

MONTHLY ROSTER MODEL FOR ANAESTHETIST ROSTERING PROBLEM AT HOSPITAL CANSOLOR TUANKU MUHRIZ

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ABSTRACT

Anaesthetists are one of the most critical human resources to handle and optimize. However, only a few studies have investigated how to optimize the real-world anaesthetist rostering problem (ARP). In actual practice, the different hospital has different ARP model due to hospital demand, labour regulations, and internal department-specific scheduling rules. Therefore, this work proposes a mixed-integer programming (MIP) model for ARP derived from Hospital Cansolor Tuanku Muhriz (HCTM), Malaysia. We begin with introducing the duty, staff, workstation, planning, and request model. The duty model determines the type of anaesthetist assignment duty: on-call (i.e., passive, active or private) or office hour. Whilst the staff model manages the level of anaesthetist (senior or junior anaesthetist) and the group for the anaesthetist. The workplace definition for the anaesthetist is described as the workstation model. The planning model deals with monthly planning days, whilst anaesthetists request for duty type or off day is handled in the request model. Based on all the model, we combine to construct a monthly roster model and proposes a MIP. The ARP model aims to minimize the number of duty for every anaesthetist assign to the workstation subject to the demand, labour regulations, and internal department-specific scheduling rules. In order to promote job satisfaction, we consider the fairness aspects and individual anaesthetist preferences in formulating the evaluation function. Then, we validate our model by collect real data from the department of anaesthesiology and Intensive Care in HCTM and implement the proposed models in the MIP using CPLEX. The result shows that our model can balance the number of assignments among anaesthetist for the monthly roster.

1 INTRODUCTION

Hospitals faced new obstacles as a result of shifting economies and demographics, including increased healthcare spending (Keehan et al. 2017). In Denmark's Rigshospitalet hospital, surgery is one of the most expensive and resource-intensive operations (Kroer et al. 2018). 40 % cost of the hospital is spent on an operating room (OR) in the Surgical Department and 60 % of patient admissions belong to this department (Fügener et al. 2017; Akbarzadeh et al. 2019). Based on research in (Demirtas 2017), National Health spending in the United States between 2000 and 2012, increased from about \$ 1.3 trillion to about \$ 2.8 trillion. As a result, the hospital manager attempted to optimize the hospital's operation for it to operate smoothly, especially in the Surgical Department. The demand for the surgery operation influenced by the populations. This challenges the provision of services with limited human resources (surgeons, nurses, anaesthetists, etc) and material resources (ORs, beds, wards, etc) (Belkhamisa et al. 2018).

Surgery operation contains three-phase that is pre-operative, intra-operative and post-operative (Xiang et al. 2015; Belkhamisa et al. 2018). An intra-operative phase is an important phase in surgery operation. This phase required ORs, surgeons, anaesthetists, and nurses. Most of the surgical cases are delay or may be cancelled in this phase. This happens due to the uncertainty of the resources (Pang et al. 2018; Zhu et al. 2019). In (Pang et al. 2018), 7 % of cancellation cases occur, affecting the hospital's margin cost. According to (Zhu et al. 2019), researchers pay less attention to the issue of human and material resource instability.

The purpose of this study is to focus on one of the important human resources in an intra-operative phase that is an anaesthetist. We consider the anaesthetist problem as Anaesthetist Rostering Problem (ARP). The idea behind the ARP already proposes by Barbara M. Smith and Sean Bennet in (Smith & Bennett 1992). Their research is focused on improving the weekly roster compilation process, which is formulated as a constraint satisfaction problem (CSP). After that, most of the researcher conducted a case study using the anaesthetist domain area (Brunner et al. 2009; Fügener et al. 2015).

Based on that we found that the ARP is one of the personnel rostering problems which less notice from the researcher. In order to introduce the real-world ARP, this work begins by introducing the ARP model based on the Hospital Canselor Tuanku Muhriz (HCTM) in Malaysia. We define the ARP as assign a set of anaesthetists with different levels, skills and from a different group to a set of the workstation of different types on each day on the weekly and monthly roster, satisfying a set of constraints including demand and request, legislation, personal preferences, and problem-specific requirements.

