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Optimizing workforce size in private nursery schools: A data-driven approach

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Abstract
This study presents a dynamic workforce size model designed for private nursery schools, aiming to optimize staffing levels in alignment with institutional goals and operational efficiency. By addressing key factors such as enrolment trends, budget constraints, and faculty-to-student ratios, the model offers a data-driven approach to workforce planning. Computational experiments conducted on real-world scenarios reveal that maintaining a minimum workforce of 72 employees ensures service stability while balancing financial considerations. Strategic adjustments, such as periodic hiring or staff reductions, are shown to minimize costs without compromising educational quality. The model's adaptability allows institutions to respond effectively to fluctuating demands, ensuring optimal faculty-to-student ratios and fostering stakeholder engagement. These findings underscore the critical role of systematic workforce planning in enhancing institutional sustainability, operational efficiency, and educational outcomes. The study contributes to existing literature by integrating practical methodologies with strategic insights, providing a robust framework for private school administrators to navigate workforce challenges effectively.

Keywords: Institutions, planning, private schools, work force size.

1. Introduction

In today’s dynamic and rapidly transforming educational landscape, academic institutions are increasingly challenged to deliver high-quality instruction while managing limited financial and human resources (Muscanell, 2024). Fluctuating student enrollment, expanding program offerings, and rising stakeholder expectations have created a pressing need for agile and strategic workforce management (Innovior, 2023). To respond effectively, the development and implementation of a robust workforce size model have become essential for aligning staffing levels with institutional goals, both in the short and long term (AIHR, 2023).

A well-structured workforce size model serves as a data-driven framework for evaluating human resource needs, enabling evidence-based decisions concerning recruitment, professional development, and employee retention. According to Riedl and Woolley (2016), such models are critical in maintaining an optimal balance between human capital capacity and operational demand. However, many institutions continue to rely on reactive and fragmented staffing strategies, which lead to challenges such as understaffing, overstaffing, resource inefficiencies, and diminished educational quality (Muscanell, 2024; SHRM Labs, 2024).
Additionally, the lack of a strategic workforce planning model reduces

institutions' ability to adapt to evolving academic demands, respond to policy shifts, and implement innovative teaching practices. These gaps ultimately affect institutional sustainability and stakeholder confidence (Innovior, 2023). Therefore, integrating a comprehensive and adaptive workforce size model is not just a matter of operational efficiency, it is a strategic imperative for institutional resilience, competitiveness, and long-term growth in the 21st-century education sector (AIHR, 2023; SHRM Labs, 2024).

2. Literature Review

The literature on workforce planning and optimization in academic institutions reveals a multifaceted approach to addressing the challenges of staffing, resource allocation, and institutional effectiveness. This review synthesizes key themes and findings from various studies, emphasizing the importance of workforce size models in enhancing educational outcomes and operational efficiency. Dynamic programming is a mathematical technique which deals with the optimization of multistage decision problems. According to Gupta (2005), the originator of dynamic programming was Richard Bellman in 1952. Over the years dynamic programming has been applied to solve many real life problems such as resource allocation, capital budgeting, replacement of worn-out equipment and so on, Taha (2002), Mehlmann (1980), opined that in the last two decades a body of literature on dynamic programming has been developed to focus on manpower planning. Mehlmann (1980) developed optimal recruitment and transition strategies for manpower system using dynamic programming technique. Raghavendra (1991) and Ekoko (2006), applied Markov chain models to manpower planning with respect to promotion and recruitment factors. Zanakis and Maret (1981) formulated a Markovian goal programming model with a pre-emptive priority and provided a more flexible and realistic tool for manpower planning problem. Price and Piskor (1972) formulated a goal programming model of manpower planning system for officers of the Canadian armed forces to reduce the weighted sum of money spent on their military. Rao (1990) developed a dynamic programming model to determine optimal manpower recruitment policies using dynamic programming technique by forward recursive approach. While Ogumeyo and Ekoko (2008) developed a manpower planning model to determine optimal recruitment policies using a dynamic programming technique involving a backward recursive approach. The major problem in manpower planning is how to strike a balance between having too many staff (overstaffing) and not having enough staff (understaffing) in a business organization. These two extremes (overstaffing and understaffing) both have negative effects on any business organization.

