



UNIVERSITI PUTRA MALAYSIA

***SOLVING SINGLE AND BI-OBJECTIVE SURGERY SCHEDULING
PROBLEMS USING LOCAL SEARCH HEURISTIC***

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PROBLEMS USING LOCAL SEARCH HEURISTIC**

By

NUR SHAFIQAH BINTI AB RASHID

**Thesis Submitted to the School of Graduate Studies, Universiti Putra
Malaysia, in Fulfillment of the Requirements for the Degree of Master
of Science**

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DEDICATIONS

*To all of my love
My Mom & Dad..*



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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January 2021

Supervisor: Nor Aliza Abd Rahmin, MPhil.

Faculty : Science

Due to the increasing number of elective patients required for surgery, the higher demand for an efficient and effective operating room planning in the health care sector is needed. Thus, better operating room planning is needed to prevent any complication to the patients for waiting too long for the treatment. A longer waiting time can affect the patient's health condition if they are not treated in the specified time frame. It is essential to ensure that higher urgency patients get the surgeries done as soon as possible to avoid any health complications. An accurate estimation for the surgery duration is also one of the challenges in creating a good operating room planning. The surgeon assignment problem is completed after the scheduling case has been solved.

The first problem is a single-objective surgery scheduling problem, where the surgeries are scheduled in the planning week by prioritizing the higher urgency patients and then assigning the available surgeons to the surgery. A simple heuristic is developed to produce an initial solution for the problem. Following from there, local search heuristic is applied to improve the solution, where the surgeries are scheduled based on the urgency value assigned to each patient. This ensures that high urgency patients are prioritized first to avoid any health complications or patients dissatisfaction. The results are compared between the exact method and the heuristics proposed in this study. The proposed heuristics shown a good performances based on the solution quality and the computational time.

Since there is no historical data from the hospital, the surgery duration needs to be generates using the statistical distribution. The surgery duration is generated using

two probability distributions based on the information from the previous researcher. The most common probability distribution used in generating the data is the uniform distribution and also the exponential distribution. These two distributions are used to generate the surgery durations tested with our heuristic to determine which distribution is better. The exponential distribution is used to generate the surgery duration since this distribution is better than the uniform distribution in maximizing the urgency value for scheduled surgeries. Not only that, the exponential distribution also managed to minimize the urgency value for the unscheduled surgeries.

Based on the single-objective problem, the model is formulated into a bi-objective and the exponential distribution is used to generate the data for the surgery duration. The aim of this study is to maximize the total urgency value scheduled and the total number of time periods scheduled in the planning week. Since exact method is time-consuming, a heuristic is proposed to solve the problem. A multi-objective local search heuristic is developed based on the previous local search heuristic to suit with the bi-objective problem. This multi-objective local search heuristic works by multiple checking the objectives in each of the iteration. The results show that the heuristic used is efficient as the average operating room productivity measures show good results.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**MENYELESAIKAN MASALAH PENJADUALAN PEMBEDAHAN TUNGGAL
DAN DWI-OBJEKTIF MENGGUNAKAN HEURISTIK CARIAN TEMPATAN**

Oleh

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Oleh kerana peningkatan jumlah pesakit elektif yang memerlukan pembedahan, permintaan yang lebih tinggi untuk perancangan bilik bedah yang cekap dan berkesan di sektor penjagaan kesihatan sangat diperlukan. Oleh itu, perancangan bilik bedah yang lebih baik diperlukan untuk mengelakkan sebarang komplikasi kepada pesakit kerana terlalu lama menunggu rawatan. Masa menunggu yang terlalu lama boleh mempengaruhi keadaan kesihatan pesakit jika mereka tidak dirawat dalam jangka masa yang ditentukan. Adalah mustahak untuk memastikan pesakit yang mempunyai nilai kesegeraan yang lebih tinggi melakukan pembedahan secepat mungkin bagi mengelakkan sebarang komplikasi kesihatan. Anggaran yang tepat untuk tempoh bedah juga merupakan salah satu cabaran dalam membuat perancangan bilik bedah yang baik. Masalah penugasan pakar bedah akan dilakukan setelah kes penjadualan selesai.