In HCTM, the anaesthetist is under the management of the department of Anaesthesiology and Intensive Care. Usually, the roster for an anaesthetist has two types (i.e., monthly roster and weekly roster). The monthly roster focuses on the workstation that will be running in a month. Whilst the weekly roster focuses on the workstation that will be running every weekday (except weekend and public holiday). In this study, we will focus only on the monthly roster. Based on the number of days on that months, the planning for the request (i.e., request duty and off-day) and the number of workstations that opens will be arranged. Since the number of workstations that will be open into the roster for each day is different, we represent this situation as a demand. Every workstation contains a different type of duty with a different type of level for an anaesthetist.

According to the anaesthetist rostering in HCTM, this work proposes mixed-integer programming (MIP) models for ARP. These are monthly roster model which is a combination of duty, staff, workstation, planning, and request model. We consider the fairness aspects and individual anaesthetist preferences by formulating these criteria in the evaluation function to promote job satisfaction. Then, a case study based on real-life data from the department of anaesthesiology and Intensive Care HCTM is conducted.

The remainder of the paper is organized as follows. In section 2, we briefly review the related literature. In Section 3, we give a precise problem description and model include the mathematical formulation. In section 4, we discuss the case study that had been done and in section 5 we conclude our work.

2 LITERATURE REVIEW

Since ARP literature is less attention by the researchers. As a result, there is much literature that pays attention to the Nurse Rostering Problem (NRP) and Physician Rostering Problem (PRP) which is relevant to ARP. We take NRP and PRP as streams of literature and derive additional findings for the model for ARP.

2.1 Nurse Rostering Problem (NRP) Review

The Nurse Rostering Problem (NRP) or Nurse Scheduling Problem (NSP) has gained the most research attention in healthcare due to the increased demands of quality healthcare, scarce resources, and the tight constraints of specific legislation around the world. NRP is described as the process of assigning a group of nurses with various skills to a group of shifts of various types on each day or timeslot of a scheduling period while meeting some constraints such as

coverage, regulations, personal preferences, and problem-specific requirements (Pillay & Qu 2018).

In order to find the same optimal solution on a smaller scale, (Lin et al. 2015) present a mathematical model for the NRP. They employ 20 nurses with the same skill set and do not consider on-call or floating nurses. Every day of the nurse's schedule consists of three shifts of duty (i.e., day shift (8.00 am-4.00 pm), evening shift (4.00 pm-0.00 am), and night shift (0.00 am-8.00 am)). The proposed model is tested by using IBM ILOG CPLEX studio. To ensure fairness in NRP, an automatic schedule generator had been introduced (Osman et al. 2019). The case study takes place in Oman's Emergency Department (ED). In their work, the nurse is categorized into three types (i.e., senior, intermediate, junior) with the planning scheduled and the type of shifts same with the (Lin et al. 2015).

In (Rasip et al. 2015) state different shift of duty (i.e., morning shift, evening shift, night shift and the day of shift) for the NRP. The nurse level consists of two types (i.e., senior or junior). In (Schoenfelder et al. 2020), the researcher focus on incorporate a quick-response method on NRP by introducing a multistage stochastic programming model and use Mixed Integer Programming (MIP) as the solution technique. MIP also had been used for the NRP in (Turhan et al. 2020) with the combination of heuristics with Simulated Annealing (SA).

2.2 Physician Rostering Problem (PRP) Review

PRP is another personnel rostering problem that focuses on the physician. In (Thielen 2018), the duty shift for the physician is categorized into two types (i.e., on-call (24-h) and late/night). While (Erhard et al. 2018) state that the duty shift has three types (i.e., morning, evening and on-call (24-h)). In (Fügener et al. 2015) present a workstation as the workplace for the physician and also present the level of the physician based on the experience. Based on that, they present a model for their problem in a mathematical model with Mixed Integer Linear Programming (MILP) to test the model.

