Workforce Planning for Cleaning Services Operation using Integer Programming

Workforce Modelling in Service Industry

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***Abstract*—The cleaning services industry in Malaysia faces significant challenges in effectively managing its workforce. Workforce planning, a critical procedure that aligns employee skills with suitable positions at the right time, is becoming increasingly essential across various organizations, including postal delivery and cleaning services. However, the absence of proper workforce planning from management teams has emerged as a primary concern in this sector. This study identifies an opportunity to improve the workforce planning in the cleaning industry by employing an optimization approach that aims to minimize hiring costs. The main objective of this study is to minimize hiring costs in cleaning services operations at a public university in Malaysia. To achieve this, an optimization model based on integer programming was proposed to represent the current situation. Data collection involved interviews and company reports for the purpose of understanding the current conditions comprehensively. Factors influencing hiring costs were meticulously selected, considering the organization's specific situation. Model evaluation was conducted through what-if analysis, which allowed the evaluation of solutions provided by the modified models in three what-if scenarios. The findings indicated that the proposed modified model could assist organizations in improving the workforce planning by optimizing the allocation of resources, reducing hiring costs, and enhancing cleaner performance. This study offers valuable insights for the management of cleaning services, paving the way for more effective and efficient workforce planning practices in the industry.**

Keywords*—Workforce planning; cleaning services industry; optimization approach; integer programming

I. Introduction

In a company or an organization, it is important for the management to plan the workforce. Workforce planning is a procedure that assigns employees with the appropriate skills to suitable positions at the right time [1, 2, 3]. The workforce planning issue is pervasive across various industries, such as services, healthcare, education, military, transportation, and many more. These industries are listed in Table I, with the related studies highlighted by different authors.

Previous studies identified and discussed the issues in workforce planning in different industries. For instance, in the services industry, workforce planning challenges were discussed in study [4], where service technicians from various locations must go to the clients' locations, resulting in escalated costs and inefficiencies. These frequent travels not only imposed financial burdens but also hindered service delivery effectiveness due to time constraints. To address these concerns, the researchers introduced a workforce planning model designed to mitigate travel costs for service technicians, concurrently enhancing the overall efficiency of operations. In fact, other industries, such as healthcare, education, military, and transportation, are facing similar workforce issues. Therefore, as these workforce planning issues impact various industries, it will be beneficial to study further especially related to the service industry, since the nature of service is wide and intangible, which will be complex to measure.

TABLE I. Related Studies on Workforce Planning Issues in Different Industries

Industry	Workforce Planning Issues	Author
Services	Service technicians located at different locations are required to travel along to the customers' locations.	[4]
Healthcare	Traveling issues happened for the medical staff, including transporting the medicines and medical equipment between warehouses and patients.	[5]
	The systemic delay happened in the hospital consultation service.	[6]
	Scheduling nurses on three shifts per day based on various preferences and constraints.	[7], [8]
Education	Allocating academic staff in quest of optimum knowledge transfer.	[9]
Military	To deploy the right employees in the right place at the right time.	[10]
	To meet the demands of the current force structure under conditions of uncertainty in officer retention.	[11]
Transportation	A pilot can be hired as a first officer or a captain, the company need to determine whether how many persons of pilot need to be hired.	[12]

A cleaning services operation is one of the popular services in the service industry. This service is provided by a contractor to an individual's or an organization's place or property. They typically take on these undesirables but necessary duties, as opposed to a person or employee who would be less than happy about the chance to deal with the dust or waste [13, 14, 15]. The cleaning services industry in Malaysia is facing numerous challenges when it comes to effectively managing its workforce. One significant challenge is determining the ideal number of cleaners required to complete cleaning tasks within a specified timeframe. In this case, a specific timeframe refers to the required working time of the cleaners assigned by the organization. The specific timeframe ensures that the cleaners complete their tasks within a designated period, allowing for efficient scheduling and resource allocation. However, this often leads to overstaffing, resulting in increased of hiring costs, or understaffing, which can adversely affect the quality of cleaning services provided. Moreover, the existing workforce’s performance in the cleaning services operation is unsatisfactory, translating into higher costs for the management team, who must hire additional workers to compensate for the inefficiencies [16]. This will finally lead to general issues in the workforce for a cleaning service operation, i.e. the high turnover rate [17]. The management team's absence of proper workforce planning seems to be the primary cause of this issue. As such, there is an opportunity to improve the workforce planning in the cleaning industry by utilizing a systematic approach to minimize hiring costs and maximize cleaners' performance. Consequently, this study was aimed to minimize the hiring cost at a cleaning services operation responsible for taking care of property-related matters and maintenance in a public university in Malaysia. A campus environment that is hygienic, healthy and pleasant plays a crucial role in shaping the learning experience and the academic performance of students [18]. As a big campus, the university requires cleaning services to manage the whole campus environment well. However, it is all aware that the cleaning service at the university can still be improved in order to achieve a satisfyingly clean and comfortable study area.

