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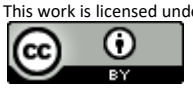

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OPTIMIZED PREFERENCE OF SECURITY STAFF SCHEDULING USING INTEGER LINEAR PROGRAMMING APPROACH

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Abstract: This paper proposes an optimized schedule for security staff using integer linear programming approach. It is important to improve the life quality of the security staff since the negative social life such as family problems, less social support or even stress following from a poor work schedule. Therefore, this study aims to maximize the preference satisfaction of the security staff by allowing them to choose their preferred shift and day off while taking into consideration the restrictions of the university rules. The mathematical model of integer linear programming approach is developed and solved by using LPSolve IDE package. The result shows the overall preference satisfaction of the security staff towards work shift and days off is successfully maximized from 228.33 to 394.33. The comparison of the real schedule and the new proposed optimized schedule is made and all the constraints are successfully satisfied. The proposed schedule will be able to assist the university management in producing the most flexible and beneficial schedule for their staff to increase the satisfaction towards the working life.

Keywords: scheduling; shift; preference; integer programming; security staff

I. INTRODUCTION

Scheduling is a complex process of assembling work timetables for different number of staff and different type of tasks [1, 2]. Scheduling is indeed important in the area of manufacturing and service. By considering the limited resources, scheduling functions as a plan to optimize the objective of management and achieve the goals of company in a fixed period of time, normally a week or a month [2, 3]. Additionally, the workforce scheduling problems are traditionally classified into three types: shift scheduling, days off scheduling, and tour scheduling. Shift scheduling determines each employee's work and breaks hours per day. Days off scheduling determines each employee's workdays and off days per week or multiple-week work cycle. Meanwhile, the tour scheduling combines the shift and days off scheduling problems by determining each employee's daily work hours and weekly workdays [4].

Security staff scheduling is the procedure of assigning staff to a certain task in a set of shifts during a fixed period of time [2]. A proper schedule for the security staff is important for an institution or a company as they are responsible to make sure the surrounding is safe and secure. Security staff should be always in a good condition physically, mentally and emotionally since their job need a high attention during all the period to keep the property as well as the people safe. In general, the schedule of security staff, which is performed for 24 hours, is assigned to the shift due to their post.

Normally, the security staff has different preference for their work shift and day off depending on their lifestyle. This is due to the diverse personal lifestyles and different degrees of physical tolerance for continuous working days [5]. The preference satisfaction of security staff enables them to have a proper rest in order to increase the quality of their service. Besides, a security staff who can work at his/her preference work shift and rest at his/her preference day can have a positive social life. On the other hand, a low preference satisfaction schedule will create disturbances in their lives, no time for family and friends as well as having health problems [6, 7]. Thus, this study is aim to produce a schedule that consider the preference and opinion of security staff to ensure their performance of work is always in high level. This win-win situation between the management and the security staff could be achieved.

There is less studies in the literature that consider the preference of workforce especially for security staff. None of them includes both criteria, the preference of work days and days off in developing the optimal schedule for security staff. To fill in the gap, this paper proposes a mathematical model for scheduling the security staff at Universiti Tun Hussein Onn Malaysia (UTHM) which includes the preference of shift and day offs for one-week period. This model includes maximum number of staff for each shift as a hard and preference rank towards each shift as a soft constraint in order to maximize the satisfaction of security staff towards the working life. The optimization approach, integer linear programming approach was applied to find the optimal schedule in thousands of solution space.

There are many types of shift and day off such as four hours shift, six hours shift and eight hours shift. Meanwhile, for days off, there are random two days in a week, two continuous days in a week or one day in a week. In UTHM, the schedule applies eight hours shift and continuous two days off after six days working for eight days' cycle. The problem exists when their working days is different than normal period which is seven days' cycle. Hence, this study proposes the seven day's schedule to overcome the problem.

The next section discusses on previous studies related to scheduling problem, followed by methodology, which discusses the development of the mathematical model and ending with the result and discussion on sensitivity analyses. At the end, the conclusion is made.

II. Previous Related Works

The scheduling functions in a company or an organization rely on mathematical techniques and heuristic methods to allocate limited resources for the activities that have to be done. This allocation of resources has to be handled efficiently in order to optimize the objectives and goals of the company or the organization. The resources could be machines in a workshop, runways at an airport, crews at a construction site, or processing units in a computing environment. Activities would be operations in a workshop, take-offs and landings at an airport, stages in a construction project, or computer programs that have to be executed. Each activity has a priority level to be done, where an earliest possible starting time and a due date are taken into consideration. The various objectives of the scheduling such as minimizing the time to complete all activities, and minimizing the number of activities that are completed after the committed due dates are considered [3].