In (Thielen 2018), Integer Programming (IP) was suggested as a solution to the issue of various duties requiring different levels of experience. The aim is to optimize the compensation from completed duties requests and certain soft constraints, minus the penalties from unwanted duties and the remaining soft constraints. (Adams et al. 2019) presented a model for PRP and used MIP to reduce the largest difference in workloads between workload classes across the planning horizon.

From both streams, we identify some of the additional findings that useful as a guide when producing the model for ARP. The basic model coming from the NRP. Then we combine

the model with PRP to produce the ARP model. We will explain more detail about the model in section

3 PROBLEM REPRESENTATION AND MODEL

We model the ARP based on the real situation from Hospital Canselor Tuanku Muhriz (HCTM). Before producing the model, we take some ideas from NRP and PRP and try to fit the real situation. With that, some model we add based on the requirement by the real problem in HCTM. In HCTM, there still use a manual technique by using Microsoft Excel to prepare the anaesthetist roster. This may hard to produce an optimal roster that considering the fairness among the anaesthetists. We aim to produce a good model that can capably tackle that issue. We implement real situation problem into the ARP model that differs situation from the NRP and PRP. We discuss more details about each model in the next section.

3.1 Duty Model

We start the model with the duty model. There are several types of duty for the monthly roster in HCTM. Each duty has different working hours based on the type of workstation. There are four types of duty for the monthly roster:

- 1) On-call active (ACTIVE) – 24-h.
- 2) On-call passive (PASSIVE) – 24-h.
- 3) On-call private (PRIVATE) – 24-h.
- 4) Office hour (OFFICE) – 9-h.

On-call duty will start from 8.00 a.m. until 8.00 a.m. the next day. Each type of on-call duty has a different characteristic. ACTIVE duty needs an anaesthetist to stay 24-h in the workstation. The anaesthetist that receives the ACTIVE duty will get post-call (off day) for the next day. PASSIVE duty does not require the anaesthetist to stay 24-h in the workstation but is required to come if necessary. The anaesthetist who receives PRIVATE duty must stay in the workstation if have a surgical case for that duty. OFFICE duty will start from 8.00 a.m. until 5.00 p.m. (i.e., the working duration is 9-h). In on-call duty, we have three types of it rather on PRP only one type of on-call. Then we add duty for office hour which is not stated in NRP and PRP.

3.2 Workstation Model

The list of the workstation (WS) in HCTM is shown in Table 1. Each WS has its operation duty mode (ACTIVE, PASSIVE, PRIVATE, OFFICE), and duty level (Senior (SE), Junior (JU), Private group (PRIVATE) and All (ALL)). Operation duty mode is related to the duty model to identify the hours of operation for the workstation. Then the duty level is related to the staff model to identify the type of anaesthetist that must be allocated to that workstation.

Table 1 List of the workstation

Workstation	Operation Duty Mode	Duty Level
WS1	PASSIVE	SE
WS2	ACTIVE	JU
WS3	PRIVATE	PRIVATE
WS4	PASSIVE	SE
WS5	OFFICE	SE
WS51	OFFICE	JU
WS6	PASSIVE	SE
WS7	PASSIVE	JU

3.3 Staff Model

The total number of the anaesthetist is not static, it might be changing due to anaesthetist who resign their job, finish their contract or another reason. In HCTM, there will be two types of anaesthetist:

- 1) Senior Anaesthetist (SE)
- 2) Junior Anaesthetist (JU)

In HCTM only, there have SE and JU. The SE is the anaesthetist who had work for more than 5 years and the JU is the anaesthetist who works below 5 years. Also, there will be a Private ward group (PRIVATE_G) for the HCTM anaesthetist. Table 2 shown the list of anaesthetists with the info of their type and the group.