The paper is structured into distinct sections to address workforce planning challenges within the cleaning services industry comprehensively. The initial segment outlines the industry's issues and the absence of adequate planning, setting the study's goal: minimizing hiring costs within a university's cleaning services operation. Subsequently, various methodologies and influential factors in workforce planning are explored in the Literature Review which is given in Section II. The Research Methodology in Section III details the study's phases, from problem definition to model evaluation. Finally, the Findings in Section IV present the results of evaluating different scenarios and examining their impact on hiring costs and operational efficiency and lastly Section V concludes the paper. Each section contributes to a comprehensive understanding of optimizing workforce planning in cleaning services.

II. Literature Review

Workforce planning involves analyzing current and future workforce needs as a way of ensuring that it has the right people with the right skills in the right place and at the right time. The significance of workforce planning for organizations has been emphasized in numerous studies. Workforce planning is a continuous process that aids organizations in aligning their workforce with their business objectives and priorities [19]. Additionally, it is closely linked to the broader business planning process. There are three categories of the workforce planning methods, judgmental, mathematical, and a combination of the two [20]. Mathematical methods for the workforce planning fall under the realm of operations research. In a review of the current state of the workforce planning, an imbalance in the field was noted [21].

A. *Factors in Workforce Planning*

A range of factors with a significant impact must be considered for workforce planning to be effective. Factors affecting workforce planning, such as skills, demand and time windows, have been identified from previous studies and tabulated in Table II.

TABLE II. Factors Affecting Workforce Planning

Factors	Author
Skill requirements	[4], [6], [10], [12], [22],[23], [24], [25], [26], [27]
Workforce demand	[4], [5], [6], [9], [22], [24]
Time windows	[4], [5], [27], [28]
Cost	[4], [8], [29]
Budget	[5], [27]
Experience / Year of services	[10], [30]
Career advancements	[10], [30]
Geographical location	[25]
Physical resources planning	[9]
Language	[25]
Potential for retraining	[25]
Quantity to produce	[28]
Contract type	[5]
Workforce retention rates	[11]
Preference for the working period	[4]
Maximum tasks assigned to the worker	[4]
Workforce holidays	[12]

The table provides a clear overview of the most commonly cited factors in the workforce planning problem by researchers. The results suggest that a significant number of studies prioritize the “skill requirement” as a primary constraint in the workforce planning, indicating the importance of having a skilled workforce to meet organizational goals. Additionally, workforce demand is a critical factor that organizations must consider in their planning. As the second most commonly cited factor, it highlights the importance of accurately estimating the needs of future workforce. Organizations must ensure they have enough resources to meet the required workload while avoiding under or overstaffing, which can lead to an increase in operational costs.

Moreover, time windows are also crucial in the workforce planning, as they help organizations allocate resources efficiently within a specified timeframe. Organizations must ensure that they have enough staff available during peak periods and that they can accommodate fluctuations in demand. Overall, the information presented in the table emphasizes the importance of considering these constraints in the workforce planning. Organizations must prioritize these factors while establishing their workforce planning strategies to ensure they have the right people with the necessary skills available at the right time to achieve their objectives.

B. *Method for Improving Workforce Planning*

In the research on workforce planning, the authors proposed several innovative methods to address its associated challenges. The authors' work sheds light on the importance of having a robust workforce planning strategy that considers various factors, such as workforce demand forecasting, skill requirements, time windows, etc. The details of these methods are comprehensively discussed and analysed in Table III.

TABLE III. METHOD FOR IMPROVING WORKFORCE PLANNING

Method	Author
Linear programming	[22]
Mixed integer linear programming	[4], [5], [12]
Integer programming	[31]
Goal programming	[9], [11]
Genetic algorithm	[9], [23]
System dynamics	[8], [23]
Discrete-Event Simulation Model	[11]
Stochastic programming	[30]
Robust optimization	[11]

Optimization is often the preferred method for solving the workforce planning issues in cleaning service operations. This is because it can help minimize costs and increase efficiency while ensuring all cleaning tasks are completed on time. An optimization approach is a mathematical method used in a variety of fields to identify the best option from a list of feasible solutions. It involves working through various solutions to maximize or minimize an objective, frequently under certain constraints. These approaches include methods such as linear and nonlinear programming as well as integer programming. Linear programming is a mathematical technique used to optimize complex problems by determining the best solution to a given set of constraints. It is particularly useful in the workforce planning because it can help organizations allocate their resources efficiently to meet the required workload. The research in [22] applied it in the workforce planning and to reduce manufacturing costs at the same time. Mixed-integer linear programming (MILP) is an extension of linear programming that allows for the inclusion of integer variables in addition to continuous variables. It is useful in the workforce planning because it can help organizations allocate their resources optimally while considering additional constraints, such as the availability of part-time workers or the minimum number of shifts an employee need to work. For instance, MILP is employed in addressing the workforce planning problems that involve task duration as a continuous variable in the constraints, as highlighted by [4, 5]. In another study conducted by study [12] demonstrated the effectiveness of MILP in addressing the workforce planning problems that involve pilot holidays as a continuous variable in the constraints. The study showed that MILP was able to produce a highly effective performance in this regard.