Masalah pertama adalah masalah penjadualan operasi dengan objektif tunggal, di mana pembedahan dijadualkan pada minggu perancangan dengan mengutamakan pesakit yang mempunyai nilai kesegeraan yang lebih tinggi dan kemudian menugaskan pakar bedah yang bertugas untuk pembedahan tersebut. *Simple heuristic* dibina bagi menghasilkan penyelesaian awal untuk masalah ini. Setelah itu, heuristik *local search* diterapkan untuk memperbaiki penyelesaiannya, di mana operasi dijadualkan berdasarkan nilai kesegeraan yang diberikan kepada setiap pesakit. Ini adalah untuk memastikan setiap pesakit yang mempunyai kesegeraan yang tinggi diutamakan terlebih dahulu bagi mengelakkan komplikasi kesihatan atau ketidakpuasan pesakit. Hasilnya akan dibandingkan antara kaedah *exact* dan heuristik yang dicadangkan dalam kajian ini. Heuristik yang dicadangkan menunjukkan hasil yang baik berdasarkan kualiti penyelesaian dan masa pengiraan.

Oleh kerana ketiadaan data sebenar dari hospital, jangka masa pembedahan perlu dibuat dengan menggunakan taburan statistik. Tempoh pembedahan akan dihasilkan menggunakan dua taburan kebarangkalian berdasarkan maklumat daripada kajian terdahulu. Taburan kebarangkalian yang biasa digunakan bagi menghasilkan data adalah taburan Seragam dan juga taburan Eksponen. Kedua-dua taburan ini digunakan untuk menghasilkan jangka masa pembedahan yang akan diuji dengan heuristik untuk menentukan taburan mana yang lebih baik. Taburan Eksponen digunakan untuk menjana tempoh pembedahan kerana taburan ini lebih baik daripada taburan Seragam dalam memaksimumkan nilai kesegeraan bagi pembedah yang telah dijadualkan. Bukan hanya itu, taburan Eksponen juga berjaya meminimumkan nilai kesegeraan bagi pembedahan yang tidak dijadualkan.

Berdasarkan masalah objektif tunggal, model tersebut akan dirumuskan menjadi dua objektif dan taburan Eksponen digunakan untuk menghasilkan data bagi tempoh pembedahan. Tujuan kajian ini adalah untuk memaksimumkan jumlah nilai kesegeraan yang dijadualkan dan jumlah jangka masa yang dijadualkan dalam minggu perancangan. Oleh kerana kaedah *exact* memakan masa, heuristik dicadangkan bagi menyelesaikan masalah tersebut. Heuristik *multi-objective local search* dibina berdasarkan heuristik *local search* sebelumnya untuk disesuaikan dengan masalah bi-objektif. Heuristik *multi-objective local search* ini berfungsi dengan memeriksa setiap objektif bagi setiap iterasi. Hasil kajian menunjukkan bahawa heuristik yang digunakan adalah efisien kerana kadar produktiviti bilik operasi menunjukkan hasil yang baik.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

BH	Backtracking Heuristic
BILP	Bi-objective Integer Linear Programming
COP	Combinatorial Optimization Problem
ED	Exponential Distribution
GA	Genetic Algorithm
ILP	Integer Linear Programming
LS	Local Search
MOLS	Multi-objective Local Search
OR	Operating Room
PDF	Probability Density Function
SH	Simple Heuristic
SA	Simulated Annealing
UD	Uniform Distribution

CHAPTER 1

INTRODUCTION

1.1 Background of the study

In health care, the hospital's management receives high demands in providing the best services for their patients. Operating room (OR) is the main facility in the hospital, and it accounts for a large part in the hospital's budget. Despite the high costs, the OR contribute to most of the hospital's profit. Therefore, the development of the OR planning and scheduling must be designed efficiently to adequately use the hospital's resources, which include the operating theatre, staffs (surgeons, nurse, anesthesiologists, etc.), recovery beds, and surgery equipment. This will also improve patient welfare and reduce operating costs.

According to Cardoen et al. (2010), surgery scheduling can be divided into two categories. The first one is the elective surgery, where this surgery can be scheduled in advance. The patients will be placed in a waiting list before they undergo the surgeries. Another category is the nonelective surgery or emergency surgery. Emergency surgery always arrives unexpectedly during the day and must be scheduled as soon as possible. In this research, the focus is only on the scheduling of elective surgeries.

It is known that emergency scheduling is rather difficult due to sudden arrival in the system. However, planning and scheduling elective surgeries are also challenging because usually the number of elective surgeries is higher than the emergency surgeries based on the emergency-to-elective surgery ratio (Prin et al. (2017)). As a consequence, lengthy waiting list causes dissatisfaction to the patients who are waiting for their surgery, and not only that, it can affect patient health and quality of life (Salci et al. (2015)).

Generally, an urgency value is evaluated by the clinician which is responsible for the patients at the first outpatient visit. This urgency value is to determine the priority of the surgery in the waiting list. According to the Australian institute of health and welfare, the urgency value is associated by the time interval in which treatment is required. In this study, an urgency value is considered to schedule the elective surgeries.