Table 2 List of the anaesthetist

Anaesthetist	Anaesthetist Type	Anaesthetist Group
SE 1	SE	PRIVATE_G
SE 2	SE	PRIVATE_G
SE 3	SE	PRIVATE_G
SE 4	SE	PRIVATE_G
SE 5	SE	PRIVATE_G

SE 6	SE	
SE 7	SE	PRIVATE_G
SE 8	SE	PRIVATE_G
SE 9	SE	
SE 10	SE	PRIVATE_G
SE 11	SE	
SE 12	SE	PRIVATE_G
JU 1	JU	
JU 2	JU	PRIVATE_G
JU 3	JU	PRIVATE_G
JU 4	JU	PRIVATE_G
JU 5	JU	
JU 6	JU	
JU 7	JU	

3.4 Planning Model

The planning model is the planning horizon for construct the monthly roster. From the planning model, the request model and monthly roster model will be constructed. We can identify the day for weekdays, weekends, or public holiday from the planning model. The number of days for the monthly roster planning is dynamic according to the numbers of days that month.

3.5 Request Model

There are different types of requests that can be applied. All the requests make a role before creating the roster. We can categorize the request into two (duty request and off day request).

The monthly request has two types:

- 1) No Call (NC)
- 2) Leave (L)

NC requests are for anaesthetist requests not to be assigned to on-call duty (i.e., ACTIVE, PASSIVE, PRIVATE) and for L request is for an anaesthetist request for off-day.

3.6 Monthly Roster Model

The monthly roster model will arrange the workstation that will be running in a month. Based on the previous model, we combine all of it to produce the monthly roster model. The monthly

roster will be arranged for the WS demand that will open in monthly horizontal planning. Only two types of operation time for this type (i.e., 24-h and 9-h). WS for PASSIVE, ACTIVE, and PRIVATE duty is for on-call duty. JU anaesthetist cannot be assigned to the PASSIVE duty workstation and the only anaesthetist from PRIVATE_G can be assigned to the PRIVATE duty workstation. Anaesthetist that has a monthly request for NC be assigned into the WS that operation duty PASSIVE, ACTIVE, and PRIVATE but can be assigned into operation duty OFFICE. While anaesthetist has a monthly request for L cannot be assigned into any WS in the monthly roster. Table 3 shown an example of the monthly roster that arranged the WS for an anaesthetist. The highlighted to show that the WS is not open for the anaesthetist. Only one anaesthetist can be assigned to each WS that open.

Table 3 List of the monthly roster workstation

	WS	Mon	Tue	Wed	Thu	Fri	Sat	Sun
PASSIVE	WS1	1	1	1	1	1	1	1
	WS4	1	1	1	1	1	1	1
	WS6	1	1	1	1	1	1	1
	WS7	1	1	1	1	1	1	1
ACTIVE	WS2	1	1	1	1	1	1	1
PRIVATE	WS3	1	1	1	1	1	1	1
OFFICE	WS5	1	1	1	1	1	1	1
	WS51	1	1	1	1	1		
	WS8	1	1	1	1	1	1	1
	WS81	1						

3.7 Mathematical Model

In this section, we construct the mathematical model for ARP. We use the following notation:

Indices

D	set of duty (index d)
D^{active}	subset of on-call active duty
$D^{passive}$	subset of on-call passive duty
$D^{private}$	subset of on-call private duty
D^{office}	subset of office hour duty
M	set of the workstation demand (index m)

M^{duty}	set of workstation demand operation duty with $\{D^{active}, D^{passive}, D^{private}, D^{office}\}$
M^{level}	set of workstation demand duty level with $\{SE, JU, PRIVATE, ALL\}$
M^{date}	set of the date on the workstation demand for anaesthetist in the monthly roster
A	set of the anaesthetist (index a)
A^{se}	subset of the senior anaesthetist
A^{ju}	subset of the junior anaesthetist
A^{group}	set of anaesthetist group with $\{PRIVATE_G\}$
P	set of the planning date in the monthly roster (index p)
R	set of the request in the monthly roster (index r)
R^{leave}	subset of leave request
R^{nocall}	subset of no-call request
Y	total number of anaesthetists
Z	total number of workstation demand

