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A Binary Integer Programming Model for Personnel Scheduling: A Case Study at Fast-Food Restaurant in Johor

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ABSTRACT

This study is about analysing the current practice of the personnel scheduling at a well-known fast-food restaurant, as the post-pandemic situation slightly change their operating system. Therefore, the personnel scheduling needs to be modified according to the real-time situation using the binary integer programming (BIP) model. Based on the observation made, the problem of the study is to modify the working schedule with a proper break time for each staff to give them a fair working time, keep the workstations occupied during their operating hours and to maintain the restaurant as a healthy workplace. Therefore, after a background study on the topic and data collection made from a fast-food restaurant done, a one-day schedule is prepared to determine the number of staffs working in a day and scheduled the staff's break period. A new schedule is obtained that meets all constraint's requirements by solving the model using Microsoft Excel Solver. The new schedule minimized the number of staffs working in a day to 11 staff as compared to 12 staff in the current schedule. In conclusion, the proposed mathematical model can serve a fast and accurate solution for minimizing the personnel size and helps each staff to have a reasonable working hour with sufficient break time.

1. Introduction

Personnel scheduling problems (PSP) have been extensively researched during the previous few decades. High-quality solutions are highly desired to assist decision-makers in improved resource management due to the high cost of human resources and the frequent allocation of resources as said by Guo [1]. According to Alwadood *et al.,* [2], it is concerned with the optimal allocation of limited resources among competing activities under a set of restrictions given by the nature of the problem under study. Many real-life decisions have relied on mathematical optimization models.

Personnel scheduling was used in many fields in the real world, however, studies related to a fast-food restaurant and regular restaurant scheduling especially in Malaysia are still lacking and about a decade ago, Choi *et al.,* [3] mentioned that only a few studies investigated labour scheduling in hospitality services like restaurants. In the post-pandemic era, the fast-food industry become more

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competitive to regain its profits, therefore, systematic operations need to be done. As mentioned by Sasaki *et al.,* [4], due to transmission between employees and their close contacts in their separate houses and communities, workplaces are popular environments for intense infectious disease outbreaks. Because of the limitations, the staffs working in a day need to be reduced to avoid overcrowding in one work area. In addition, another problem arises due to the staff's unscheduled break time where the staff break time is not predetermined in the schedule prepared by the person in charge. An appropriate staff scheduling should be well organized in order to have job satisfaction among all workers [5].

Therefore, this study aims to analyze the current practice of personnel scheduling at the fast-food restaurant under study. This study was also intended to modify the personnel scheduling model according to binary integer programming (BIP) model suit to the problem faced by the restaurant. BIP could signify a choice being made or not, or many other situations including in determining the staff that should be in charged or not as mentioned by Chinneck [6]. The modification was made by using a model built by Ang *et al.,* [7] as a reference. This paper is chosen as the reference because the research framework done is quite similar to this study and the constraints are relatively related to the constraint that can be adapted in the fast-food restaurant industry.

This paper focuses on minimizing the number of fast-food restaurant staff by having an optimal working schedule that follows the considered factors. A comparison between the real schedule and the proposed schedule is made to identify the difference between the two schedules and to identify whether the newly proposed schedule is an optimal working schedule that meets all the conditions and limitations set by the fast-food restaurant under study. The proposed schedule was derived based on the calculation made using BIP model constructed in this research. Four break periods were added into the daily personnel schedule to solve the problem stated.

1.1 Literature Review
1.1.1 Review on personnel scheduling

Personnel scheduling, often known as staff scheduling or workforce scheduling, is a problem that affects every sector. Staff scheduling is very crucial to ensure that a company can perform smoothly without experiencing understaffing or overstaffing at one time at the same point the task can be done promptly. In other words, good staff scheduling can optimize the cost of operation in the form of time and labour costs. Since the 1950s, computational methods for rostering and staff scheduling have been a subject of continuous research and commercial interest [8]. It is becoming increasingly important to organisations as the businesses are changing, with a greater focus on customer service and cost awareness. The issue affects a variety of industries, including aircraft, transportation, and manufacturing, as well as healthcare and the restaurant business. Nurse rostering, transportation, and call centres are the most frequently researched areas. On top of that, the methodologies, and methods for resolving scheduling problems differ. They can be manually solved by employing graph colouring, integer programming, mixed integer programming, goal programming and genetic algorithms.

