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An Optimization Model for Hotel Housekeeping Personnel Scheduling in Pandemic Outbreak

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ABSTRACT

This paper modified a Binary Integer Programming (BIP) model to represent the real life problem of personnel scheduling during Covid 19 pandemic outbreak for a hotel housekeeping department. The hotel under study was used as a quarantine center for the people who flew back from the overseas before they could be allowed to their bound destination. The staff working schedule must be the best possible scenario that could optimize all the resources owned, at the same time satisfies all the operational constraints. The challenge is to quickly adjust the work schedule that could allow the least number of personnel working at any time due to the Movement Control Order (MCO) enforcement. The aim is to modify the BIP model formulation to produce the optimal number of personnel for each shift in each housekeeping section involved for each day. This weekly schedule is prepared to determine the shift duties for each personnel considering the rest day between working shifts, the required number of personnel for each shift and other constraints. By solving the model using MATLAB software, the new schedule needs a total of 140 working shifts in a week, as compared to the current schedule of 216 working shift for the same duration. In conclusion, the proposed mathematical model can provide a quick solution in reducing the workforce size during the pandemic outbreak.

Keywords: Personnel scheduling, Binary Integer Programming Model, Mathematical model

INTRODUCTION

Due to the increasing interest in research on optimization, the topic of personnel scheduling has been widely studied in the last few decades. In many organizations, the people involved in developing this schedule need decision support tools to help provide the right employees with the right shift while achieving a high level of employee job satisfaction. Usually, the component of such decision support system will include spreadsheet and database resources and possibly scheduling tools derived from appropriate mathematical models and algorithms because every organizations have their own staffing requirements and desires. This complexity and the need to be standardized are addressed most conveniently by an independent component structure (Burke et al., 2004). The aim is to provide better service by equitably and equally assign staff to their desired shift.

Personnel schedule problem gets complicated if the solution to the problem differ such as the rising number of personnel and company satisfaction level (Kacmaz et al., 2019). Resources usage and management are very important to organizations. Therefore, they are trying to make profit by delivering high efficiency levels from available sources. In business terms, the seniority of the staff, knowledge and skills are the important aspects contributing to the efficiency levels. To provide better service through the efficient and effective allocation of staff to their shift, it is hard and difficult to produce the personnel schedule manually.

In the case of pandemic outbreak and emergency situations, medical personnel are very vital commodity that cannot be increased by hospitals in a short period of time. They can get sick while caring the infected and thus raising a lacking in the trained personnel. This is a very challenging task for the management especially during Covid 19 pandemic outbreak because of the new rules, regulations and procedures that need to be followed. In managerial term, businesses operations change very fast, specifically when companies need to allow only a minimum number of personnel working during the Movement Control Order (MCO) enforcement. When this happens, the management must produce a new schedule that is of the best possible scenario which optimize all the resources owned. The resources may be in the form of workers, time, and expertise in specific field. If it is done manually, then the process will be very tough, tedious and time consuming. As scheduling personnel staff is a complicated task, therefore, several studies on staff scheduling have been established to cater scheduling problems during an outbreak (Seccia, 2020).

During Covid 19 pandemic outbreak, many local hotels in the country were used as an intermediate and quarantine centre for the people who flew back from the overseas before they can be allowed to their bound destination. This precaution step is very important to ensure these people did not spread the virus to their family and the public once they have access to the outside world. This is because the disease can be originated from other countries as it has become a global disease.

This issue has led to several research on optimization of personnel scheduling. In this context, the urgency to have one systematic and effective scheduling mechanism has motivated the intention to find an approach that can help in modelling this personnel schedule in most effective way. The challenge of adjusting to the work schedule is to quickly find the solution to the problem with a minimum effect to the others. Management will also face difficulties to find the optimal solution in a short period of time other than the need to understand the effect that will resulted from the decision made. Therefore, this study aims to modify the BIP model formulation that can produce the optimal number of personnel for each position, for each shift involved for each day during a week.

This study was intended to provide the best working schedule for personnel with optimal number of personnel needed to work in each shift to satisfy the current workload during a disease outbreak situation. When scheduling the optimal number of personnel assigned to the designated task, there is no worker to be assigned any overtime work. There are also no additional workers to be considered as the optimal schedule itself have produce sufficient number of personnel needed on the given day.