Parameters

$O_{ma}^{monthly}$	1, if the workstation demand m close for the anaesthetist a in the monthly roster, 0 otherwise
S_a^{group}	1, if the anaesthetist a is from the group of anaesthetist, 0 otherwise
$Q_{apr}^{monthly}$	1, if the anaesthetist a in the planning date p have a request r in the monthly roster, 0 otherwise
T_{ap}^{post}	1, if the anaesthetist a in the planning date p have a post-call, 0 otherwise
V_{am}^{mean}	Mean for the number of duty for anaesthetist a for the workstation demand m

Decision Variables

X_{ma}	1, if the workstation demand m is allocated by the anaesthetist a , 0 otherwise
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Eq (1) had been used to calculate the value for the mean for the number of duty for the anaesthetist for the workstation demand which the value will be used when trying to balance the number of duty that will be received by each anaesthetist when generating the monthly roster.

$$V_{am}^{mean} = \left[\sum_{m \in M} Z \div \sum_{a \in A} Y \right], \forall a \in \{A^{se}, A^{ju}\}, m = M^{level} \in \{SE, JU, PRIVATE, ALL\} \quad (1)$$

Eq (2) will be used to minimize the number of duty that will be received by each anaesthetist subject to hard constraints from the HCTM. The reason for doing this is to make fair distribution for the number of duty.

$$\text{Minimize } \sum_{m \in M, a \in A} X_{ma} \times O_{ma}^{\text{monthly}} \quad (2)$$

Subject to

Hard Constraint 1:

Eq (3) ensure that all the workstation demand must be allocated by the anaesthetist.

$$X_{ma} = 1 \forall a \in A, m \in M, O_{am}^{\text{monthly}} = 0 \quad (3)$$

Hard Constraint 2:

Eq (4) ensure that every workstation demand must be allocated by one anaesthetist.

$$\sum_{a \in \{A^{se}, A^{ju}\}} X_{ma} \leq 1 \forall m \in M \quad (4)$$

Hard Constraint 3:

Eq (5) ensure that every workstation demand duty level for SE and JU must be allocated based on anaesthetist level SE and JU.

$$X_{ma} = 1, \forall a \in \{A^{se}, A^{ju}\}, m = M^{\text{level}} \in \{SE, JU\} \quad (5)$$

Hard Constraint 4:

Eq (6) ensure that every workstation demand duty level for PRIVATE must be allocated based on an anaesthetist from PRIVATE_G.

$$X_{ma} = 1, \forall a = A^{\text{group}} \in \text{PRIVATE_G}, m = M^{\text{level}} \in \text{PRIVATE}, S_a^{\text{group}} = 1 \quad (6)$$

Hard Constraint 5:

Eq (7) ensure that the anaesthetist on the planning date has a leave request that must not be allocated to any workstation demand.

$$X_{ma} = 0, \forall a \in A, m \in M^{\text{date}}, p \in P, r \in R^{\text{leave}}, Q_{apr}^{\text{monthly}} = 1 \quad (7)$$

Hard Constraint 6:

Eq (8) ensure that the anaesthetist on the planning date has a no-call request that must not be allocated to any workstation demand operation duty for ACTIVE, PASSIVE and PRIVATE.

$$X_{ma} = 0, \forall a \in A, m = M^{\text{date}}, m = M^{\text{duty}} \in \{D^{\text{active}}, D^{\text{passive}}, D^{\text{private}}\}, p \in P, \\ r \in R^{\text{nocall}}, Q_{apr}^{\text{monthly}} = 1 \quad (8)$$

Hard Constraint 7:

Eq (9) ensure that the anaesthetist on the planning date has a post-call must not be allocated to any workstation demand.

$$X_{ma} = 0, \forall a \in A, m = M^{date}, p \in P, T_{ap}^{post} = 1 \quad (9)$$

Hard Constraint 8:

Eq (10) ensure the total number of duty of every anaesthetist level SE and JU for workstation demand duty level SE and JU on operation duty ACTIVE, PASSIVE and OFFICE must be less than or equal than the mean for the number of duty for anaesthetist for that workstation demand operation duty.

$$\sum_{m=M^{duty} \in \{D^{active}, D^{passive}, D^{office}\}} X_{ma} \leq V_{am}^{mean}, \forall a \in \{A^{se}, A^{ju}\}, m = M^{level} \in \{SE, JU\} \quad (10)$$