Previously, there are three forms of staff scheduling problems identified by Baker [9]. It was classified to shift scheduling, days off schedule, and tour scheduling problems. Shift scheduling, often known as time-of-day scheduling, requires planning over a daily planning horizon. Non-overlapping shifts are the most basic sort of schedule. This means that the staffing needs for each shift can be considered separately for calculating appropriate allocations. On the other hand, the length of the facility's operational week does not match the length of an employee's working week when days off or day-of-week scheduling is used. Employees have 5-day work weeks, and the company has a 7-day operating week, which is a widely used solution to this problem. The third category is the tour scheduling problem which is the combination of the shift scheduling and the days-off scheduling problem. In this study, the tour scheduling problem is probably referred to as the fast-food restaurant operates seven days a week with more than one shift a day. As the employees must be given daily and weekly breaks, the employee's tour such as the hours of the day and days of the week must be determined.

One of the most important factors influencing production and operating system performance is effective personnel scheduling. It is critical to allocate the appropriate task to the appropriate person at the appropriate time. Traditional staff scheduling mechanism is inflexible and inconvenient because they are more concerned with quantity than with quality, preventing the schedule from being flexible enough to meet the expanding demand of rapidly changing economic realities [10]. Labour or efficient staff scheduling can save human resource costs while simultaneously improving customer service and satisfaction as for the majority of businesses, human resources are the most expensive [11]. The difficulty of staff scheduling now is vastly different from that of the 1950s. In staffing and scheduling decisions, the relative importance of meeting employee demand has risen. Part-time contracts or flexible work hours are available, and employers consider employee preferences when developing work schedules.

1.1.2 Overview of integer linear programming and binary integer programming

According to Hillier and Lieberman [12], one of the most significant scientific developments of the middle of the 20th century was the development of linear programming (LP), which is now a standard tool used by most companies or businesses of even moderate size in the various industrialized nations of the world. A mathematical model is used by LP to define the issue at hand. The term ‘linear’ denotes the necessity of all mathematical functions in this paradigm being linear. Planning is fundamentally what the word programming means here, and it does not refer to computer programming. Thus, LP entails the planning of actions to achieve an optimal result, which is the result that among all feasible options, best achieves the defined goal according to the mathematical model.

Based on the assumption of divisibility, which demands that non-integer values be acceptable for decision variables, is a major restriction that limits many further applications to use the regular linear programming model. The decision variables only make sense in many real-world situations if they have integer values. In simpler words, integer programming (IP) is needed when certain variables must have a whole number, or integer values in order to solve certain LP problems. When the variables reflect things like packages or persons that cannot be divided fractionally, this requirement automatically arises [13]. With the additional requirement that the variables have integer values, the LP model serves as the mathematical model for IP.

On the other hand, problems involving a number of connected yes or no decisions fall under another application area that may be of even higher significance. There are only two options available in such decisions which are yes, and no. We can describe such decisions with just two options using decision variables that are limited to just two values, 0 and 1. These variables are referred to as binary variables. Therefore, IP problems that exclusively use binary variables may also be referred to as binary integer programming (BIP) problems or 0-1 integer programming problems. BIP is one of the integer programming branches apart from pure integer programming and mixed-integer programming. This could signify a choice being made or not, a switch being turned on or off, a yes or no response, or many other situations [6].

In a book written by Conforti *et al.,* [14], BIP is normally used in solving the generalized assignment problem, travelling salesman problem, Sudoku game, Crucipixel game, finding shortest paths and finding matchings in graphs. The BIP used in solving the following problems can be either pure BIP or mixed-BIP. Pure BIP only involved the value 0 and 1 while mixed-BIP included other integer values. In order to more accurately simulate the real-world scenarios that involve choices, decisions, or other circumstances, binary variables are added. Several simulated problems that were solved using BIP included routing problems, scheduling problems, set covering problems and many more.

1.1.3 Past studies on personnel scheduling in fast-food restaurants

Personnel scheduling in fast-food restaurants is not a common topic studied by scholars all over the world. Therefore, only a few research papers or studies were found that related to the subject matter. However, the lack of past studies on the same topic is one of the concerns of this study where there is a need to write more about the scheduling problem for the fast-food restaurant service field as this field is one of the leading industries in the world. Based on previous studies, most of the scheduling problems for various fields of research were solved by using linear programming whether, integer programming, binary integer programming or mixed-integer programming. The same goes for the research made for the fast-food industry, the common mathematical model applied a few decades ago for solving the problem is linear programming.

Research by Strakhov [15], Choi [16], Choi *et al.,* [17], Love and Hoey [18], Liggayu *et al.,* [19] and Budak and Chen [20] were all using linear programming to find the solution for the scheduling problem despite different goals. Out of all, Budak and Chen [20] were using a mixed-integer programming approach for scheduling problems. Mixed-integer programming involved both pure integer programming and binary integer programming also known as 0-1 integer programming. Pure integer programming is used when the variables represent quantities that can only be an integer such as humans while binary integer programming is applied due to the integer variables represent decisions like present or absent.