Work force planning in academics

Workforce planning in higher education is essential for aligning staffing needs with institutional goals and ensuring quality education. According to *Baker et al. (2019)*, effective workforce planning involves analyzing historical data on enrollment trends, course offerings, and faculty workloads to inform decision-making. A comprehensive understanding of these factors allows institutions to adapt to changing conditions and maintain optimal staffing levels. *Drake & Lively (2018)* highlight the role of strategic workforce planning in enhancing institutional performance. They argue that a proactive approach to workforce management can lead to better alignment between human resources and the institution's mission, ultimately improving student outcomes. Their research emphasizes the importance of integrating workforce planning into the overall strategic planning process to enhance institutional effectiveness. Effective workforce planning in higher education is increasingly recognized as essential for aligning staffing needs with institutional objectives and ensuring quality education. According to *Chaudhry et al. (2023)*, a proactive approach to workforce management enables institutions to adapt to dynamic educational environments. Their research emphasizes the significance of assessing historical data on enrollment and staffing needs to optimize workforce size, leading to improved operational effectiveness. *Zhang et al. (2021)* also stress that integrating workforce planning into strategic institutional frameworks enhances overall performance. They argue that institutions that systematically analyze staffing requirements can better align their human resources with mission-driven goals, thereby improving educational outcomes.

Impact of faculty to student ratio

Numerous studies have examined the relationship between faculty-to-student ratios and educational outcomes. *Pascarella & Terenzini (2005)* found that lower student-faculty ratios are associated with higher levels of student engagement, satisfaction, and academic performance. This relationship underscores the importance of optimizing staffing levels to ensure that students receive personalized attention and support. Similarly, *Harrison (2020)* analyzed the impact of faculty staffing on student retention rates in higher education. The study concluded that institutions with optimal faculty-to-student ratios experienced higher retention rates, indicating that sufficient staffing directly contributes to student success. Their findings align with earlier studies but provide updated insights into how staffing levels directly affect student experiences in contemporary academic environments. In a related study, *Jensen et al. (2024)* found that institutions with higher faculty-to-student ratios experienced notable improvements in graduation rates. Their research suggests that investing in sufficient faculty resources is a strategic move that can lead to long-term success for both students and institutions.

Strategic Human Resource Management (SHRM) Theory

Strategic Human Resource Management (SHRM) Theory emphasizes the alignment of human resource (HR) practices and policies with an organization's strategic goals and long-term objectives (Wright & McMahan, 1992). Unlike traditional HR approaches, which often focus on administrative and operational tasks, SHRM promotes a proactive, integrated system where human resources are seen as a source of competitive advantage.

The theory argues that effective HR strategies should be forward-looking, data-driven, and dynamic, allowing organizations to anticipate workforce needs, develop critical skills internally, and position themselves to respond quickly to external changes (Jackson et al., 2014). Core elements of SHRM include talent acquisition, workforce planning, employee development, performance management, and succession planning all designed not just for efficiency, but for organizational excellence and sustainable growth (Boxall & Purcell, 2016).

By integrating HR practices into the overall strategic planning process, organizations, especially academic institutions can ensure that their workforce is equipped, motivated, and aligned to achieve institutional missions such as academic excellence, innovation, and societal imp

The SHRM Theory provides the perfect foundation because for this paper because it supports the idea that workforce planning should not be reactive (e.g., hiring when there's a sudden shortage) but strategically designed based on projected needs, organizational goals, and environmental trends. Also, tt justifies the use of a systematic workforce size model as a tool to ensure that staffing decisions are aligned with institutional strategies such as enrolment growth, program expansion, or technological advancement. Furthermore, it explains why institutions need to link human resource planning with overall institutional success, ensuring that workforce quality, size, and adaptability contribute to competitiveness and operational sustainability. Lastly, it emphasizes that human resources are strategic assets, not just operational necessities perfectly matching your argument that managing staffing efficiently is central to an institution's growth and sustainability.