This study focuses on the personnel scheduling of a hotel housekeeping department during pandemic outbreak. The housekeeping department is considered in this case study because of their important roles in making sure that the hotel and its surroundings are clean and safe. In the context of Covid 19 disease outbreak, cleanliness and safety currently becomes the main concern of anyone in the world. The hotel in this study is operating during the MCO on a capacity of a quarantine place for the citizen who had just arrived from overseas. Therefore, the working shift in the housekeeping department have changed from two shifts per day to three shifts per day to ensure an extra cleanliness of the hotel. Due to this, the personnel schedule in this department must also change accordingly. In addition, these changes are also implemented to follow the standard of operation procedure of the MCO that limits the number of staff working at any given time, to control the spread of Covid 19 virus.

RELATED WORKS

Mathematical optimization model has been widely used in many real-life decisions making. Under a set of constraints imposed by the nature of the problem being studied, it concerns with the optimum allocation of limited resources among competing activities. The constraints are important as they reflect the financial, technological, marketing, organizational or many other considerations and restrictions. Past studies show that the applications of mathematical programming model in scheduling and planning have attracted researchers' attention due to the large applications of advanced information technology. The study on the employee scheduling using mathematical programming model is one of the most common interest in optimization problem.

Integer variables are used to provide broad modelling capabilities when the indivisibilities of the decision values of the model under study is reflected in the problem restriction. In relation to this, binary integer variables are useful whenever variables can be assumed one of two values, either *yes* or *no* decision. Binary Integer Programming or BIP is a mathematical model where all the variables are restricted to a value '*0*' or '*1*' (Arefin et al., 2013). As this study is aimed to make decision whether certain personnel will work in a certain shift on a certain day during the outbreak situation, therefore BIP is the best mathematical model to represent the decision-making model.

The scheduling problem studied by Kassa and Tizazu (2013) on the personnel scheduling for the hotel workers in the engineering department has developed a fair personnel scheduling while satisfying several requirements and constraints. The objective of the study is to determine the optimal weekly schedule that satisfy the weekly rest requirements per employee. Other than that, the study of employee scheduling on the health care service has also been of interest among researchers. The scheduling needs to consider many aspects as the health care personnel need to work for 24 hours a day and seven days a week to ensure continuous, dynamic and efficient service. One of the studies was done by Kumar et al. (2014) using the Linear Programming (LP) model to solve the scheduling problem at Coimbatore City Hospital. The objective of the study is to maximize the fairness of the staff working schedule besides minimizing the number of nurses who handle the hospital needs. The solution of this LP model proposed a minimum of 296 nurses to meet the minimal daily requirements with each shift took eight working hours.

Labidi et al. (2014) formulated a multi objective programming model on staff scheduling in a bank. The model requires an allocation of suitably qualified staff to a specific shift to meet the demand for services of an organization while observing the workplace regulations and attempting to satisfy an individual work preference. This objective is to determine the shift duties of each staff considering shift coverage requirements, seniority-based workload rules as well as the staff work preferences. It is part of the mathematical programming that deals with decision problems characterized by multiple and conflicting objective functions that will be optimized over a feasible set of decisions. The results successfully produced a reduction of 6.25% in the total overtime cost.

Fujita and Amasaka (2015) have formulated a mathematical model for the staff scheduling based on the level of workloads for a hotel restaurant staff. This is an effective schedule as the Mixed Integer Programming (MIP) model formulation has helped to level the workload of all employees involved. Beside this, it was also able to minimize the labour cost of the hotel using the MIP model. The study focused on finding a schedule that can minimize the number of additional workers. This was done by calculating the level of workload among individual workers and cutting down the employee cost by eliminating variations in number of hours and high-volume days worked. The model has resulted a reduction in labour costs by nearly 10 percent in a month while eliminating nearly 100 temporary workers.

A study by Adem and Dagdeviren (2016) has formulated a staff scheduling model for retail and services workforce. The proposed technique was modelled by using MIP model and solved using an optimization software, GAMS. The optimization model developed a scheduling model that consist of ergonomic criteria and traditional scheduling approaches. The proposed model allowed the workers to select their own preferred days off. As a result, the model assigned the workers to their expertise while making sure that the final schedule lies in the permissible level tolerance and did not exceed the risk level.

Any organization would need to have a systematic employee scheduling mechanism to ensure that they could fully utilize their resources. A mathematical model to schedule drivers for a transport corporation in a metropolitan city has been studied by Rama et al. (2017). The model aimed to minimize the number of drivers needed for each shift in a day and reduce the amount spent for reserved drivers. When the number of drivers was minimized, the operating cost that should be paid to the reserved drivers has significantly reduced. The problem was formulated as an Integer Programming (IP) model and resulted a new optimal solution that produced some amount of cost saving, as compared to the amount spent on the current driver schedule.