Based on the problem above, this study focuses on the elective surgery schedul-

ing considering the urgency value. Heuristic procedures are proposed to solve the scheduling problem involving a single and multi-objectives. An estimate for the surgery duration is made to further improve our proposed heuristics.

1.2 Problem statement

Operating room (OR) scheduling problem is explored by many researchers throughout the year. Nevertheless, the study on scheduling of patients and surgeons assigned for the surgery is still limited. Pradenas et al. (2012) studied on the surgery scheduling and surgeon assignment problem by using an exact method for the scheduling problem, while heuristic is developed for the assignment problem. Based on the study, the exact method managed to obtain the surgery schedule in minimal time when compared to the current manual procedure. However, the exact method shows disadvantages when solving for larger data size. Therefore, this research will focused on solving the elective surgery scheduling problem using heuristic procedures by considering the urgency value. The heuristic procedures will replace the exact method since the results obtained show the great performances of the heuristic when solving a large data size. Not only that, the heuristic method will be used to solve a bi-objective surgery scheduling problem which will be conducted in this study. Another problem arise from this research is generating of data for the surgery duration. It is known that the real data from the hospital is needed to generate the data. However, not every hospital will easily give their data since it is confidential to share the patient information to others. Since data is needed to conduct the study, numerous researchers used different method to generate data for their research. Thus, this research will generate data using a statistical distribution by using the surgery duration from Marques et al. (2015), since they have the information on a similar surgery type as in this study. There are two distributions used to generate data and it will be compared in order to achieve more reliable data.

1.3 Objectives

Based on the problem statement mentioned in this chapter, the objectives of this research are as follows:

- To develop a simple heuristic and apply a local search heuristic to solve the elective surgery scheduling problem considering the urgency value.
- To compare a Uniform distribution with Exponential distribution to determine which distribution is better in generating surgery duration data.

- To formulate a bi-objective integer linear programming model based on the integer linear programming model.
- To modify the local search heuristic into a multi-objective local search heuristic to solve the bi-objective surgery scheduling problem.

1.4 Scopes & limitations

The scope for this research is emphasizing on the OR scheduling for elective surgeries with urgency value included to determine the priority of patients. Another aspect is to focus on the heuristic method instead of exact method in order to obtain better performances in terms of solution quality and computational time when solving larger instances.

The major limitation of this study is there is no real data provided by the hospital since it is difficult to access due to its confidentiality. Thus, the data is generated by using the probability distribution.

1.5 Importance of study

The scheduling of elective surgeries considering the urgency value is important as it involves the patient satisfaction and operating room utilization. The urgency value will help the hospital manager to determine the priority of the surgeries in the waiting list. However, poor planning and scheduling system will not only affect the patient health condition, but reduced the operating room efficiency. Therefore, an efficient and effective method is needed to overcome this shortcoming.

In optimization, exact method is a method which able to find an optimal solution for the problem. Nonetheless, this method is not suitable for a NP-hard problem, unless for a small size instance (Zufferey et al. (2018)). Thus, heuristic or metaheuristic method is needed to quickly find a satisfying solution. Chen and Zeng (2020) developed two heuristic algorithms for the metaheuristic algorithm to improve the solutions of the optimization problem. Since good initial solution will produces a quality solution.

Thus, this thesis will use heuristic method to solve the single and multiobjective surgery scheduling problem in order to produce quality solution in short time. This

heuristic can be used as a starting point for a metaheuristic which is an advanced method in solving more complicated problem. Furthermore, a good probability distribution is also needed to generate the data for the surgery duration which will be used to test the proposed heuristic.

1.6 Thesis Overview

The rest of this thesis is organised as follows. Chapter 2 will discuss on the overview of the literature review on COP, scheduling in health care involving different resources, and OR scheduling. The literature on different methodologies to solve the surgery scheduling problem is also provided in Chapter 2. In Chapter 3, the model and heuristic proposed to solve the single-objective surgery scheduling problem considering patient's urgency value are presented. On the other hand, Chapter 4 discusses the distributions to generate the surgery duration. Two distributions are tested and compared to decide which distribution is better in generating the data for the surgery duration. The distribution will be used to generate the data for problem studied in chapter 5. In Chapter 5, the multi-objective problem is developed by modifying the integer linear programming model used in Chapter 3. A multi-objective heuristic is then developed to solve the multi-objective problem. Finally, Chapter 6 contains the conclusion and also future work for the thesis.

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