Meanwhile, for a complex problem, Genetic Algorithm (GA) can be used to address the workforce planning problems in a dynamic environment where demand, resources and other constraints are continuously changing [9]. It can also be used to optimize multiple objectives simultaneously such as maximizing productivity while minimizing labour costs. In a study by [23], GA seeks the optimal workforce flow between different ranks. However, it is important to note that GA has limitations, where there is a chance that GA will become trapped in local optima, making it difficult to find the overall optimal solution, which is normally addressed as a near-optimal solution.

Other than optimization, Goal Programming is another popular mathematical programming technique that can help organizations optimize their workforce planning strategies by simultaneously considering multiple objectives or goals. According to [9], the study involves constraints like physical resource planning, for instance, library, laboratory, etc., which must be considered simultaneously. Therefore, it is suitable to use goal programming in solving the problem.

In addition, System dynamics (SD) and Discrete-Event Simulation (DES) are also frequently used in the workforce planning issues. SD is a modeling approach that is useful in workforce planning because it allows for the analysis of complex systems with feedback loops, time delays, and other dynamic factors. The SD model helps simulate the workforce's career progressions from recruitment to interim separation and retirement [6], [23]. Meanwhile, DES is useful in workforce planning because it allows for the analysis of complex systems with a large number of discrete events that occur over time. In workforce planning, DES models can be used to simulate the behavior of the workforce planning system under different scenarios and policies. Although effective for evaluating complicated workforce planning, SD has a limitation when constructing an accurate SD model requires a thorough comprehension of the underlying dynamics of the system, which can be resource-intensive and time-consuming. Similarly, DES has limitations despite being good at capturing discrete events in workforce planning. When simulating complex systems with numerous events, DES models can become computationally difficult and time-consuming, thus restricting their application in real-time decision-making scenarios.

Additionally, as per [30], Stochastic Programming (SP) provides a range of modeling methods to incorporate uncertainty into manpower planning problems. Moreover, Robust Optimization (RO) techniques offer valuable insights as they do not require specific probability distributions for uncertain parameters. These methods might be useful for workforce planning; however, they also bring disadvantages. For instance, SP, while addressing uncertainty in manpower planning, can sometimes lead to complex mathematical formulations that are computationally intensive and challenging to solve, particularly for large-scale workforce scenarios. Including probabilistic components could also need a significant amount of historical data for precise parameter estimates, providing limits in circumstances when the data is limited or unreliable. Similarly, RO can sometimes produce overly conservative solutions, potentially underutilizing resources or failing to capture the full range of possible outcomes, despite their advantages in handling uncertainty without exact probability distributions. Particularly in situations where finding a balance between robustness and optimization is essential, the practical implementation of RO might require careful evaluation of the trade-off between robustness and optimization performance.

In conclusion, there are numerous methods available for solving workforce planning problems. However, it is essential to select a method that is best suited to meet the constraints and requirements of the specific problem at hand. In this study, the use of integer programming (IP) is considered appropriate. This mathematical optimization approach enables the optimization of the objective function while adhering to constraints in terms of integer values only. The decision variables in the optimization problem can only assume integer values, making IP particularly useful when variables are restricted to discrete values. In the services industry, IP is not commonly used in solving problems. However, IP has been used in other industries such as research by [31], who investigated a hospital contact center that proposed a workforce planning framework using IP to optimize staffing. The decision variables are restricted to be integers in this method, which is the number of agents assigned to each shift. Another research in the education industry was conducted by [32] to allocate students to preferred lecturers for supervision of internships among undergraduate students. Since all the decision variables are integers, IP was the most suitable method to consider. The exact algorithms used in these models help solve the problem efficiently and accurately.

Returning to this study, the decision variable is an integer, i.e. the number of cleaners assigned. Thus, by utilizing IP, the optimal combination of variables satisfies the constraints while achieving the highest possible objective value, which is to minimize hiring costs, can be achieved.

III. Research Methodology

This study aims to develop an IP model for cleaning services operations in order to improve their current workforce planning. This section discusses on how this research is conducted in achieving the objective. The research is designed in a few phases of research activities that help to ensure progress throughout the study. These phases are problem definition, data collection, data analysis, results, and discussion, as shown in Table IV. The detail of each step is briefly discussed in the following subsection.