Liggayu *et al.,* [19] integrated two methods to achieve their objective, optimizing a restaurant's available staffing capacity to reduce customers' waiting times and boost customer satisfaction. This was done by applying customer service requirements to labour resource planning and allocation in the restaurant. The problem arose as the present system's simulation at the counter and in the dining, area revealed that the wait times were not in compliance with the customers' reasonable wait times. The two methods mentioned were Monte Carlo Simulation to determine particular daily and hourly performance and integer programming for optimizing the assignment of staff in each workstation. The integer programming model formulated was very simple since the objective was more focusing on customers' satisfaction but not the staff's satisfaction. Results from the study showed that the number of production and service crew is reduced from 18 staff to 15 staff from Monday to Thursday and 16 staff for Friday to Sunday.

Different from the study by Budak and Chen [20], who proposed multi-objective mixed-integer programming in solving the problems of customer service time and the changeable demand over time. When the demand from the customer is high, the number of staff to be at work should be more and vice versa. By using the historical demand data, they were able to run their model and obtained the optimal solution immediately. To improve customer waiting time and operating expenses, the strategy relies on reassigning personnel among workstations. The model's output could imply that more staff are needed to improve service quality, or that some employees are overworked and should be assigned to activities such as cleaning, accounting, inventory, or other tasks that do not directly serve customers. Unlike previous models, this one takes a unique approach as it provides a mathematical model that allows for real-time personnel assignment. The mathematical model's optimal solution specifies the number of personnel to be assigned to each workstation as well as the projected customer service rate.

On the other hand, Strakhov [15] and Choi *et al.,* [17] did not provide much information on their research apart from the research objectives. Minimizing total labour cost over the one-week scheduling horizon by ensuring sufficient staffing for each day and meeting the minimum staffing requirements for each day were the objective and constraint proposed by Choi *et al.,* [17]. Meanwhile, Strakhov [15] only stated that the cost of the wages of scheduled hourly employees, and the cost of understaffing and overstaffing are minimized as the result of the study.

Love and Hoey [18] considered minimizing surplus hours scheduled and manpower skills as the objective function of their study and the main purpose of the study made was not focus on staff scheduling, therefore, it was not significant to this study. They considered a few aspects for the weekly personnel scheduling such as staff requirements in each work area, fast-food restaurants have no standard work shifts or workweeks, staffs work time preferences and staffs' skills. Last but not least, there was research made by Choi [16] solving the personnel scheduling problem using integer programming. The main reason for the study was to investigate an efficient use of labour in personnel scheduling for the restaurant industry and the result said that a new method in personnel scheduling allowed the industry to save labour cost, yet the method is not recognizable since the article was written in the Korean language. Table 1 shows the summary of research on the same topic done before using different models.

Table 1
Summary of past research on similar topic

Authors	Title	Method Used
Abdul Aziz *et al.*, [21]	A Linear Programming Approach in Solving Staff Scheduling Problem at Fast Food Restaurant	Linear Programming
Mohd Nasir *et al.*, [22]	Shift Scheduling with the Goal Programming Approach in Fast-Food Restaurant: McDonald's in Kelantan	Goal Programming
Budak and Chen [20]	A Multi-Objective Mathematical Model for Real-Time Employee Assignment in the Service Industry	Multi-objective Mixed-integer programming
Backman [23]	Scheduling Restaurant Staff using Integer Programming	Integer Programming
Liggayu *et al.*, [19]	A Mixed-Method Approach Workforce Optimization for Fast-Food Restaurants	Monte Carlo Simulation and integer programming
Choi *et al.*, [17]	Scheduling Restaurant Workers to Minimize Labor Cost and Meet Service Standards.	Linear Programming
Choi [16]	Personnel Scheduling of Restaurant Using Integer Programming	Linear Programming
Strakhov [15]	Mathematical Modelling Technique to Improve Fast Food Labor Scheduling	Linear Programming involving heuristics
Love and Hoey [18]	Management Science Improves Fast-Food Operations	Linear Programming

1.1.4 Current research
1.1.4.1 Research gap

Based on the analysis made, the majority of the research has the staff scheduled as the decision variables. The other variables are chosen to be used suit to the problems that need to be solved in the research. In this study, the decision variables used are the staff schedule, the chosen shift and day-off. Other variables were included based on the data collected during data collection.