Nursing scheduling is one type of the workforce scheduling which generate a schedule for each nurse that involves in shift duties and days off within a certain planning period. Multiple sources of uncertainties are considered in the real world application to provide a higher quality schedule, where the minimum demand and other time related constraints are met to maximize the preference of nurse [8]. Staff scheduling considers three varieties of shift work including a stable/permanently, rotating shift and on-call shift with organized in an eight-hour working time [5].

Other than the workforce scheduling, single machine schedule, flow shop scheduling, and job shop scheduling are the three basic types of scheduling in machine schedule [9]. Meanwhile, in academic area, educational scheduling problem is classified into three main classes which are school, course, and examination timetabling [10]. Examination scheduling is a scheduling problem to distribute a number of exams into a potential time period or slots within the examination period [11].

Linear programming is well-performed to produce optimal class schedule [12, 13], nursing schedule [14, 15, 16, 17] and manpower schedule [18, 19, 20, 21, 22, 30]. Class scheduling solves the class schedule to fit into timetables with limited facilities and teachers, while [14] solved the nursing schedule with a right mix of nursing skills for 24 hours' effectiveness and different shift allocation.

Besides that, integer linear programming approach had been applied to maximize the capacity of bed allocation [16], to build an effective maintenance schedule for manpower in airport service [18] and to minimize the training cost for academic and non-academic staff [20]. These studies showed the integer linear programming approach is successfully obtained a comprehensive schedule in different fields to achieve the objectives of company.

In addition, the study of [23] focuses on the maintenance workforce scheduling at Afam Power Station in Nigeria, with the objective to optimize the schedule in order to satisfy growing maintenance labour requirements with the minimum cost and the highest efficiency by applying the integer linear programming.

Integer programming is also used to maximize the nurse preferences in nurse scheduling problem [15, 24]. The preference of staff becomes the soft constraint due to the humanity when designing the schedule [5, 25], where the nurse staff's preference satisfaction to the shift is considered [5]. Meanwhile, [25] also solved the schedule with optimizing the employee satisfaction by applying the binary integer programming approach.

From the previous studies [30], integer linear programming is widely used in different fields to solve complex scheduling problem. It also obtains solution faster than constructing a schedule manually. With the recent big

data trend, the workforce schedule should be run by computer to produce more possible solutions to achieve the objectives effectively.

When the scheduling problem become more complex and involve thousands of variables, heuristic approaches are the best technique to obtain the best or near optimal solution. [26, 27] classified heuristic methods into several categories which are decomposition method, inductive method, reduction method, constructive method and local search method. [28] used tabu search algorithm to resolve the course schedule with the aim to minimize the conflict between lessons in the same section. Meanwhile, [29] applied genetic algorithm to solve the scheduling problem in well-service companies. Both studies show both heuristic techniques were successful producing efficient schedule in less computational time. In addition, genetic algorithm is a flexible method that can provide an acceptance result and easily extended to various resource scheduling areas such as process scheduling and transportation scheduling.

III. METHODOLOGY

In this study, both qualitative data and quantitative data are involved where the data are collected through interview and survey form distribution.

A. Interview

Interview was conducted with the person in charge in developing the schedule of security staff at UTHM in order to understand how the current schedule is built and the constraints that should be fulfilled. UTHM has 55 security staffs under the general section. The male staffs go on duty for six continuous days, which starts with the morning shift for two days, the afternoon shift for two days and the night shift for two days. Meanwhile, the female staffs go on duty for six continuous days, which starts with the morning shift for two days and followed by the afternoon shift for four days. Note that the difference between the male and female staffs is that the female staffs are not assigned to the night shift due to safety purpose.

There are 45 staffs are required to be on duty in each day, which consists of 13 staffs for the morning shift, 17 staffs for the afternoon shift and 15 staffs for the night shift. Besides that, we were informed that the staff should only be assigned one shift in each day and have at least eight hours rest between two shifts in two continuous days. Apart from that, a survey form was constructed and distributed to collect the data of preferred shift and the day off of each security staff. The real schedule of one week, starting on 6 March 2017- 12 March 2017 was collected with the purpose of comparison with the proposed schedule from this study.