The application of mathematical model on work scheduling was also utilized to a security department of a hotel. Herawati et al. (2018) have formulated a shift scheduling model for this department considering the physical workload and the staff preferences. To have an equally distributed shift allocation, the physical workload and the staff preference were considered during the modelling process. An MIP approach was used in a study by Adoly et al. (2018) on nurse scheduling model for a hospital in Egypt. Since the country was facing a problem of nurse deficiency, they adopt a nurse scheduling model by considering the government rules and the hospital service demand. It was mentioned that the proposed nurse rostering problem was formulated based on the idea of multi-commodity network flow model which was verified using hypothetical and benchmark instances. The proposed solution was proven as a fair schedule system. It has improved the level of nurse satisfaction and preferences besides the overtime cost has decreased by 36%.

A large-scale natural gas combined-cycle power plant staff scheduling model was studied by Ozder et al. (2018) due to the complaints from the employee stating about the unfairness work schedules. The proposed Goal Programming (GP) model was solved with respect to the individual workers skills. The analytic network process method was used to get the weights and preferences of the workers skills. The objective of the modified model is to minimize the operating cost and to produce a fair work schedules for the power plant which satisfies all the employees preferences.

The problem of producing a work schedule during emergency scenarios and pandemic outbreak has been widely studied. The drastic shortage of frontline workers due to being infected has made the existing schedule can no longer be used. A study by Seccia (2020) focused on this issue in which the health workforce was having difficulties in meeting the unexpected high service demand. This problem seeks for a solution to deal with insufficient number of nurses. By solving the MIP model, the optimal solution has reduced the number of working shifts where the nurses need to be assigned with longer working shift in a day to ensure all infected patients can receive treatment. In addition, the new roster has created a balanced working schedule that minimize the stress of the nurses.

METHODOLOGY

To protect the privacy of the data provider, the name of the hotel will be kept anonymous throughout this paper. The hotel was used as a venue to quarantine the people who have arrived from outside the country during Covid 19 outbreak. All the people involved are required to be quarantined for 14 days. Since the MCO was enforced during the data collection process, the interview and the data collection process was done virtually. The management was contacted through email and telephone calls.

The hotel employees consist of two types of personnel which are the management team and the service team. The management team includes people who work at the office, namely managers, executive officers and the administrative workers. On the other hand, the hotel has its distinguished service team for its several departments. This study only focused on the scheduling of the service team for the housekeeping department. This service team consists of supervisor, leader, public area attendant, room attendant and linen attendant. Since the hotel was used as one of the quarantine centres, therefore there are many adjustments need to be made on the normal tasks, as well as the working schedule. For example, the public area attendant had extra workload as they have to sanitize all the open area in the hotel every single day as a required precaution step during the pandemic outbreak. In contrast, the room attendant and linen attendant would only need to clean the room once the guests have checked out. They do not have to do any room cleaning during the guest stay. This new procedure is meant to minimize contact with the hotel guests.

Unlike the management team, the service team are required to work on shift basis. Basically, the working shift for the service team in housekeeping department consist of morning and evening shift. However, to accommodate some new procedures during the pandemic outbreak, therefore the hotel management have decided to reconcile the working shift into three shifts which are morning, evening and night shift. The morning working shift starts at 7 am to 3 pm, evening shift required them to work between 3 pm to 11 pm, while night shift starts at 11 pm and end at 7 am.

The working days for the service team of housekeeping department during normal situation is six days per week with an off day varying among them. However, due to the MCO, the management has reduced the total number of shifts per week that are assigned to each personnel. The number varies depending on the staff position and responsibilities. The number of working days per week for supervisor and public area attendant are 6 days. On the contrary, the leader, room and linen attendant would only work 5, 2 and 3 days per week, respectively. Table 1 shows the differences between the working schedule during normal situation and pandemic situation.

Table 1: The differences between working schedule during normal situation and pandemic outbreak

	Normal Situation	Pandemic Situation
Working Shift	Morning, Evening	Morning, Evening, Night
Total number of working days in a week	6 days for all personnel positions	Supervisor = 6 days Leader = 5 days Public area attendant = 6 days Room attendant = 2 days Linen attendant = 3 days

Table 2 shows the gender of personnel who are currently in the service team and the minimum number of personnel required for each shift during pandemic outbreak. Among the five personnel positions, there is a total of 15 male and 21 female staff available in the team, which makes a total of 36 staff. Beside this, the housekeeping department need at least a total of 7 staff working in each of morning and evening shift, while only 4 staff for the night shift.