1.1.4.2 Significant of research

The results of this study will contribute to the improvement of a company or workplace management not only in fast food restaurants but also in other service providers. This study is intended to assist fast-food restaurants by adopting this approach to schedule their workers or personnel more effectively, hence benefiting more parties such as staff and customers. The staff will probably satisfy with their working schedule as they no need to find a suitable time to get a break and just follow the prepared schedule. As for the customers, they will be satisfied with the services as they are served by the staff with minimum delay.

The result obtained is supposed to help the fast-food restaurant remains competitive in the industry as it continues to be the front runner resulting from the minimized cost and the improvement in term of service quality. At the same time, with the method used, it can save time to build a schedule for the staff. Using a proper and systematic technique is always preferable than doing everything manually in terms of time consumption. This will give more time and opportunity to the manager who builds the schedule to focus on the other duties and obligations.

1.1.4.3 Research objectives

There are three objectives for this research being conducted. The research objectives for this study are as follows

i. To analyse the current practice of personnel scheduling at the fast-food restaurant.
ii. To modify the personnel scheduling model according to the binary integer programming model.
iii. To minimize the number of fast-food restaurant staff by having an optimal working schedule that follows the considered factors.

2. Methodology

2.1 Observation

The identity of the fast-food restaurant will be kept unknown throughout this study to preserve the privacy of the data provider. The data was collected from a fast-food restaurant in Johor.

Based on a few days observation on different working time of the staff made at a fast-food restaurant in Johor at the end of January 2022, the biggest problem seen was the break time among the staff of the fast-food restaurant were unscheduled. The observation was done with the permission from Restaurant Manager. The staff need to take turns in order to have a break during their working hours so that the counters and the other workstations are not left idle without any staff.

2.2 Interview

The data was collected at the end of June 2022 by interviewing the Restaurant Manager. A total of 13 staff involved in this study not including the managers and the supervisors. The details of the data collected from the interview is shown in Table 2.

Table 2
The data collected from the fast-food restaurant

Item Details for Data Collection	Feedback												
Number of managers and supervisors	Managers						Supervisors						
	2 persons						2 persons						
Number of the staff	Full-time						Part-time						
	5 persons						8 persons						
Number of staff according to gender	Male						Female						
	7 persons						6 persons						
Number of the departments and details of the departments	Four departments												
	1. Cashier (CA)	2. Back-up (B)					3. Dining (D)			4. Cooking (CO)			
Minimum and maximum working hours for every staff	Minimum working hours						Maximum working hours						
	6 hours						8 hours						
Number of shifts in a day and state the shift time	Three shifts per day												
	Shifts						Shift Time						
	Opening/Morning						7:00 am – 3:00 pm						
	Middle						11:00 am – 7:00 pm						
	Closing/Night						3:00 pm – 11:00 pm						
Number of staffs needed in each shift according to the departments	Shifts	Opening				Middle				Closing			
	Department	CA	B	D	CO	CA	B	D	CO	CA	B	D	CO
	Number of Staff	1	1	0	1	1	1	1	1	1	2	0	1
Wage rate of staff per hour	Staff Status					Wage Rates							
	Full-time					RM 8.20 per hour							
	Part-time					RM 6.70 per hour							

2.3 Assumptions

In this study, the model was modified by implementing one break time for each staff during their working hours and the new modified model will be based on a one-day scheduling horizon. The implementation of this research work has some unavoidable limitations. Therefore, there are several assumptions made based on the observation and the interview made. The assumptions include

i. The model can be modified to suit the current situation of the fast-food restaurant.
ii. The staff in the model do not include the managers and supervisors.
iii. The schedule made is one-day scheduling focusing on the staff break time in the shift.
iv. The model does not offer day-off flexibility to the staff.
v. If the staff in charged is having break time, the supervisor or manager will replace them so that no workstation will be idle.
vi. Overlap shifts do not affect the scheduling but required more staff since it on peak hour.
vii. The staff status such as part-timer or full-timer is not affecting the scheduling.
viii. All staff in the cashier department are female and all staff in the cook department are male, however, the scheduling is not influenced by the gender of the staff.
ix. The break period is divided into four only since the number of staff is small.

2.4 Binary Integer Programming (BIP) Approach

BIP could signify a choice being made or not, a switch being turned on or off, a yes or no response, or many other situations. The BIP model in this study was constructed to minimize the number of staff that need to come for work in a day. The parameters used are as in Table 3 while the sets are as in Table 4. The sets of indices define the basic structural elements of the model.