B. Integer Programming Approach

The mathematical model consists of three components, which are decision variable, objective function and constraints. The integer programming model is constructed to maximize the overall preference satisfaction of the security staffs towards the shifts and the days off.

The symbols of subscript in the model are:

i Index of a security staff
j Index of a shift type
k Index of day off
p Index of preference

The symbols of the parameters in the model are:

I Set of the security staff (i.e., $i \in I$, $I = \{1, 2, \ldots, 55\}$)
J Set of shift types (i.e., $j \in J$; J = {1 (morning shift), 2 (afternoon shift), 3 (night shift)})
K Set of days off (i.e., $k \in K$, K = {Mon, Tues, Wed, Thurs, Fri, Sat, Sun})
$P_{i,j}$ The preference shift of each security staff = {0 (not preferred), 1 (preferred)}
$A_{i,j}$ The availability shift of each security staff = {0 (not preferred), 1 (preferred)}
$W_{i,j}$ The preference weight of each security staff
$D_{j,k}$ Manpower demand in shift *j* on day *k*
$\tau_{i,j}^{\min}$ Minimum number of shift that the staff *i* assigned in shift *j* in a week
$\tau_{i,j}^{\max}$ Maximum number of shift that the staff *i* assigned in shift *j* in a week
$S_{i,j}$ The number of shift for security staff to be assigned in each day

C. Decision Variable

$X_{i,j}$ Staff *i* is scheduled for shift *j*, $\in$ {0 (off shift), 1 (on shift)}.
$X_{i,k}$ Staff *i* is scheduled on day off *k*, $\in$ {0 (day off), 1 (day on)}

D. Objective Function

First, the objective function of the model is explained as follows. The overall preference satisfaction of the security staff towards work shifts and days off [25] is given by

$$Max = \sum_{i}^{I} \sum_{j}^{J} \left(X_{i,j} W_{i,j} \right) \tag{2.1}$$

where $i = 1, 2, 3, \ldots, 55$; $j = 1, 2, 3$

The weight of preference satisfaction [25] for each security staff is calculated by

$$W_{i,j} \begin{cases} 0 & , \quad A_{i,j} = 0, P_{i,j} = 1 \\ 1+\alpha & , \quad A_{i,j} = 1, P_{i,j} = 1 \\ 1-\beta & , \quad A_{i,j} = 1, P_{i,j} = 0 \end{cases} \tag{2.2}$$

where α and β in the weight of preference satisfaction [25] in Eq. (2.2) is obtained from

$$\alpha = \frac{\sum A_{i,j} - \sum P_{i,j}}{\sum A_{i,j}} \quad (2.3)$$

$$\beta = \alpha\left(\frac{\sum P_{i,j}}{\sum A_{i,j} - \sum P_{i,j}}\right) \quad (2.4)$$

where $i = 1, 2, 3, \ldots, 55$
$j = 1, 2, 3$

E. Constraints

For the first constraint, the manpower demand and the number of security staff in each shift for each day should be met. For the morning shift, there are 13 staffs on duty, that is,

$$D_{1,k} = 13 \quad (2.5)$$

For the afternoon shift, there are 17 staffs on duty, that is,

$$D_{2,k} = 17 \quad (2.6)$$

For the night shift, there are 15 staffs on duty, that is,

$$D_{3,k} = 15 \quad (2.7)$$

The second constraint consists of each security staff is given at least one day off but not more than two days off for each week, that is,

$$1 \le \sum_{i}^{I}\sum_{k}^{K} X_{i,k} \le 2 \quad (2.8)$$

The third constraint is each security staff is assigned to at most one work shift for each day, that is,

$$S_{i,j} \le 1 \quad (2.9)$$

The forth constraint is the interval between two shifts to be assigned for each staff must equal or more than 8 hours if we want to as-signed in two continuous days, that is,

$$\sum_{j}^{j+2} X_{i,j} \le 2 \quad (2.10)$$

where $i = 1, 2, 3, \ldots, 55$; $j = 1, 2, 3$

The fifth constraint is the maximum total number of security staff are allowed to have day off in each day, that is,

$$\sum_{i}^{I}\sum_{k}^{K} X_{i,k} \le 10 \quad (2.11)$$

where $i = 1, 2, 3, \ldots, 55$; $k = 1, 2, 3,4,5,6,7$

The sixth constraint is the security staff should work between their minimum and maximum shifts per week.

