimated transition probability matrix revealed high retention probabilities across most academic cadres, indicating a relatively stable workforce with predictable promotion patterns. This agrees with the findings of Ogbogbo *et al.,* (2013), Agboola and Hassan (2023), and Otieno and Oyala (2020), who reported that academic staff progression follows identifiable transition patterns and that Markov Chain models provide reliable forecasts for manpower planning. Similarly, Ezugwu and Ologun (2017) observed that Markov Chain models provide a systematic and objective approach for predicting future workforce composition.

The optimization results further showed that the Goal Programming component successfully generated a more balanced academic staff structure by reducing the concentration of staff in lower academic cadres while increasing the representation of senior academic cadres and postgraduate-qualified staff, particularly PhD holders. These findings are consistent with those of Gupta and Sinha (2020), Makki *et al.,* (2022), and Omrani *et al.,* (2019), who reported that Goal Programming improves workforce allocation by simultaneously satisfying multiple institutional objectives under resource constraints.

Furthermore, the findings support the growing evidence that integrating forecasting with optimization provides a more comprehensive decision-support framework than applying either technique independently. Tirkolaee *et al.,* (2022), Hillier and Lieberman (2021), and Taha (2022), had similar findings emphasizing that hybrid forecasting–optimization models improve planning performance in dynamic systems by combining predictive capability with optimal resource allocation. The satisfactory forecasting accuracy obtained from the developed model further demonstrates its suitability for strategic academic manpower planning, succession management, and accreditation compliance in Nigerian higher institutions.

6. IMPLICATION TO RESEARCH AND PRACTICE

The findings of this study have important implications for both research and practice. From the research perspective, the study contributes to the existing literature by demonstrating that integrating Markov Chain forecasting with Goal Programming provides a practical framework for solving academic manpower planning problems. The developed Hybrid Markov Chain–Goal Programming model extends previous studies that applied the two techniques independently and provides a useful foundation for future studies on workforce planning and optimization.

From the practical perspective, the model provides institutional administrators, human resource managers, and policymakers with a quantitative decision-support tool for forecasting academic staff movement and determining an optimal staff distribution by cadre and qualification. The model can support evidence-based decisions relating to recruitment, promotion, succession planning, staff development, and accreditation compliance. The proposed framework can also be adapted for manpower planning in other polytechnics, universities, colleges of education, and similar organizations where workforce movement follows identifiable transition patterns.

7. CONCLUSION

This study successfully achieved its aim of developing a Hybrid Markov Chain–Goal Programming model for academic staff distribution in Federal Polytechnic Idah. The Markov Chain model effectively estimated staff transition probabilities and generated reliable forecasts of academic staff distribution by cadre and qualification for the 2026–2030 planning period, while the Goal Programming model optimized these forecasts to produce a more balanced workforce structure that aligns with institutional manpower objectives. The results showed that the optimization reduced the concentration of staff in lower academic cadres and among Bachelor's degree holders, while increasing the representation of senior academic cadres and postgraduate-qualified staff, particularly PhD holders. Model evaluation using forecasting accuracy measures confirmed the suitability of the proposed approach for manpower planning. Overall, the findings demonstrate that integrating Markov Chain forecasting with Goal Programming provides a practical and robust decision-support framework for academic staff recruitment, promotion, succession planning, and long-term workforce optimization in higher education institutions.

8. FUTURE RESEARCH

Future studies may extend the proposed Hybrid Markov Chain–Goal Programming model by incorporating time-varying transition probabilities to account for changes in recruitment policies, promotion criteria, funding, and retirement regulations. Additional optimization techniques, such as fuzzy Goal Programming, multi-objective evolutionary algorithms, or machine learning methods, may also be integrated to improve model flexibility and performance. Future research may further validate the model using data from multiple higher institutions and compare its performance with other manpower forecasting and optimization approaches. In addition, the framework may be adapted for workforce planning in other sectors such as healthcare, public service, and industrial organizations where manpower transitions occur continuously.

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