Table 3
Parameters used in modified model

Parameter	Details
p_{ik}	Minimum number of staff working per shift
q_{ik}	Maximum number of staff working per shift
r_{ijk}	Minimum number of staff working in one day for all shifts
s_{ijk}	Maximum number of staff working in one day for all shifts
t_{il}	Minimum number of staff having a break in one break period
u_{il}	Maximum number of staff having a break in one break period
v_i^k	Maximum working shift per staff per day

Table 4
Sets used in modified model

Set	Details
I	Set of the fast-food restaurant staff (i.e., *i* ∈*I*, *I*={1, 2, ⋯, 13})
J	Set of the departments (i.e., *j* ∈*J*, *J*={1 (Cashier), 2 (Back-up), 3 (Dining), 4 (Cook)})
K	Set of shift types (i.e., *k* ∈*K*, *K*={1 (Opening Shift), 2 (Middle Shift), 3 (Closing Shift)})
L	Set of the break periods (i.e., *l* ∈*L*, *L*={1 (Period 1), 2 (Period 2), 3 (Period 3), 4 (Period 4)})

2.5 Decision Variable

The binary variable is represented as x_{ijkl}, is the decision variable that most accurately depicts the model's answer. The decision variable value 1 indicates that staff i is working in department j on shift k and having a break in period l. The value 0, on the other hand, suggests the opposite. Consequently, the decision variable for the model is represented as follows

$$x_{ijkl} = \begin{cases} 1, & \text{staff } i \text{ is working in department } j \text{ on shift } k \text{ and having break in period } l \\ 0, & \text{otherwise} \end{cases}$$

2.6 BIP Model

The full BIP model for the personnel scheduling is expressed as

Minimize personnel, $Z = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{l=1}^{L} x_{ijkl}$ (1)

subject to

$$p_{ik} \le \sum_{k=1}^{K} x_{ijkl} \le q_{ik}, \ \forall i \in I, j \in J, l \in L \quad (2)$$

$$r_{ijk} \le \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{l=1}^{L} x_{ijkl} \le s_{ijk} \quad (3)$$

$$t_{il} \le \sum_{l=1}^{L} x_{ijkl} \le u_{il}, \ \forall i \in I, j \in J, k \in K \quad (4)$$

$$\sum_{i=1}^{I} x_{ijkl} \le v_i^k, \ \forall j \in J, k \in K, l \in L \quad (5)$$

For *j* = 1, *k* = 1, 2, 3

$$\sum_{j=1}\sum_{k=1}^{3} x_{ijkl} = 1, \ \forall i \in I, l \in L \quad (6)$$

For *j* = 2, *k* = 1, 2

$$\sum_{j=2}\sum_{k=1}^{2} x_{ijkl} = 1, \ \forall i \in I, l \in L \quad (7)$$

For *j* = 2, *k* = 3

$$\sum_{j=2}\sum_{k=3} x_{ijkl} = 2, \ \forall i \in I, l \in L \quad (8)$$

For *j* = 3, *k* = 1, 3

$$\sum_{j=3}\sum_{k=1,3} x_{ijkl} = 0, \ \forall i \in I, l \in L \quad (9)$$

For *j* = 3, *k* = 2

$$\sum_{j=3}\sum_{k=2} x_{ijkl} = 1, \ \forall i \in I, l \in L \quad (10)$$

For *j* = 4, *k* = 1, 2, 3

$$\sum_{j=4}\sum_{k=1}^{3} x_{ijkl} = 1, \ \forall i \in I, l \in L \quad (11)$$

$$x_{ijkl} = \begin{cases} 1, & \text{staff } i \text{ is working in department } j \text{ on shift } k \text{ and having break in period } l \\ 0, & \text{otherwise} \end{cases} \quad \forall i, j, k, l \quad (12)$$

The objective function (1) intends to minimize the number of staff working for the day. The objective function also helps in defining the staff's day-off and the period for their break if they are in their working day. Constraint (2) ensures that the number of staff working per shift are satisfying both minimum and maximum boundaries. Constraint (3) considers the total number of staff working in one day for all shifts according to the minimum and maximum requirements. On the other hand, constraint (4) is a new constraint introduced in this study to restrict the number of staff that can have break time in one break period to keep the workstations occupied. Constraint (5) restricts the maximum working shift that each staff should be working in a day. Constraints (6) until (11) are limiting the number of staff in each department stated for each shift which is predetermined by the restaurant's management. Lastly, constraint (12) is the binary decision variable where if the value is 1, shows that staff *i* work in department *j* on shift *k* and having *l* break period. Otherwise, it will be 0.