$$5 \le \sum_{i}^{I}\sum_{j}^{J} X_{i,j} \le 6 \quad (2.12)$$

where $i = 1, 2, 3, \ldots, 55$; $j = 1, 2, 3$

The decision variables of work shifts and days off should be either zero or one, given by

$$X_{i,j} \in \{0,1\}, \forall_i \in I, j \in J \quad (2.13)$$

$$X_{i,k} \in \{0,1\}, \forall_i \in I, k \in K \quad (2.14)$$

IV. Result and Discussion

In this paper, a schedule is created to maximize the overall preference satisfaction of the security staff towards work shifts and days off, Z which is targeted on 55 security staffs at UTHM which consists of 48 males and 7 females. The female staffs are coded as A11, A12, B11, B12, C12, D11 and D12, while the other codes represent male staffs.

A. Data Analysis

The schedule of security staff for each day is divided into three shifts which consist of morning shift (1), afternoon shift (2) and night shift (3). Each shift has 8 hours. The preference weight of each security staff is calculated using Eq. (2.2).

The availability shift means that the staffs are free at the particular shift while the preference shift means that the staff is willing to work at the specific shift. For example, if staffs prefer to work at the morning shift, the staff will choose every morning shift as preference and not choosing the afternoon or night shift. From the availability and preference shift of a staff, α and β are calculated to get the preference weight of each security staff.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	Day of Week		Mon			Tue			Wed			Thur			Fri			Sat			Sun		
2	Shift of Day		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
3	Readable Shift		12A	8AM	4AM	12A	8AM	4AM	12A	8AM	4AM	12A	8AM	4AM	12A	8AM	4AM	12A	8AM	4AM	12A	8AM	4AM
4		*Employee*																					
5		A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
6		AA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
7		A1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
8		A2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0

Fig. 1: Availability Shift for Partial UTHM Security Staff

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	Day of Week		Mon			Tue			Wed			Thur			Fri			Sat			Sun		
2	Shift of Day		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
3	Readable Shift		12A	8AM	4AM	12A	8AM	4AM	12A	8AM	4AM	12A	8AM	4AM	12A	8AM	4AM	12A	8AM	4AM	12A	8AM	4AM
4		*Employee*																					
5		A	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1
6		AA	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
7		A1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1
8		A2	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0

Fig. 2: Preference Shift for Partial UTHM Security Staff

For example, from Fig. 1, staff A2 is available from Monday until Friday and wish to take off on Saturday and Sunday. So, the shift for Monday until Friday is coded as 1

while Saturday and Sunday is coded as 0. Staff A2 prefers to work at the afternoon shift, then every afternoon shift is coded as 1, while the other shifts are coded as 0 as shown in Fig. 2. After that, α and β are computed to get the preference weight of each security staff, $W_{i,j}$. With Fig. 1 and Fig. 2, the total availability of staff A2, is 15 and the total preference of staff A2, is 7.

Result from the survey showed that majority of staffs prefer to work on morning shift (40%), followed by night shift (36%) and afternoon shift (24%) (refer Fig. 3(a)). Fig. 3(b) illustrated Saturday, Sunday, Thursday and Monday is the most preferred day off in ascending order which have 33 staffs, 25 staffs, 20 staffs and 14 staffs respectively. Friday and Wednesday is the fifth and sixth preferred day off. There are 9 staffs chose Friday and 7 staffs chose Wednesday as their day off. The less preferred day off is Thursday where there are only 2 staffs preferred that day as their day off.

In the proposed schedule, Fig. 3(c) show that 40 staffs (73%) are successfully allocated according to their preference and only 15 staffs (27%) are partially allocated to their preference. Meanwhile, for the day off, the Fig. 3(d) demonstrates 11 staffs (20%) are successfully allocated to their preferred day off, 35 staffs (64%) are partially allocated to their preferred day off and 9 staffs (16%) are not allocated according to their preferred day off.

The demand for one day requires 45 staffs to be on duty with 13 staffs for the morning shift, 17 staffs for the afternoon shift and 15 staffs for the night shift. Therefore, a seven day cycle needs 315 staffs to be on duty. By having 55 staffs, and each staff given two days off in a cycle, there will only be 275 shifts (5 working days x 55 staffs) to be fulfilled in a seven days cycle. As a result, there will be less than forty shifts to be assigned to the security staffs to work.