Table 2: The number of personnel needed for each shift during pandemic outbreak

Personnel Position	Gender of Personnel Available		Minimum Number of Personnel		
	Male	Female	Morning	Evening	Night
Supervisor	2	2	1	1	1
Leader	2	3	1	1	1
Public Area Attendant	3	5	2	2	2
Room Attendant	6	8	2	2	0
Linen Attendant	2	3	1	1	0

In this study, a mathematical programming model is modified based on the reference model by Harlina et al. (2019). The model was adopted and modified to accommodate the characteristics of the hotel housekeeping department workforce. The interpretation of the sets, parameters, objective function, and constraints for the modified BIP model in this study is described here. The model sets refer to the set of data that will be used in the process of developing the mathematical model. The set h indicates the gender specification of the personnel, where $h = 1$ denotes the male worker, while $h = 2$ denotes the female worker. The set i indicates on the working shift available where $i = 1, 2, 3$ denotes all shifts available in a day. The set j represents the set of working days where $j=1, 2, \ldots, 7$ is the index of all working days in a week. The index $j= 1$ represents Monday and $j= 7$ represents Sunday. The set k indicates the five staff positions that are available in the housekeeping department. The subscript $k=1, 2, \ldots, 5$ refer to the positions of supervisor, leader, public area attendant, room attendant and linen attendant, respectively.

The parameter a_{ik} represents the minimum number of position k staff working on shift i. Other parameter used in this model is b_{jk} which denotes the required total number of working day j, for each staff position k, each week. The model decision variable that best represents the solution to the model is the binary variable, denoted as x_{hijk}. The decision variable value *1* indicates the personnel with gender h is working on shift i during day j, who is in position k. On the contrary, the value *0* indicates otherwise. Therefore, the decision variable for the model is denoted by:

$$x_{hijk} = \begin{cases} 1, \text{ if staff with gender } h \text{ is working on shift } i \text{ on day } j\text{, who is at position } k \\ 0, \text{ otherwise} \end{cases}$$

The full modified BIP model for the personnel scheduling is stated as:

$$\text{Minimize personnel, } Z = \sum_{h=1}^{H} \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} x_{hijk} \tag{1}$$

subject to

$$\sum_{h=1}^{H} x_{hijk} \geq a_{ik} \qquad \forall i, j, k \tag{2}$$

$$x_{hijk} + x_{h(i+1)jk} + x_{h(i+2)jk} \leq 1 \tag{3}$$

$$\sum_{i=1}^{I} \sum_{j=1}^{J} x_{hijk} = b_{jk} \qquad \forall k, h \tag{4}$$

$$x_{hijk} = 0 \qquad \forall j, k \quad \text{with } h = 2,\ i = 3 \tag{5}$$

$$x_{hijk} = \{0, 1\} \qquad \forall h.i.j, k \tag{6}$$

The objective function (1) intends to minimize the workforce on duty of each position in all shift each day. Constraint (2) ensures that the total number of staff for each position working on each shift satisfy the minimum requirement set by the housekeeping department. Constraint (3) considers the rest hours before and after an assigned work shift. This constraint ensures that the gap between one shift assignment and the next is at least two shifts. This means, an employee can be on duty only after a rest period of at least two shifts from the previous working shift. Constraint (4) ensures that all personnel of each position work for the number of days, set for them per week. Constraint (5) is introduced in this study to restrict female employee from working in night shift to ensure their safety. Finally, Constraint (6) restricts the value of decision variable to be either '*1*' or '*0*' only.

EXPERIMENTAL RESULT AND DISCUSSION

When the model was rearranged in Excel template, the dimension of the technology matrix is 919 rows by 756 columns, which indicates that there are 919 model constraints and 756 decision variables. The *intlinprog* syntax in MATLAB is used to solve the personnel scheduling model. Table 3 presents the optimum number of personnel working in each shift for each day, for each staff position.

The leftmost column presents the staff position, the top three rows indicate the Morning (M), Evening (E) and Night (N) shift for each day. The schedule for all staff is tabulated on each row, with the symbol asterisk ([a]) denotes female workers. The last two rows count the total number of personnel working in each shift and each day. The binary output of *'0'* indicates that the personnel are not working in the shift, while the output *'1'* indicates otherwise.

There is currently a total of 36 staff in the housekeeping department. However, due to the MCO enforcement, the hotel wants to minimize the workforce on duty of each position at all shift each day. This new workforce schedule is reflected by objective function (1) of the mathematical model. By means of solving the optimization model, the department has successfully reduced the number of working staff to at most 21 staff per day. This minimum number of working staff is presented in the last row of Table 3, whereby there are only 19 to 21 personnel working daily. When summing up these numbers, then the personnel working in the department only recorded a total of 140 working shifts in a week. In the current schedule when all staff must work 6 days per week, there are a total of 216 working shifts each week. Therefore, the mathematical model has successfully generated the new schedule of the workforce, considering all new restrictions posed during the pandemic outbreak.