Hard Constraint 9:

Eq (11) ensure the total number of duty of every anaesthetist for workstation demand duty level ALL on operation duty OFFICE must be less than or equal than the mean for the number of duty for anaesthetist for that workstation demand operation duty.

$$\sum_{m=M^{duty} \in \{D^{office}\}} X_{ma} \leq V_{am}^{mean}, \forall a \in A, m = M^{level} \in \{ALL\} \quad (11)$$

Hard Constraint 10:

Eq (12) ensure the total number of duty of anaesthetist from PRIVATE_G for workstation demand duty level PRIVATE on operation duty PRIVATE must be less than or equal than the mean for the number of duty for anaesthetist for that workstation demand operation duty.

$$\sum_{m=M^{duty} \in \{D^{private}\}} X_{ma} \leq V_{am}^{mean}, \forall a = A^{group} \in PRIVATE_G, m = M^{level} \in PRIVATE, S_a^{group} = 1 \quad (12)$$

Hard Constraint 11:

Eq (13) ensure the anaesthetist level JU that allocated into workstation demand operation duty for ACTIVE must get off-day on next day.

$$\sum_{m=M^{duty} \in \{D^{active}\}} X_{ma} + \sum_{m=M^{duty} \in \{D^{active}\}} X_{ma+1} \leq 1, \forall a \in \{A^{ju}\}, m \in M^{date} \quad (13)$$

The model is applied to create the monthly roster for anaesthetist in HCTM by using the data of December 2020 (i.e., 1/12 to 31/12) from the Department of Anaesthesiology and Intensive Care HCTM. CPLEX optimization software and Microsoft Excel had been used to test the model. Based on the solution that had been produced by HCTM and the model, we present it in the box plot. In the case study, there will be 12 senior anaesthetists (SE) and 7 junior anaesthetists (JU) with the identity of the anaesthetist group as we have shown previously in the staff model section. Also, there will be 273 workstation demand where 124 of the workstation from operation duty on-call passive, 31 from operation duty on-call active, 31 from operation duty on-call private and 87 from operation duty office. We represent the solution based on the manual roster from HCTM as Real-Data and the solution from our model as ARP Model. Next section we discuss more detail about the result based on the case study that had been done.

4.1 On-Call Passive Duty

The mean of the senior anaesthetist for the Real-Data and ARP Model in on-call passive duty as we see from the Senior on-call Passive duty is 7.75 as seen from Figure 1. Based on the solution on Real-Data maximum number of duty for on-call passive duty that received by senior anaesthetist will be 31 which is far from the mean. While the ARP Model produces the maximum number of duty it is 8 which is close to the mean. The minimum number of duty for on-call passive duty on the solution Real-Data is 3 while the ARP Model produces the minimum number of it is 5. It is shown that the ARP Model produce the minimum number close to the mean compare to the Real-Data.

The mean of the junior anaesthetist for the Real-Data and ARP Model in on-call passive duty as we see from the Junior on-call Passive duty box plot is 4.43 as seen from Figure 1. Based on the solution on Real-Data maximum number of duty for on-call passive duty that received by junior anaesthetist is 16 which is far from the mean. While the ARP Model produces the maximum number of on-call passive duty is 5 which is close to the mean. The minimum number of duty for on-call passive duty on the solution Real-Data is 0 which show that there have a junior anaesthetist did not receive any on-call passive duty. While the ARP Model produces the minimum number of it is 3. It is shown that the ARP Model produce the minimum number close to the mean compare to the Real-Data.

4.2 Office Duty

The mean of the senior anaesthetist for the Real-Data and ARP Model in office duty as we see from the Senior Office duty is different as seen from Figure 2. The mean for Real-Data is 5 and the mean for ARP Model is 4. This difference is because there has the workstation demand level is ALL which is senior or junior anaesthetist can be assigned to it. Based on the solution on Real-Data maximum number of duty for office duty that received by senior anaesthetist is 16 which is far from the mean for Real-Data. While the ARP Model produces the maximum number of duty is 5 which is close to the mean for ARP Model. The minimum number of duty for office duty based on the solution on Real-Data is 0 while the ARP Model produces the minimum number is 2. It is shown that the ARP Model distribute the office duty to all of the senior anaesthetists.