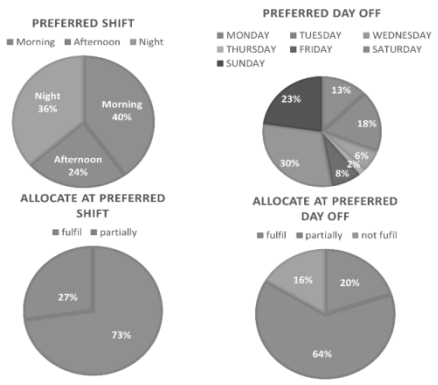

Fig 3: The preferred shift (a), preferred day off (b), allocate at preferred shift (c) and allocate at preferred day off (d).

From the survey, most of the security staffs at UTHM prefers to work overtime and there is only one staff who dislikes overtime work. Thus, the forty shifts need to be covered by overtime worker. 40 staffs will be needed to do overtime and the other 15 staffs will not be needed to do any overtime work. Therefore, the management does not need to choose 3 to 4 staffs during their day off to meet the demand of every shift. By changing the schedule from the eight days cycle to the seven days cycle, the staffs have more probability to work on fixed shift on a certain day.

B. Comparison of Real Schedule and Proposed Schedule

Table 1 shows the real schedule of UTHM security staff for one week. There are several weaknesses found in the real schedule. First, from Table 1, we can see that the female staffs are assigned to the night shift which contradicts the rule of security department. Second, there are lack of staff for every shift demand required by security department where the symbol *E* represents the staff needed to be chosen by the management to fulfil the requirement of each shift. From Table 1, four staffs are needed to be selected for duty during their day off for each day. As a result, we can conclude that the real schedule of UTHM security staff does not follow the rule appropriately and do not considered the preference of staff for shift and day off where the objective function, *Z* value for real schedule is only 228.33.

Thus, this study is conducted to improve the performance of security department in term of scheduling problem. The new proposed schedule in Table 2 represents the *Z* value is maximized up to 394.33. Moreover, in the new proposed schedule, there is no female staffs are assigned to any of the night shifts. This is the hard constraint which the real schedule could not fulfil. The female staffs are not encouraged to work at the night shift because night seems more dangerous for them. As a working mother, they also need to look after their children especially those with small children or babies. With the use of the new proposed schedule, it is a great help to allow working mothers to balance their working life and responsibilities at home both as a wife and a mother.

Besides that, the demand for each shift is fulfilled. There is no issue in lacking of staff for every shift. The security staff would never being call back for duty during their day off. However, each staff will have at least one day off but not more than two days off in a week. So, the staff that works for six days will have only one day off. They are required to work one day extra than those staffs who work five days in a week. So, the extra one day is known as the overtime work.

The objective of this study is to maximize the overall preference satisfaction of the security staff towards work shift and days off. From the result, there are 5 staffs totally fulfil their preferred work shift and day off, which are staff B12, C7, C12, D1 and D11. Staff B12, D1 and D11 prefers the afternoon shift while staff C7 and C12 prefer the morning shift. Staff B2 and D7 prefer to off at Thursday and Friday, staff C12 and D1 prefer to off at Tuesday and Wednesday and staff D11 prefer to off at Friday and Saturday.

Other than that, 40 staffs were successfully allocated according to their preference shift while the other staffs only fulfil partially. It means that some days they are allocated at their preferred shift but some days are not. As shown in Table 2, the staff AA prefers to work at the morning shift and he was allocated to work at the morning

shift on Monday and Tuesday, but he need to work at the afternoon shift on Wednesday, Saturday and Sunday. Staffs A9, A11, B5, B8, B10, C, CC, C1, C3, C4, C6, D8, D9 and D10 are staffs that partially fulfil the constraint.

There are 46 staffs met the soft constraint of having the preferred day off, while staff A, AA, A1, A9, A10, A11, D8, D9 and D10 do not meet the constraint. This due to 9 of them chose Saturday and Sunday as their preferred day off. These two days are the most preferred day off among the 55 security staffs. There are 33 staffs chose to off on Saturday and 25 staffs chose to off on Sunday. Therefore, those staffs that rest on Saturday and Sunday in Table 2 will rest at the other day and these 9 staffs will off according to their preference day off on the next following week.