A. Phase 1: Problem Definition

In the current scenario, cleaners are being assigned by the cleaning services operation based on the location of buildings. This means they will only be placed at one location to concentrate and clean for the duration of the day. These cleaners will work regardless of the type of cleaning task, but only in the assigned building. The cleaners are compensated as full-time workers with work duration of nine hours per day and receive monthly wages. As an initial study, three academic buildings have been considered as the main focus of this study, which involves 25 cleaners. These buildings are the newest buildings in the university and thus appear to be the most organized and systematic. The number of cleaners is quite large when comparing the size of the building to the number of employees, which causes a high turnover rate. Therefore, this cleaning service tries to search for possibilities to reduce the rate and increase profit. Therefore, in order to improve the rate, this research experimented with different scenarios.

TABLE IV. METHOD FOR IMPROVING WORKFORCE PLANNING

Phase	Methods and Techniques
Phase 1: Problem Definition	1. Spotting the real-world problem. 2. Setting the research topic, objectives, and overall project plan. 3. Review of the literature.
Phase 2: Data Collection	1. Gather the potential factors that affect the workforce planning. 2. Interview sessions with the company representative. 3. Reviewing company reports.
Phase 3: Data Analysis	1. Select the suitable factors. 2. Develop an optimization model for the workforce planning. 3. Construct an objective function. 4. Construct mathematical formulation for the constraints.
Phase 4: Model Evaluation	1. Performing model evaluation based on what-if analysis using Microsoft Excel Solver 2. Giving suggestions to the cleaning services operation's management based on the findings.

B. Phase 2: Data Collection

The data collection process for this project involves two main sources: interview sessions with company representatives and analysis of company reports. Interviews provided valuable insights into the current situation of an organizational structure, job requirements, staffing levels, skills, competencies and task types within the cleaning services operation. These insights guide identifying areas for improvement and developing strategies to address the workforce planning challenges. Company reports offer critical data on workforce size, experience levels, pay scales, performance metrics, and other factors influencing the workforce planning. Analyzing this data helps organizations understand their current workforce state, identify skill gaps and make informed decisions for more effective planning while considering the available financial resources. The company report serves as a reference to comprehend company issues and financial performance, aiding in determining available resources for the workforce planning efforts.

C. Phase 3: Data Analysis

In this phase of the study, the focus shifts to selecting critical factors that will play a pivotal role in shaping the objective function of the workforce planning model. With these factors in mind, the study proceeds to construct an IP model that captures the essence of the workforce planning problem. The model integrates the factors seamlessly, facilitating the development of mathematical equations and constraints that reflect the real-world considerations of the cleaning services operation.

1) Factors selection: This study carefully selected several factors to be used as constraints in formulating an objective function. These factors have been chosen based on previous research, as discussed in Section II(A), and how well they align with the specific problem being investigated in this cleaning services operation. Table V shows the factors to be considered in the model formulation of the study.

TABLE V. FACTORS TO BE CONSIDERED

Factors	Definition
Size of the cleaning area	The total size of the area to be cleaned in the campus of the university.
Task duration	The given time frame for the cleaners to complete the task.
Scheduling	To ensure that the given cleaners are available in the time period.
Experience level	To ensure the cleaners efficiently perform the cleaning task within the given time.

Considering the size of the cleaning area as one of the important factors in the workforce planning affects the number of cleaners needed to clean up the area efficiently. A larger facility typically requires more cleaners to handle the workload, while a smaller facility may require fewer cleaners. Task duration is another important factor in the workforce planning for a cleaning service operation because it directly impacts the amount of time that a cleaner will need to spend on a particular task. In this study, the cleaners are given a time frame and are obliged to complete all the tasks allocated to them within the particular time frame.

In addition, effective scheduling helps to optimize the use of available staff and resources, reducing hiring costs and ensuring that the cleaning services are delivered on time and to the required standard. Moreover, experience level is important in the workforce planning for cleaning services operations to ensure that the premises are cleaned and maintained to the desired standard. Cleaning tasks requiring specialised skills or a high level of experience are more likely to be successfully completed by cleaners with sufficient experience within the allotted time frame. This is because it helps cleaners know how to do different cleaning tasks effectively, solve problems, and train new cleaners, resulting in better quality services that meet customer expectations and promote business growth for instance, carpet cleaning, computer lab cleaning, plant care, etc.

2) Model formulation: The problem for this study is now being addressed through an IP model, which incorporates the four factors discussed previously. Subsequently, the mathematical model is developed along with the corresponding constraints.

Indices:

Cleaner: $\{1, \ldots, i, \ldots, I\}$

Task: $\{1, \ldots, j, \ldots, J\}$

Time period: $\{1, \ldots, t, \ldots, T\}$

Parameters:

Cij: The cost of assigning cleaner i to task j at time t

Sj: The size of the area to be cleaned for task j

Ai: The maximum area that cleaner i can clean in one time period

Rj: The required experience level for task j

Ei: The experience level of cleaner i

Variables:

$Xijt = 1$ if cleaner i is assigned to task j at time period t, and $Xijt = 0$ otherwise.