3. Results

3.1 Current Practice of Personnel Scheduling at the Fast-food Restaurant

Based on the observation made, the problem of unscheduled break time during working hours among the staff was the most remarkable issue. The current scheduling was done based on the weekly horizon where a new schedule will be distributed to all staff by the managers every Sunday. The day-off of each staff is randomly determined by the schedule's maker.

3.2 Staff Allocation for Optimal Working Schedule

Currently, 13 staff are working in the restaurant with 4 different departments and 3 shifts in a day. The staff are coded as number 1 until number 13. The details of the staff are shown in Table 5 while Table 6 and Table 7 shows the details of the shift time and break period time respectively.

Table 5
Details of the staff

Staff (*i*)	1,2,3,4	4,5,6,7,8	9,10	10,11,12,13
Department (*j*)	Cashier	Back-up	Dining	Cook

Table 6
The shift time

Shift (*k*)	Shift Types	Time
1	Opening Shift	7:00 am – 3:00 pm
2	Middle Shift	11:00 am – 7:00 pm
3	Closing Shift	3:00 pm – 11:00 pm

Table 7
The break period time

Period (*l*)	Time
1	10:00 am - 11:00 am
2	12:00 pm - 1:00 pm
3	4:00 pm - 5:00 pm
4	6:00 pm - 7:00 pm

The scheduling must follow the restrictions set by the company where there will be only a certain number of staffs who can work in each department for the shift. According to the data gathered from the fast-food restaurant, the value of the parameters is as shown in Table 8.

Table 8
The value of the parameters for the modified model

Parameters	p_{ik}	q_{ik}	r_{ijk}	s_{ijk}	t_{il}	u_{il}	v_i^k
Value	3	5	11	12	1	3	1

With all the data collected and the modified model developed previously, the numerical data as shown before can be applied to the model and solved using Microsoft Excel Solver. The dimension of the technology matrix is 41 rows by 90 columns which represent that there are 41 constraints expansion and 90 decision variables.

3.2.1 Comparison of real schedule and proposed schedule

A comparison between the real schedule and the proposed schedule is made to identify the difference between the two schedules and to identify whether the newly proposed schedule is an optimal working schedule that meets all the conditions and limitations set by the fast-food restaurant. Table 9 shows the real and proposed personnel schedule of fast-food restaurant for one day.

Table 9
Real and proposed personnel schedule of the fast-food restaurant

Department	Staff (x_i)		Working Time	Shift	Total Staff in Department		Shift	Break Period	Total Staff in Department
Cashier	1 (F)	Real Personnel Schedule	8.00 am – 4.00 pm	1	3	Proposed Personnel Schedule	2	3	3
	2 (P)		3.00 pm – 11.30 pm	3			3	3	
	3 (P)		11.00 am – 10.00 pm	2			1	1	
	4 (F)		-	-			-	-	
Back-up	4 (F)		7.00 am – 3.00 pm	1	4		2	3	4
	5 (F)		-	Day-off			1	1	
	6 (P)		10.00 am – 5.00 pm	2			Day-off	-	
	7 (P)		5.00 pm – 11.30 pm	3			3	4	
	8 (P)		4.00 pm – 11.00 pm	3			3	4	
Dining	9 (P)		1.00 pm – 10.00 pm	2	1		2	2	1
	10 (P)		-	-			-	-	
Cook	10 (P)		3.00 pm – 11.00 pm	3	4		1	2	3
	11 (F)		7.00 am – 3.00 pm	1			2	2	
	12 (F)		11.00 am – 7.00 pm	2			Day-off	-	
	13 (P)		4.00 pm – 11.30 pm	3			3	4	
				Total working staff	12			Total working staff	11

The weakness of the current scheduling is there is no predetermined break period for the staff. The staff need to find some time for themselves to have a break in the mid of their working hours to perform prayer and have a meal. Another weakness found in the real schedule is the working time for some staff is not equal to 8 hours which contradicts the shift timing for the fast-food restaurant.

A new schedule on the right side of Table 9 was proposed by adapting the modified model using a binary integer programming model to overcome the weaknesses of the real schedule made by the manager. The break period of the staff is taken into account while considering the shift time for each staff not exceeding or less than 8 hours.

Based on the result derived from the modified BIP model, the schedule is now pre-set the break time for each staff and the working hour for each staff is fairly distributed. The timing of the shift and the break period is similar as indicated in Table 6 and Table 7 respectively. Based on Table 9, there are a few differences that can be pointed out to validate the proposed schedule is better than the real schedule. Table 10 is prepared to illustrate the comparison between the two schedules.