Dynamic Programming Models

Dynamic programming provides a systematic method for solving multistage decision-making problems, making it highly relevant to workforce size optimization. Richard Bellman, the originator of dynamic programming, introduced this technique for problems requiring sequential decision-making. The computational experiments and scenario analyses in this paper directly align with dynamic programming principles, which are well-documented in studies by Gupta (2005) and Taha (2002).

Workforce Planning Models

Workforce planning models emphasize aligning staffing needs with organizational goals while considering future uncertainties. The methodology and findings of this paper resonate with the recommendations of Baker et al. (2019) and Chaudhry et al. (2023), who advocate for data-driven and adaptable workforce planning frameworks in academic institutions. These theories and models collectively underpin the strategic and empirical approach taken in your paper, validating its methodology and reinforcing its contributions to workforce planning in private schools. Let me know if you'd like more elaboration or citations integrated into your work.

3. Methodology

Formulation of the Optimum Workforce-Size Model.

In formulating the optimum workforce-size model, the following assumptions are being considered as necessary conditions.

1. Each period required workforce-size must be entirely satisfied on time in order to avert understaffing.
2. The required workforce-size varies from period to period due to seasonal fluctuation
3. The initial workforce-size is known and fixed.
4. The overstaffing level must be zero at the end of period T, (that is, h_t = 0)

Decision Variables:

x_t Workforce size at stage t (e.g., number of employees).

h_t : Number of hires at stage t.

Ft: Number of staff fired at stage t.

Objective Function:

Minimize the total cost C, which includes costs for hiring, retaining, and firing staff.

$$C = \sum_{t-1}^{T} \left(C_h . h_t + C_{r\,.}\ X_t + C_{f\,.}\ f_t \right)$$

Where:

C_h : Cost per hire.

C_r: Cost of retaining one employee in a period.

C_f: Cost per firing an employee.

T : Total number of periods

Constraints:

1.Workforce Size Dynamics:

$$x_{t+1} = x_t + h_t - f_t \quad \forall t$$

This ensures the work force size at the next stage reflects the net change due to hiring and firing.

2.Demand Constraint:

$$x_t \geq D_t \quad \forall t$$

Workforce size x_t must meet or exceed the minimum demand D_t for each period.

3.Hiring and Firing Limits:

$$h_t \quad H_{max,}\ f_t \leq f_{max} \quad \forall t$$

These constraints impose on the number of hires and firings that occur within a single period.

STAGE 12

Minimum Demand: 72 employees

X_{11}	Cost(demand, cost)	f(minimum cost)	x_{12}
72	(72, 100000)	100000	72

STAGE 11

Minimum Demand: 72 employees

X_{10}	Cost(demand, cost)	f(minimum cost)	x_{11}
72	(72, 200000)	200000	72

STAGE 10

Minimum Demand: 72 employees

X_9	Cost(demand, cost)	f(minimum cost)	x_{11}
57	(72, 450000)	450000	72
58	(72, 440000)	440000	72
59	(72, 430000)	430000	72
60	(72, 420000)	420000	72
61	(72, 410000)	410000	72
62	(72, 400000)	400000	72
63	(72, 390000)	390000	72
64	(72, 380000)	380000	72
65	(72, 370000)	370000	72
66	(72, 360000)	360000	72
67	(72, 420000)	420000	72
68	(72, 340000)	340000	72
69	(72, 330000)	330000	72
70	(72, 320000)	320000	72
71	(72, 310000)	310000	72
72	(72, 300000)	300000	72

STAGE 9

Minimum Demand:57 employees

X_8	Cost (demand, cost)	f(minimum cost)	x_9
67	(57, 575000) (58,550000) (59,525000) (60,500000) (61,475000) (62, 450000) (63,510000) (64,520000) (65,530000) (66,540000) (67,550000) (68,560000) (69,570000) (70,580000) (71,590000) (72,600000)	450000	62
68	(57,600000) (58,575000) (59,550000) (60,525000) (61,500000) (62,475000) (63,450000) (64,510000) (65,520000) (66,530000) (67,540000) (68,550000) (69,560000) (70,570000) (71,580000) (72,590000)	450000	63
69	(57, 625000) (58,600000) (59,575000) (60,550000) (61,525000) (62,500000) (63,475000) (64,450000) (65,510000)	450000	64