Objectives:

In this model, we consider the objective of minimizing hiring costs, which can be formulated as:

$$\text{Minimize} \sum i\in I \sum j\in J \sum t\in T \; Cijt \; Xijt \quad (1)$$

Constraints:

$$\sum i\in I \sum t\in T \; Xijt \geq 1, \text{ for all } j\in J \quad (2)$$

$$\sum j\in J \; Xijt \leq 1, \text{ for all } i\in I, t\in T \quad (3)$$

$$Xijt \geq 0, \text{ for all } i\in I, j\in J, t\in T \quad (4)$$

This model is formulated to present the current scenario in the cleaning services operation, in which the cleaners are assigned to each building according to the total size of the cleaning area regardless of the skill requirements for the cleaners.

The objective function for this study is shown in Eq. (1). The aim is to minimize the hiring cost of the cleaning services. It is calculated by multiplying the hiring cost by the number of cleaners. Eq. (2) ensures that each task must be assigned to at least one cleaner during its entire duration. Eq. (3) ensures that each cleaner can perform at most one task during each period. Eq. (4) limits all the variables to a non-negative value. This model is then analysed to obtain the solution of the existing scenario.

D. Phase 4: Model Evaluation

In this study, the model evaluation was conducted using what-if analysis. What-if analysis is a process by which we adjust the model and then examine how those modifications will impact the model's results. In a study, there will typically be what-if analysis reflecting several situations. To better solve the problem, it would be good to see how the current results compare to the modified scenario. By conducting what-if analysis, it can gain insights into the potential outcomes and make informed decisions based on the model's sensitivity to different variables. This approach allows us to explore various scenarios and understand the implications of different adjustments on the overall results. This study has three modified scenarios: Model 2, Model 3, and Model 4. The current situation in Model 1 involves the cleaners working nine hours daily for a wage of 1,500 MYR per month. Consequently, the other three scenarios are as follows.

1) Model 2: What if the cleaner is assigned according to the size of the cleaning area?

A book on Setting Household Standards states that it takes four hours to clean 2000 sqft, which is an average of 500 sqft per hour [33]. However, the current assignment in the cleaning services operation is only focused on assigning the cleaners to the building areas without taking any consideration. In this modified scenario, the fewest cleaners possible are used to keep the building clean. Model 2 is the modification of the current Model 1 by adding the new constraint it to ensure the whole building is clean as shown in Eq. (5)

$$\sum j \in J\ Sj\ Xijt \leq Ai, \text{ for all } i \in I,\ t \in T \quad (5)$$

This equation is to ensure that each cleaner should clean at least a given size of area. To ensure that the cleaners can complete the assigned workload, the cleaning area multiplied by the number of cleaners should be larger than the total size of the cleaning area.

2) Model 3: What if the cleaners work in a part-time mode?

Model 3 is an improvement idea modified from the previous model. In this scenario, the cleaners are considered to be part-time workers, and therefore they will work for four hours and receive 30 MYR as their wages per day. The cleaner is assumed to clean 2000 sqft per day. It is possible to decrease the hiring cost due to the number of cleaners needed. Besides, according to the cleaning services operation, the cleaners might need only four hours to clean the building area. Therefore, cutting down the paid wages might help in minimizing the cost.

3) Model 4: What if the cleaner is assigned according to the task type?

In this scenario, similarly, the cleaners are considered to be part-time workers, and they will work for four hours and receive 30 MYR as their wages per day. This scenario was modified in Model 4 to retain all the current cleaners. In this scenario, the cleaners are assigned according to task type without considering the size of the cleaning area.

There are four different task types that make up the cleaning tasks: "General cleaning and maintenance," "Washroom maintenance," "Specialize cleaning," and "Plant care." Table VI shows the cleaning tasks included in the given task types. Each cleaner's performance level was gathered and converted to a range of experience levels. This is due to no available data on the cleaners' experience level. In this study, cleaners with more experience were assumed to perform their jobs more effectively. This assumption allows us to assign suitable cleaners to the given types of task.

Depending on their current experience level, the cleaners will be assigned a task type; for example, if their experience level is below 2, they will be given the task type "General cleaning and maintenance." Then, if they have an experience level of 2, the task will be "Washroom maintenance," and an experience level of 3, "Special cleaning," respectively. However, "Plant care" will only be assigned to cleaners with experience levels above 4, which can call for more patience and competence.