The schedule is built based on a week rotation and the rotation of the schedule also follows week by week. A staff can have a fixed day off and the fixed shift in every week. From the analysis, there are 39 staffs (70.9%) who prefer to work on the fixed shift while only 16 staffs (29.1%) vice versa. It seems like they can arrange their lifetime easier if they have to work at a fixed rotation compared to a random shift assigned every week.

C. Sensitivity Analysis

Sensitivity analysis demonstrates how optimal solution and the value of the objective function changes with the given changes in various inputs to the problem. Sensitivity analysis helps to figure out "*what if*" questions and validate the flexibility of the mathematical model. The varying number of the objective function represents the sensitivity.

Table 1: Real Schedule for UTHM Security Staffs in A Week (6 March 2017- 12 March 2017)

Day	**Mon**			**Tue**			**Wed**			**Thur**			**Fri**			**Sat**			**Sun**		
Shift	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	A	A11	C	A	A11	C	B	B1	D	B	B1	D	C	C11	A	C	C11	A	D	A	B
2	AA	A12	CC	AA	A12	CC	B2	B12	DD	B2	B12	DD	CC	C12	AA	CC	C12	AA	DD	AA	B1
3	A1	B	C1	A1	B	C1	B3	C	D1	B3	C	D1	C1	D	A1	C1	D	A1	D1	A1	B2
4	A2	B1	C2	A2	B1	C2	B4	CC	D2	B4	CC	D2	C2	DD	A2	C2	DD	A2	D2	A2	B3
5	A3	B2	C3	A3	B2	C3	B5	C1	D3	B5	C1	D3	C3	D1	A3	C3	D1	A3	D3	A3	B4
6	A4	B3	C4	A4	B3	C4	B6	C2	D4	B6	C2	D4	C4	D2	A4	C4	D2	A4	D4	A4	B5
7	A5	B4	C5	A5	B4	C5	B7	C3	D5	B7	C3	D5	C5	D3	A5	C5	D3	A5	D5	A5	B6
8	A6	B5	C6	A6	B5	C6	B8	C4	D6	B8	C4	D6	C6	D4	A6	C6	D4	A6	D6	A6	B7
9	A7	B6	C7	A7	B6	C7	B9	C5	D7	B9	C5	D7	C7	D5	A7	C7	D5	A7	D7	A7	B8
10	A8	B7	C8	A8	B7	C8	B10	C6	D8	B10	C6	D8	C8	D6	A8	C8	D6	A8	D8	A8	B9
11	A9	B8	C9	A9	B8	C9	B11	C7	D9	B11	C7	D9	C9	D7	A9	C9	D7	A9	D9	A9	B10
12	A10	B9	C10	A10	B9	C10	E	C8	D10	E	C8	D10	C10	D8	A10	C10	D8	A10	D10	A10	B11
13	E	B10	C11	E	B10	C11	E	C9	D11	E	C9	D11	E	D9	A11	E	D9	A11	E	A11	B12
14		B11	C2		B11	C2		C10	D12		C10	D12		D10	A12		D10	A12		A12	E
15		B12	E		B12	E		C11	E		C11	E		D11	E		D11	E		D11	E
16		E			E			C12			C12			E			E			D12	
17		E			E			E			E			E			E			E	
Z	**228.33**																				

Table 2: New Proposed Schedule For Security Staff in A Week After Maximizing Their Preferences