Table 10
Comparison of real schedule and proposed schedule

Real Schedule	Proposed Schedule
The schedule is done manually	The schedule is generated using the BIP model
Take time to build the schedule	Save time in making the schedule
Inflexible when there are changes that need to be made	Easily change the schedule by adjusting the constraints
Does not consider the break time of the staff	Pre-set the break period for the staff
Unfair working hours	Fairly distributed working hours
Working hour does not necessarily follow the shift timing	Working hours strictly follow the shift timing
The number of working staff in one day is 12	The number of working staff in one day is 11

Through the comparison made in Table 10, it is proven that the proposed schedule is far better than the real schedule in most aspects.

3.2.2 Cost minimization

With the data obtained the salary cost can be calculated by multiplying the hourly wage rate by the total working hours. The salary cost calculation made is shown in Table 11.

Table 11
Calculation of salary cost

Calculation	Real Schedule	Proposed Schedule
Salary cost per day for full-time staff = Σ (RM 8.20 × working hours × number of staff)	RM 8.20 × 8 hours × 4 staff = RM 262.40	RM 8.20 × 8 hours × 4 staff = RM 262.40
Salary cost per day for part-time staff = Σ (RM 6.70 × working hours × number of staff)	(RM 6.70 × 8.5 hours × 1 staff) + (RM 6.70 × 11 hours × 1 staff) + (RM 6.70 × 7 hours × 2 staff) + (RM 6.70 × 6.5 hours × 1 staff) + (RM 6.70 × 9 hours × 1 staff) + (RM 6.70 × 8 hours × 1 staff) + (RM 6.70 × 7.5 hours × 1 staff) = RM 432.15	RM 6.70 × 8 hours × 7 staff = RM 375.20
Salary cost per month = (Salary cost per day for full-time staff × 24 days) + (Salary cost per day for part-time staff × 24 days)	(RM 262.40 × 24 days) + (RM 432.15 × 24 days) = RM 16 669.20	(RM 262.40 × 24 days) + (RM 357.20 × 24 days) = RM 14 870.40

Based on the calculation made, it is convinced that the proposed schedule can minimize the salary cost by reducing RM 1 798.80 from the current salary cost using the real schedule.

4. Conclusions

This study intended to minimize the number of fast-food restaurant personnel who must be working in a day following the restrictions set by the fast-food restaurant based on the identified problem through the analysis of their current practice on personnel scheduling. The process of minimizing the working personnel is done by modifying an integer programming model to a binary integer programming model before substituting the data collected into the model.

The current practice of personnel scheduling for the fast-food restaurant is not practical to be implemented as the staff do not have predetermined break time, therefore, the study modified the model by Ang *et al.,* [7] to build a model that suits the current practice of personnel scheduling at the fast-food restaurant under study according to the binary integer programming model. The objective function of the actual model was then modified and simplified in the form of the BIP model as in Eq. (1) with some similar constraints and a new constraint, constraint (4) which restricts the number of staffs that can have break time in one break period to keep the workstations occupied.

Finally, the model was run using the collected data to minimize the number of fast-food restaurant staff by having an optimal working schedule that follows the considered factors. The results attained where 11 staff should be working in one day, therefore, it was successfully minimized the number of the staff by reducing 1 staff from the current schedule. The values of the decision variables were then extracted and gathered to build a new and optimal personnel schedule. A comparison between the real schedule and the new proposed schedule also was made. Considering all of the facts, the BIP model really helps in scheduling the staff of a fast-food restaurant.