Since every hired cleaner should get one assigned task, therefore a new constraint as shown in Eq. (6), is modified from Eq. (3) in this model.

$$\sum j \in J\ Xijt = 1, \text{for all } i \in I,\ t \in T \quad (6)$$

Eq. (6) ensures that each cleaner must be assigned one task during the given time period. At the same time, a new equation, as shown below, is added to this model in order to ensure that the cleaner manage to fulfill their given task in the given time span as they have relevant skills for their given task.

$$Xijt = 0, \forall i \in I, \forall j \in J, \forall t \in T \text{ where } Rj > Ei \quad (7)$$

TABLE VI. TASK TYPES AND THE CLEANING TASKS

Task Type	Cleaning Task
General cleaning and maintenance	Cleaning desks and chairs, dusting furniture and fixtures, emptying trash bins, sweeping and mopping the floor, cleaning corridors, cleaning stairwells, cleaning windows and mirrors
Washroom maintenance	Cleaning the washroom and refill the supply
Specialized cleaning	Cleaning lift, cleaning computer set, cleaning carpet
Plant care	Trimming and pruning the plants, fertilizing the plants, watering the plant

Eq. (7) enforces that only cleaners with sufficient experience levels can be assigned to the tasks that require specific skills, which ensures that the tasks are completed properly. If the required experience level for task j is higher than the experience level of cleaner *i*, then cleaner *i* cannot be assigned to task *j* during the time period *t*.

IV. FINDINGS

This section discusses the results and findings obtained from the developed models. The model evaluation will be made by comparing the current model with all the modified models.

A. Discussion for Model 1 (Current scenario)

Model 1 was created to reflect the current situation of cleaning services operation. The size of the cleaning area and the task types were not taken into consideration when cleaners were assigned according to buildings. The three academic buildings taken into consideration, named as buildings X, Y and Z, received these cleaners randomly, assigned by the cleaning services operation. These cleaners would do any task types in the assigned building during nine working hours. Their performance level was monitored by the supervisor from the cleaning services operation. The number of cleaners involved in the current existing scenario and their performance are shown in Table VII. These data are provided by the cleaning services operation and will be compared later to the modified scenario.

The number of hired cleaners is multiplied by their monthly wages to determine the hiring cost for this model. In this model, there are 25 cleaners assigned, and their monthly pay is 1,500 MYR. In this situation, the total cost of hiring is 37,500 MYR. Reducing hiring costs is necessary since the high hiring costs strain the cleaning services operation.

B. Model Evaluation

Model evaluation is an important phase in this study, involving the comparison of the current model with modified models. The objective is to evaluate each model's advantages and limitations in order to find a better solution that suits the organization's needs. By assessing the models' performance in different scenarios, management will gain insights into how well the models address the problem. Microsoft Excel's Data Solver is used to run these models, with a computer powered by AMD Ryzen 7 5800X along with 16GB RAM.

TABLE VII. NUMBER OF CLEANERS INVOLVED AND THEIR PERFORMANCE IN THE CURRENT SCENARIO

Cleaner	Performance	Cleaner	Performance
Cleaner 1	80%	Cleaner 14	70%
Cleaner 2	95%	Cleaner 15	90%
Cleaner 3	70%	Cleaner 16	80%
Cleaner 4	75%	Cleaner 17	70%
Cleaner 5	70%	Cleaner 18	70%
Cleaner 6	85%	Cleaner 19	85%
Cleaner 7	80%	Cleaner 20	70%
Cleaner 8	85%	Cleaner 21	70%
Cleaner 9	90%	Cleaner 22	75%
Cleaner 10	70%	Cleaner 23	90%
Cleaner 11	80%	Cleaner 24	70%
Cleaner 12	80%	Cleaner 25	80%
Cleaner 13	85%		

Discussion for Model 2: Due to the high cost of the cleaning services operation to hire cleaners in the current scenario, Model 1 is used as a guideline to modify and come out with a new model in different scenarios. In this scenario, the size of the cleaning area is considered while assigning cleaners. The allocated cleaners must clean at least 14463 sqft for Building X, 12006 sqft for Building Y and 7320 sqft for Building Z. It took about 49 minutes to come up with the optimal solution, as shown in Table VIII.

TABLE VIII. THE ASSIGNMENT OF CLEANER IN MODEL 2

Cleaner	Assigned Location	Cleaner	Assigned Location
Cleaner 1	Building X	Cleaner 14	Not assigned
Cleaner 2	Not assigned	Cleaner 15	Not assigned
Cleaner 3	Not assigned	Cleaner 16	Building Z
Cleaner 4	Not assigned	Cleaner 17	Not assigned
Cleaner 5	Not assigned	Cleaner 18	Not assigned
Cleaner 6	Not assigned	Cleaner 19	Building Y
Cleaner 7	Not assigned	Cleaner 20	Building X
Cleaner 8	Not assigned	Cleaner 21	Building Y
Cleaner 9	Not assigned	Cleaner 22	Building X
Cleaner 10	Not assigned	Cleaner 23	Building Z
Cleaner 11	Not assigned	Cleaner 24	Building X
Cleaner 12	Not assigned	Cleaner 25	Building Y
Cleaner 13	Not assigned		

According to the result, four cleaners were assigned to Building X, three were assigned to Building Y, and two were assigned to Building Z. In a nutshell, total of nine cleaners were assigned to do the cleaning tasks at these buildings. If this model was used, the cleaning services operation would have to pay a monthly hiring cost of 13,500 MYR. Due to the decreased number of cleaners, this value is lower than the existing model. The result is graphically displayed in Fig. 1.