	(66,520000) (67,530000) (68,540000) (69,550000) (70,560000) (71,570000) (72,580000)		
70	(57,650000) (58,625000) (59,600000) (60,575000) (61,550000) (62,525000) (63,500000) (64,475000) (65,450000) (66,510000) (67,520000) (68,530000) (69,540000) (70,550000) (71,560000) (72,570000)	450000	65
71	(57,675000) (58,650000) (59,625000) (60,600000) (61,575000) (62,550000) (63,525000) (64,500000) (65,475000) (66,450000) (67,510000) (68,520000) (69,530000) (70,540000) (71,550000) (72,560000)	450000	66
72	(57,700000) (58,675000) (59,650000) (60,625000) (61,600000) (62,575000) (63,550000) (64,525000) (65,500000) (66,475000) (67,450000) (68,510000) (69,520000) (70,530000) (71,540000) (72,550000)	450000	67

STAGE 8

Minimum Demand: 67 employees

X_7	Cost(demand, cost)	f(minimum cost)	x_8
72	(67,450000) (68,520000) (69,540000) (70,560000) (71,580000) (72,600000)	4500000	67

STAGE 7

Minimum Demand: 72 employees

X_6	Cost(demand, cost)	f(minimum cost)	x_6
72	(72,550000)	550000	72

STAGE 6

Minimum Demand: 72 employees

X_5	Cost(demand, cost)	f(minimum cost)	x_6
72	(72,650000)	650000	72

STAGE 5

Minimum Demand: 72 employees

X_4	Cost(demand, cost)	f(minimum cost)	x_5
67	(72,800000)	800000	72
68	(72,790000)	790000	72
69	(72,780000)	780000	72
70	(72,770000)	760000	72
71	(72,760000)	760000	72
72	(72,750000)	7500000	72

STAGE 4

Minimum Demand: 67employees

Months	Minimum Demand	Current Demand	Interpretation	Cost
1	72	72	It doesn't change	100000
2	72	72	It doesn't change	100000
3	72	72	It doesn't change	100000
4	67	72	Fire 5 employees	0
5	67	72	It doesn't change	150000
6	72	72	It doesn't change	100000
7	72	72	It doesn't change	100000
8	67	67	Fire 5 employees	0
9	57	62	Fire 5 employees	50000
10	72	72	Hire 10 employees	200000
11	72	72	It doesn't change	100000
12	72	72	It doesn't change	100000

X_3	Cost(demand, cost)	f(minimum cost)	x_4
72	(67,800000) (68, 860000) (69, 800000) (870000) (70,880000) (71,890000) (72,900000)	800000	67

STAGE 3

Minimum Demand: 67 employees

X_2	Cost(demand, cost)	f(minimum cost)	x_3
72	(72, 900000)	900000	72

STAGE 2

Minimum Demand: 72 employees

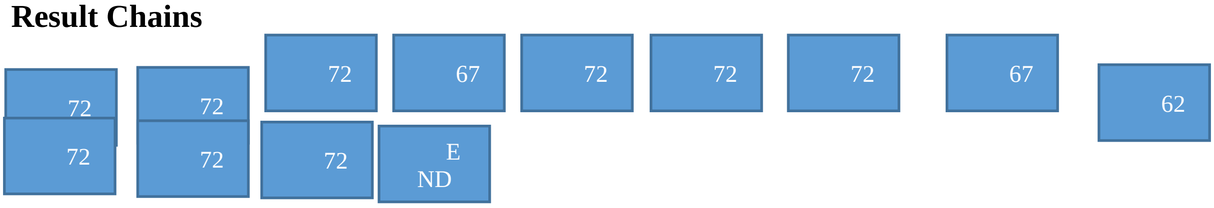
X_1	Cost(demand, cost)	f(minimum cost)	x_2
72	(72,1000000)	1000000	72