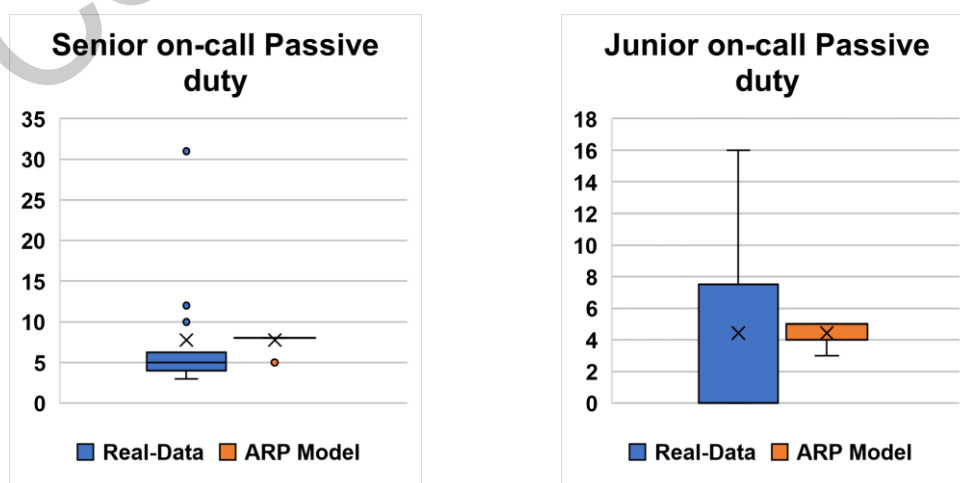


Figure 1 Senior on-call Passive duty and Junior on-call Passive duty

The mean for the junior anaesthetist in office duty also different same from the condition that had been stated in senior office duty as seen from Figure 2. The mean for Real-Data is 3.86 and the mean for ARP Model is 5.57. Based on the solution on Real-Data maximum number of duty for office duty that received by junior anaesthetist is 9 which is far from the mean. While the ARP Model produces the maximum number for office duty is 6 which is close to the mean. The minimum number of duty for office duty on the solution Real-Data is 1. While the ARP Model produces the minimum number of it is 5. It is shown that the ARP Model produce the minimum number close to the mean compare to the Real-Data.

4.3 On-Call Active and On-Call Private Duty

The mean of the junior anaesthetist for the Real-Data and ARP Model in on-call active duty as we see from the Junior on-call Active duty is 4.43 as seen from Figure 3. Based on the solution on Real-Data maximum number of duty for on-call active duty that received by junior anaesthetist is 5 same as the ARP Model. It is shown that the Real-Data and ARP Model produce the maximum number close to the mean. The minimum number of duty for on-call active duty based on the solution on Real-Data is 3 while the ARP Model produces the minimum number is 2. It is shown that the Real-Data produce a minimum number close to the mean. But from 7 number of junior anaesthetist for on-call active duty, Real-Data produces only 4 junior anaesthetists get the number of duty is 5. While the ARP Model produce 5 junior