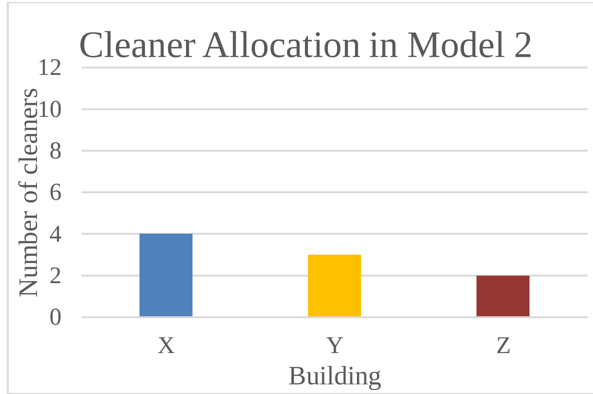

Fig. 1. Cleaner allocation in building based on Model 2.

1) Discussion for Model 3: Based on the interview with the cleaning services operator, the cleaners might only spend four hours cleaning the building despite being obligated to work nine hours every day. Therefore, it would be wise if we could reduce their working hours so that they could increase their level of efficiency. The optimal solution required a long running duration of 19 days. The assignment of cleaners in Model 3 is shown in Table IX.

TABLE IX. THE ASSIGNMENT OF CLEANER IN MODEL 3

Cleaner	Assigned Location	Cleaner	Assigned Location
Cleaner 1	Building X	Cleaner 14	Building X
Cleaner 2	Building Z	Cleaner 15	Building X
Cleaner 3	Building Z	Cleaner 16	Not assigned
Cleaner 4	Building Y	Cleaner 17	Building Y
Cleaner 5	Building Z	Cleaner 18	Not assigned
Cleaner 6	Building X	Cleaner 19	Not assigned
Cleaner 7	Building Y	Cleaner 20	Building Y
Cleaner 8	Building X	Cleaner 21	Not assigned
Cleaner 9	Building X	Cleaner 22	Not assigned
Cleaner 10	Not assigned	Cleaner 23	Building Y
Cleaner 11	Building Z	Cleaner 24	Building X
Cleaner 12	Building Y	Cleaner 25	Building Y
Cleaner 13	Building X		

Based on the result from Model 3, eight cleaners were assigned to the Building X. Besides, seven cleaners were assigned to Building Y while four cleaners were assigned to the Building Z. In this model, a total of 19 cleaners were assigned to carry out the cleaning tasks. The cleaning services operation might spend 570 MYR on the daily hiring cost for these three buildings. Since cleaners would work for 26 days per month, the total hiring cost in this model is 14,820 MYR, which is lower than the current hiring cost. However, compared to Model 2, the hiring cost would be a little higher because this model might require more cleaners. Fig. 2 presents the cleaner allocation in Model 3.

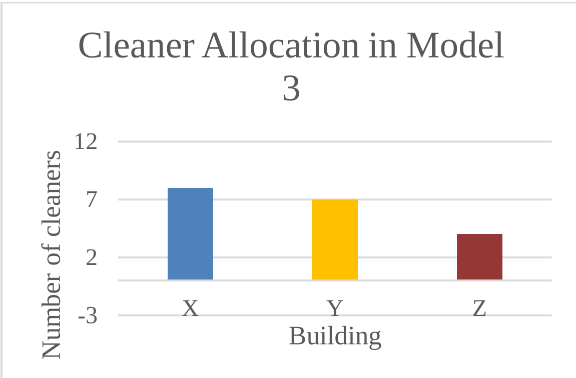

Fig. 2. Cleaner allocation in building based on Model 3.

2) Discussion for Model 4: As in the previous scenario of Model 3, all the cleaners remain considered as part-time workers in this scenario and will work four hours per day for 30 MYR. This scenario aims to enhance the cleaners' performance level, where they are assigned based on specific tasks. Cleaners should perform more effectively when carrying out a task that they are familiar with; thus, cleaners may result in higher performance levels since they are more expert with the task at hand. Therefore, the cleaners are assigned to a given task type based on their experience level in this model. Additionally, the cleaning services operator gets to maintain all the hired cleaners by employing this scenario. The assignment of cleaners in Model 4 are shown in Table X.