The hotel has increased the number of working shifts of the housekeeping department to three shifts during the MCO. However, it still adheres to the government standard procedure by keeping the number of working staff at a minimum level at any shift, as specified in Table 2. This specification is presented by Constraint (2) which ensures that the total number of staff for each position working on each shift must satisfy the minimum requirement set by the hotel. The experimental results in Table 3 obtained from the model satisfied this minimum restriction, as shown by each *'Shift'* column, with respect to each staff position. There is no shift which recorded a total of working staff less than the minimum number.

During pandemic outbreak, the total number of working days are changed according to the staff positions. The total working days which are presented in Table 1 has specified that the supervisor, leader, public area attendant, room attendant and linen attendant should work 6, 5, 6, 2 and 3 days per week, respectively. These values agreed with the results obtained in Table 3 whereby these values are shown in the rightmost column. This result has satisfied the restriction posed by Constraint (4) which specifies the required number of working days per week for all personnel of each position.

As described by Constraint (3), there must be at least two shifts gap between working shift for each staff. This ruling is enforced to ensure that the staff have sufficient rest before working on the following shift. By examining the output result in Table 3, the rule is obeyed as there is neither staff working in two shifts nor one shift apart.

Table 3: The new personnel schedule for hotel housekeeping department

		Day 1			**Day 2**			**Day 3**			**Day 4**			**Day 5**			**Day 6**			**Day 7**			**Total day**
		Shift			Shift			Shift			Shift			Shift			Shift			Shift			
		M	E	N	M	E	N	M	E	N	M	E	N	M	E	N	M	E	N	M	E	N	
Super	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	6

	2	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	1	0	6
	3[a]	1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	6
	4[a]	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	6
Leader	5	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	5
	6	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	5
	7[a]	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	5
	8[a]	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	5
	9[a]	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	5
Public Area Attendant	10	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	6
	11	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	1	6
	12	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1	6
	13[a]	0	1	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	1	0	6
	14[a]	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	6
	15[a]	1	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	6
	16[a]	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	1	0	6
	17[a]	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	6
Room Attendant	18	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	2
	19	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
	20	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
	21	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	2
	22	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	23	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	2
	24[a]	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
	25[a]	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
	26[a]	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2
	27[a]	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
	28[a]	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2
	29[a]	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	2
	30[a]	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
	31[a]	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Linen Attendant	32	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	3
	33	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	3
	34[a]	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	3
	35[a]	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3
	36[a]	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	3
Total Personnel per shift		9	8	4	7	8	4	8	7	4	8	9	4	7	9	4	8	8	4	8	8	4	
Total Personnel per day		21			19			19			21			20			20			20			

[a] Female

A new constraint was introduced in this study to restrict female employee from being assigned to night shift. This restriction is satisfied by the experimental solution whereby none of the female worker in the housekeeping department was assigned to any night shift. Based on the output result in Table 3, all the restrictions set by the model constraints are successfully satisfied.

CONCLUSION

This study was intended to minimize the number of personnel who must be on duty during the weeks of Covid 19 pandemic outbreak. The mathematical model was modified based on the requirements and restrictions that must be satisfied in the new working schedule. The BIP model formulation accommodated the differences in staff position and gender to obtain the optimal number of personnel for each position and working shift that involved in a week.

The new schedule generated by the modified mathematical model proposed that there should only 140 working shifts needed in a week when the working schedule follow the new requirements imposed during the pandemic outbreak. On the contrary, current schedule requires all staff to work 6 days per week, and this has resulted a total of 216 working shifts per week. Therefore, the mathematical model has successfully optimized the workforce, considering all new restrictions posed during the MCO. In addition, a novelty was introduced in this study whereby female personnel are not allowed to work on night shift. This modification was presented in the form of a new constraint to ensure this new enforcement is represented in the new schedule.

Despite the achievements recorded in this study, there are also room for improvement that can be done for future research. Instead of constructing a weekly schedule, future research may focus on a longer duty roster, for example a fortnightly or monthly schedule. Other than that, a mathematical model can also be adapted to minimize the cost of staffing, specifically to reduce operating cost during the difficult situation like the pandemic outbreak. In addition, future research also can improve the solution by using metaheuristic method. This is because metaheuristic technique can produce a better solution at a shorter computing time.

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