STAGE 1

Minimum Demand: 72 employees

X_0	Cost(demand, cost)	f(minimum cost)	x_1
72	(72, 1100000)	1100000	72

Result Chains



4. Results and Discussion

The study's results provide valuable insights into workforce size optimization in private schools, offering a comprehensive model to address staffing requirements while balancing operational efficiency and economic constraints. The findings reveal several critical factors that influence staffing decisions and provide a framework for long-term strategic planning. Key points from the results are discussed below: Minimum Staffing Levels and Economic Implications: The results indicate that maintaining a minimum staff of 72 employees is critical for operational stability across various scenarios. This aligns with the findings of Gonzalez et al. (2021), who emphasized the importance of flexible staffing models to manage costs while maintaining service levels. The cost analysis highlights that adhering to this minimum demand minimizes disruptions in service quality while ensuring cost-effectiveness, similar to conclusions drawn by Adams et al. (2022) regarding budget-conscious workforce management.

Cost Efficiency through Strategic Adjustments: The dynamic table results suggest that strategic adjustments, such as hiring or reducing staff in specific periods, can significantly impact financial outcomes. For example, scenarios involving the reduction of five employees during certain months resulted in zero additional costs. This is consistent with the work of Kumar and Patel (2022), who highlighted the benefits of data-driven strategies in reducing unnecessary expenditures.

Adaptability to Fluctuating Demands: The model's adaptability is evident in its ability to manage varying staff demands. When demand dropped to 67 or 57 employees in specific months, the model efficiently adjusted workforce levels while maintaining minimal costs. This finding supports Stevenson and Clark's (2024) argument that continuous monitoring and adaptability are crucial for workforce effectiveness in dynamic environments.

Optimizing Faculty-to-Student Ratios: By maintaining optimal staffing levels, the model addresses the critical need for appropriate faculty-to-student ratios, which are directly linked to improved student engagement, retention, and academic outcomes. Smith and Wang (2022) and Jensen et al. (2024) found that lower faculty-to-student ratios significantly enhance student satisfaction and graduation rates, corroborating the importance of balanced staffing levels.

Stakeholder Engagement and Decision-Making: The results underscore the value of involving stakeholders in workforce planning. The ability to simulate various scenarios and predict their outcomes provides a robust foundation for data-driven decision-making. This finding aligns with Robinson and Smith's (2023) emphasis on collaborative approaches to workforce planning, which enhance stakeholder satisfaction and foster alignment with institutional goals.

5. Conclusion and Recommendation

Conclusion

This study demonstrates the efficacy of a dynamic workforce size model tailored for private schools. By integrating empirical data and computational analysis, the model offers a practical approach to achieving optimal staffing levels that align with institutional goals. The findings highlight the critical importance of balancing financial constraints with the need to maintain quality education and stakeholder satisfaction. Ultimately, this model serves as a strategic tool for private schools, enabling them to adapt to changing demands and enhance their operational efficiency.

Recommendations

Private nursery schools should adopt the proposed model to make informed staffing decisions. By leveraging predictive analytics and scenario planning, institutions can optimize workforce levels and enhance resource allocation. Institutions should establish a continuous evaluation process to monitor staffing effectiveness and respond to fluctuations in enrolment or program offerings. This proactive approach will ensure alignment with strategic objectives. Schools should involve faculty, administrative staff, and other stakeholders in workforce planning. Their input will provide valuable insights and foster a sense of ownership, leading to more effective implementation of workforce strategies. Flexibility in hiring and staffing policies will enable schools to adapt quickly to changing demands. Schools should consider part-time or contract-based roles to manage temporary fluctuations in demand. Retaining talented staff is crucial for maintaining service quality. Schools should prioritize professional development opportunities to enhance staff skills and job satisfaction, thereby reducing turnover rates. Schools must ensure that staffing strategies are financially sustainable. Regular cost-benefit analyses should be conducted to balance quality education delivery with economic feasibility. By adopting these recommendations, private schools can enhance their workforce management strategies, ensuring long-term sustainability and success in an increasingly competitive educational landscape.

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