Based on the result from Model 4, 11 cleaners were assigned to “General cleaning and maintenance”. Besides, 6 cleaners were assigned to “Washroom maintenance” while 4 cleaners were assigned to “Specialized cleaning”. At the same time, the 4 cleaners with the highest performance level were assigned to “Plant care”. In this scenario, all the hired cleaners would remain with the cleaning services operation and be assigned with cleaning tasks. They might spend 750 MYR on the daily hiring cost for these three buildings. Since cleaners will work for 26 days per month, the total hiring cost in this model is 19,500 MYR, which is lower than the current hiring cost. However, compared to Model 2 and Model 3, the hiring cost will be the highest as it tends to remain all cleaners in the organization. 52 minutes of time is taken to run this model and finding the optimal solution. The cleaner allocation in this Model 4 is clearly presented in Fig. 3.

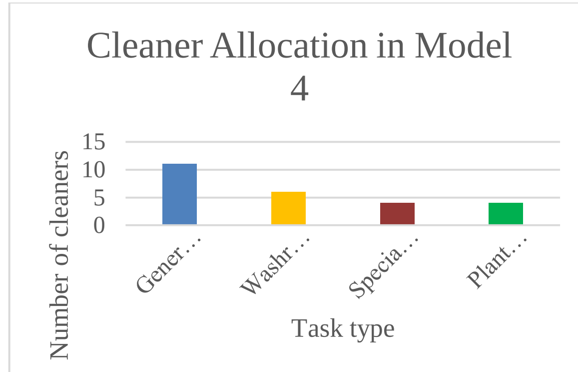

Fig. 3. Cleaner allocation in building based on Model 4.

TABLE X. THE ASSIGNMENT OF CLEANER IN MODEL 4

Cleaner	Experience level	Task type
Cleaner 1	2	Washroom maintenance
Cleaner 2	5	Plant care
Cleaner 3	0	General cleaning and maintenance
Cleaner 4	1	General cleaning and maintenance
Cleaner 5	0	General cleaning and maintenance
Cleaner 6	3	Specialized cleaning
Cleaner 7	2	Washroom maintenance
Cleaner 8	3	Specialized cleaning
Cleaner 9	4	Plant care
Cleaner 10	0	General cleaning and maintenance
Cleaner 11	2	Washroom maintenance
Cleaner 12	2	Washroom maintenance
Cleaner 13	3	Specialized cleaning
Cleaner 14	0	General cleaning and maintenance
Cleaner 15	4	Plant care
Cleaner 16	2	Washroom maintenance
Cleaner 17	0	General cleaning and maintenance
Cleaner 18	0	General cleaning and maintenance
Cleaner 19	3	Specialized cleaning
Cleaner 20	0	General cleaning and maintenance
Cleaner 21	0	General cleaning and maintenance
Cleaner 22	1	General cleaning and maintenance
Cleaner 23	4	Plant care
Cleaner 24	0	General cleaning and maintenance
Cleaner 25	2	Washroom maintenance

3) Model comparison: In this section, the result of all the models is compared and shown in Table XI.

TABLE XII. COMPARISON OF RESULTS

Model	Scenario	Number of Cleaners	Hiring Cost (MYR)
1	Cleaners are assigned randomly to the building.	25	37,500
2	What if the cleaner is assigned according to the size of the cleaning area?	9	13,500
3	What if the cleaner works in a part-time mode?	19	14,820
4	What if the cleaner is assigned according to the task type?	25	19,500

Originally, Model 1 required a high hiring cost of 37,500 MYR with 25 cleaners. Then, the first what-is scenario of Model 2 maintains normal working hours but reduces hiring costs by assigning nine cleaners based on cleaning area size, resulting in a 13,500 MYR cost. Meanwhile, Model 3 aims to enhance performance by minimizing cleaner working hours and employing 19 part-time cleaners for four hours daily at 14,820 MYR/month. On the other hand, Model 4 enhances cleaner performance via task specialization, retaining all cleaners. However, it has the highest cost at 19,500 MYR. It can be seen that these models offer distinct approaches, where Model 2 focuses on area size, Model 3 on efficiency, and Model 4 on specialization.

V. CONCLUSION

This study explores the workforce planning issues in cleaning service operations and provides helpful recommendations. Integer programming (IP) was used to create an optimization model to minimize hiring costs with a focus on three academic buildings in a public university in Malaysia. The current model with three different scenarios was investigated according to several identified factors, such as cleaning area size, task duration, scheduling, and experience level. Each model focused on a different approach and came out with improved hiring costs. Based on the analysis of scenarios, cleaning services operations can choose any model suited to their budget and future planning. However, of all models, Model 3 is recommended due to its lower cost and part-time working hours, which can benefit students and organizational efficiency.

This study contributes significantly to knowledge and practice, though limited by scope and time constraints. As a way to address constraints and improve model evaluation and effectiveness, the research highlights the necessity for heuristic methodologies in future work, especially involving the broader scenarios such as the whole building in a university. In fact, more input factors need to be added to future models for more reliable results.

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