Day	**Mon**			**Tue**			**Wed**			**Thur**			**Fri**			**Sat**			**Sun**		
Shift	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	AA	A2	A	AA	A2	A	C4	AA	A	C6	A2	A3	C6	A2	A	C7	AA	A	C7	AA	A
2	A9	A12	A1	A9	A12	A1	C6	A2	A1	C8	A12	A4	C8	A9	A1	C8	A2	A1	C8	A9	A1
3	A11	B	A3	A11	B	A3	C7	A12	A3	C10	B	A5	C10	A11	A3	C10	A9	A3	C10	A11	A6
4	B8	B4	A4	B8	B4	A4	C8	B	A4	C11	B4	A6	C11	A12	A4	C11	A11	A4	C11	B4	A7
5	B10	B5	A5	B10	B5	A5	C10	B4	A5	C12	B5	A7	C12	B	A5	C12	A12	A5	C12	B5	A8
6	C	B11	A6	C7	B11	A6	C11	B5	A6	D	B8	A8	D	CC	A6	D	B	A10	D	B8	B6
7	C1	B12	A7	C8	B12	A7	D	B8	A7	DD	B11	A9	DD	C1	A7	DD	B4	B1	DD	B10	B7
8	C7	C2	A8	C10	C	A8	DD	B10	A8	D2	B12	A10	D2	C2	A8	D2	B5	B2	D2	B11	B9
9	C12	C3	A10	C11	C2	A10	D2	B11	A10	D3	CC	B1	D3	C3	A10	D3	C	B3	D3	B12	CC
10	D4	C5	B1	D	C3	B1	D3	B12	B1	D4	C1	B2	D4	C4	B1	D4	CC	B6	D4	C	C3
11	D5	C9	B2	DD	C5	B2	D4	CC	B2	D5	C2	B3	D5	C5	B2	D5	C1	B10	D5	C1	C4
12	D6	D1	B3	D2	C9	B3	D5	C3	B3	D6	C4	B6	D6	C9	B3	D6	C2	B11	D6	C2	C6
13	D12	D7	B6	D3	D7	B6	D6	D7	B6	D12	C5	B7	D12	D1	B7	D12	C4	D8	D12	C5	D8
14		D8	B7		D8	B7		D8	B7		C9	B9		D7	B9		C5	D9		C9	D9
15		D9	B9		D9	B9		D9	B9		D1	C3		D8	C		C6	D10		D1	D10
16		D10			D10			D10			D7			D9			C9			D7	
17		D11			D11			D11			D11			D10			D1			D11	
Z	**394.33**																				

Below are the situations that are set to identify the sensitivity of the integer linear programming model of this study. The analysis is focus on Monday output. Both situations are compared with the Monday obtained from the new proposed schedule (refer Table 2).

Situation 1: What happens if the security staffs are assigned according to the ascending order to fulfil the demand and neglects their preferences of work shifts and day off on Monday.

Situation 2: What happens if four security staffs (S1, S2, S3 and S4) were added who prefers to work in the afternoon shift in the Monday schedule.

Day	**Monday**			**Situation 1**			**Situation 2**		
Shift	1	2	3	1	2	3	1	2	3
1	AA	A2	A	A	A12	C2	AA	A2	A
2	A9	A12	A1	AA	B	C3	A9	A12	A1
3	A11	B	A3	A1	B1	C4	A11	B	A3
4	B8	B4	A4	A2	B2	C5	B8	B4	A4
5	B10	B5	A5	A3	B3	C6	B10	B5	A5
6	C1	B11	A6	A4	B4	C7	C1	B11	A6
7	C7	B12	A7	A5	B5	C8	C7	B12	A7
8	C12	C	A8	A6	B6	C9	C12	C2	A8
9	D4	C2	A10	A7	B7	C10	D4	C5	A10
10	D5	C3	B1	A8	B8	C11	D5	C9	B1
11	D6	C5	B2	A9	B9	C12	D6	D1	B2
12	D9	C9	B3	A10	B10	D	D9	D7	B3
13	D12	D1	B6	A11	B11	DD	D12	D11	B6
14		D7	B7		B12	D1		S1	B7
15		D8	B9		C	D2		S2	B9
16		D10			CC			S3	
17		D11			C1			S4	
Z	**63.33**			**34.00**			**70.01**		

In Table 3, the preference value, Z from the proposed schedule is 63.33 for Monday. Situation 1 represents the security staffs are being assigned in an ascending order where their preferences are not included when designing the schedule. The Z value obtained is decreased to 34. This clearly shows that the security staffs dislike the schedule.

In Situation 2, four staffs that prefer to work in the afternoon shift were added which causes the increasing value of Z up to 70.01. It shows that, when the number of security staffs increases, the value of Z increases as well. This situation able to overcome the problem of under-staff happened in the security department currently. Based on the proposed schedule, there is several staff need to work overtime due to lack of staff.

V. CONCLUSION

Manpower schedule is a plan to assign people to complete their task at a certain time and at a certain place. In this study, the optimal and efficient schedule for the UTHM security staffs is successfully produced in order to meet the demand of each shift and to make sure that each staff is assigned to at most one shift in each day.

The satisfaction of security staff towards UTHM management is increased when they are given opportunity to choose their preferred shift and day off. This flexibility is definitely benefits the staffs towards time management with their family and social life. This study shows that the integer linear programming approach is able to produce optimal schedule for scheduling problem. However, further study can be done by developing a schedule system using optimization or metaheuristic approach with friendly user interface that allow staff to key in their data easily. This system is able to make the scheduling process to be more efficient and less time consuming.

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