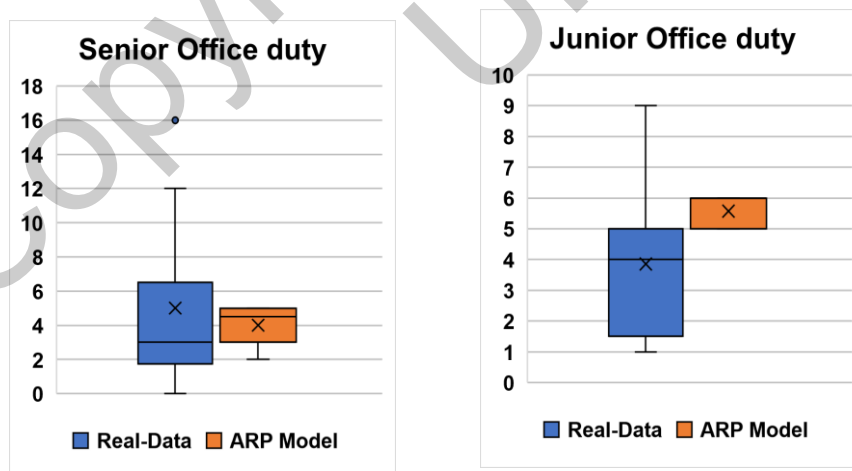


Figure 2 Senior Office duty and Junior Office duty

anaesthetists get the number of duty is 5 which is more balanced than the Real-Data.

The mean of the private group anaesthetist for the Real-Data and ARP Model in on-call private duty as we see from the Private group on-call Private duty box plot is 2.58 as seen from Figure 3. Based on the solution on Real-Data maximum number of duty for on-call private duty

that received by the private group anaesthetist is 4 which is far from the mean. While the ARP Model produces the maximum number for on-call private duty is 3 which is close to the mean. The minimum number of duty for on-call private duty on the solution Real-Data is 0. It shows that there have anaesthetist from the private group did not receive any on-call private duty. While the ARP Model produce the number of minimum is 1 which is also far from the mean. But the ARP model able to distribute the on-call private duty to all the anaesthetist from the private group. While in the Real-Data, there have 3 anaesthetists with 0 on-call private duty.

From the result that had been produced, we can state that the ARP Model can produce a better solution compared to the Real-Data in order to produce the fair number of duty that receives among each anaesthetist.

5 CONCLUSION

This study focuses on introducing the real-world ARP model. We propose proposes mixed-integer programming (MIP) monthly roster model for ARP which is a combination of duty, staff, workstation, planning, and request model. Based on the result our model able to balance the number of duty that will be received by each anaesthetist in the monthly roster. This showed that the fairness aspect which is important for job satisfaction among the anaesthetist is achievable. Although our model can produce a better solution from the manual roster, there has a lack which is needed to be improved in future. The model didn't consider the balance on the number of the working hour as every duty has a different working hour with different characteristic on it. Also,

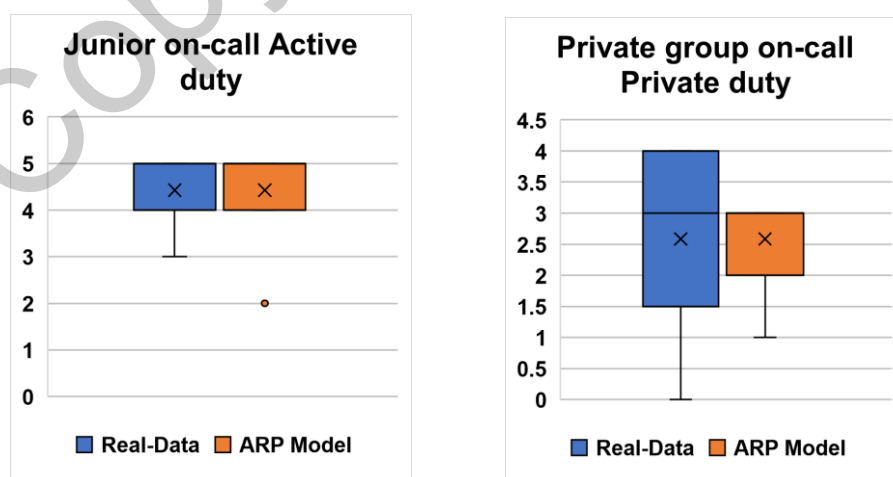


Figure 3 Junior on-call Active duty and Private group on-call Private duty

the model fulfils all the request that had been made by the anaesthetist without consideration of the fairness aspect. Some anaesthetist makes a lot of requests compared to another anaesthetist

which may give effect on the balance number of duty. Another aspect that should be considered to improve the model is to take care of the preference task for the anaesthetist. Some anaesthetist may have their preferred task of duty.

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