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References
[1] Guo, Junhong. "Optimization Approaches for Solving Large-Scale Personnel Scheduling Problems." *PhD diss., University of Michigan*, 2021. https://doi.org/10.7302/2803
[2] Alwadood, Zuraida, Norlenda Mohd Noor, and Nurul Ainaa Mainor. "An optimization model for hotel housekeeping personnel scheduling in pandemic outbreak." *Menemui Matematik (Discovering Mathematics)* 43, no. 2 (2021): 83-92.
[3] Choi, Kyuwan, Johye Hwang, and Myoungju Park. "Scheduling restaurant workers to minimize labor cost and meet service standards." *Cornell Hospitality Quarterly* 50, no. 2 (2009): 155-167. https://doi.org/10.1177/1938965509333557
[4] Sasaki, Natsu, Reiko Kuroda, Kanami Tsuno, and Norito Kawakami. "Workplace responses to COVID-19 associated with mental health and work performance of employees in Japan." *Journal of Occupational Health* 62, no. 1 (2020): e12134. https://doi.org/10.1002/1348-9585.12134
[5] Mahmud, Norwaziah, Siti Hafawati Jamaluddin, Intan Syafina Hamidun, and Nur Syuhada Muhammat Pazil. "Optimization of workforce scheduling using integer goal programming approach." *Jurnal Intelek* 13, no. 1 (2018): 27-36.
[6] Chinneck, John W. *Practical Optimization: A Gentle Introduction*. Carleton University, 2000.
[7] Ang, Shin Yin, M. Razali, S. N. Asyikin, and S. L. Kek. "Optimized preference of security staff scheduling using integer linear programming approach." *An International Journal of Advanced Computer Technology* 8, no. 4 (2019): 3103-3111.
[8] Ernst, Andreas T., Houyuan Jiang, Mohan Krishnamoorthy, Bowie Owens, and David Sier. "An annotated bibliography of personnel scheduling and rostering." *Annals of Operations Research* 127, no. 1-4 (2004): 21-144. https://doi.org/10.1023/B:ANOR.0000019087.46656.e2
[9] Baker, Kenneth R. "Workforce allocation in cyclical scheduling problems: A survey." *Journal of the Operational Research Society* 27, no. 1 (1976): 155-167. https://doi.org/10.1057/jors.1976.30
[10] Othman, Mohammed, Gerard J. Gouw, and Nadia Bhuiyan. "Workforce scheduling: A new model incorporating human factors." *Journal of Industrial Engineering and Management (JIEM)* 5, no. 2 (2012): 259-284. https://doi.org/10.3926/jiem.451
[11] Brunner, Jens O. "Literature Review on Personnel Scheduling." *Flexible Shift Planning in the Service Industry: The Case of Physicians in Hospitals* (2010): 5-12. https://doi.org/10.1007/978-3-642-10517-3_2
[12] Hillier, Frederick S., and Gerald J. Lieberman. "Introduction to operations research." *Nkumba University* (2001).
[13] Fourer, Robert, David M. Gay, and Brian W. Kernighan. *AMPL: A Modeling Language for Mathematical Programming*. Thomson/Brooks/Cole, 2003.
[14] Conforti, Michele, Gerard Cornuejols, and Giacomo Zambelli. "Integer Programming." *Operations Research and Management Science Handbook* (2014). https://doi.org/10.1007/978-3-319-11008-0_2
[15] Strakhov, Catherine Ludmilla. "A mathematical modeling technique to improve fast-food labor scheduling." *PhD diss., Massachusetts Institute of Technology*, 1991.
[16] Choi, Kyu-Wan. "Personnel Scheduling of Restaurant using Integer Programming." *Korean Journal of Community Nutrition* 12, no. 5 (2007): 630-638. https://doi.org/10.5711/morj.12.1.5
[17] Choi, Kyuwan, Johye Hwang, and Myoungju Park. "Scheduling restaurant workers to minimize labor cost and meet service standards." *Cornell Hospitality Quarterly* 50, no. 2 (2009): 155-167. https://doi.org/10.1177/1938965509333557
[18] Love, Robert R., and James M. Hoey. "Management science improves fast-food operations." *Interfaces* 20, no. 2 (1990): 21-29. https://doi.org/10.1287/inte.20.2.21

[19] Liggayu, Alaine, Danilo David, Venniel Lubguban, and Maria Cielo Perez. "A Mixed-Method Approach Workforce Optimization for Fast-Food Restaurants." In *Proceedings of International Conference on Technological and Social Innovations 2018*. 2018.

[20] Budak, Gercek, and Xin W. Chen. "A Multi-Objective Mathematical Model for Real-Time Employee Assignment in the Service Industry." *Research Square* (2021). https://doi.org/10.21203/rs.3.rs-842497/v1

[21] Abdul Aziz, Nurul Liyana, Nur Lidiya Irdina Azmi, Nurul Aina Afiqah Azhar, and Siti Syafiqa Safie'e. "A linear programming approach in solving staff scheduling problem at fast food restaurant." *Mathematics in Applied Research* 2 (2022): 28-32. https://doi.org/10.55606/kreatif.v2i2.449

[22] Nasir, Diana Sirmayunie Mohd, Nur Darina Aimi Sabri, Nor Hayati Shafii, and Suzanawati Abu Hasan. "Shift Scheduling with the Goal Programming Approach in Fast-Food Restaurant: McDonald's in Kelantan." *Journal of Computing Research and Innovation* 7, no. 2 (2022): 107-115. https://doi.org/10.24191/jcrinn.v7i1.279

[23] Backman, Inga María. "Scheduling restaurant staff using integer programming in cooperation with Matur og drykkur." *PhD diss., Reykjavik University*, 2020.