

MONTE CARLO SIMULATION FOR ANALYZING OPERATING THEATRE UTILIZATION

SIMULASI MONTE CARLO DALAM MENGANALISIS UTILISASI KAMAR OPERASI

Mursyid Hasan Basri, Julyafanny Asnawiyah

School of Business and Management, Institut Teknologi Bandung,
Bandung

ABSTRACT

Background: Previous researches in different countries studied about operating theatre performance, but in Indonesia less research has been conducted. Operating theatre performance is measured by utilization rate, however the way utilization measured in practice is different with the general terminology. We conduct research in one referral hospital. It was declared that although the utilization of operating theatre is not high, many patients wait for the services. Therefore, the objectives of this research are to validate the low utilization rate and to identify causes of unutilized capacity of operating theatre.

Method: This research applied statistical description method to analyze the utilization with general terminology, and the Monte Carlo simulation is run to identify what factors that cause unutilized capacity. Three scenarios are used in the simulation. First scenario is simulation with no cancellation occurs, the second is simulation with cancellation, and the third scenario is simulation for determining unutilized capacity due to waiting and idle time in operating theatre.

Results: This study has successfully revealed factors causing unutilized capacity of operating theatre i.e. number of cancellation, waiting for facilities, and idle capacity. Our study shows that 1% of cancellation rate will reduce utilization about 1%. This study also indicates that unutilized capacity due to waiting for facilities and idle capacity in these operating theatres is fairly high.

Conclusion: It had confirmed that operating theatres in the hospital are in low utilization and need for improvement. Determining utilization rate with Monte Carlo simulation provides more information to hospital manager for decision making process.

Keywords: operating theatre, utilization, monte carlo simulation, healthcare services

ABSTRAK

Latar Belakang: Penelitian-penelitian sebelumnya tentang kinerja kamar operasi sudah banyak dilakukan di berbagai negara, namun tidak demikian halnya dengan di Indonesia. Kinerja kamar operasi diukur dengan tingkat utilisasi. Namun pengukuran utilisasi pada praktiknya berbeda dengan terminologi yang umum. Penelitian ini dilakukan di salah satu rumah sakit rujukan. Fenomena yang terjadi menunjukkan bahwa meskipun utilisasi kamar operasi tidak tinggi, banyak pasien yang menunggu untuk mendapatkan pelayanan. Oleh karena itu, penelitian ini untuk memvalidasi tingkat utilisasi dan untuk mengidentifikasi penyebab kapasitas kamar operasi yang tidak termanfaatkan.

Metode: Penelitian ini menggunakan metode statistik deskriptif yang digunakan untuk menganalisis utilisasi secara umum, dan simulasi Monte Carlo yang dijalankan untuk mengidentifikasi faktor-faktor apa yang menyebabkan utilisasi tidak maksimal.

Tiga skenario dikembangkan dalam simulasi. Skenario pertama adalah simulasi tanpa faktor pembatalan. Skenario kedua adalah simulasi dengan melibatkan faktor pembatalan. Skenario ketiga adalah simulasi untuk menentukan kapasitas yang tidak termanfaatkan karena menunggu dan waktu senggang di kamar operasi.

Hasil: Penelitian ini berhasil mengungkapkan faktor penyebab kapasitas kamar operasi yang tidak termanfaatkan yaitu jumlah pembatalan operasi, menunggu fasilitas, dan kapasitas menganggur. Penelitian ini menunjukkan bahwa tingkat pembatalan 1% akan mengurangi utilisasi sekitar 1%. Penelitian ini juga menunjukkan bahwa kapasitas yang tidak termanfaatkan karena menunggu fasilitas dan kapasitas menganggur dalam kamar operasi cukup tinggi.

Kesimpulan: Penelitian ini mengkonfirmasi bahwa utilisasi kamar operasi di rumah sakit ini relatif rendah dan masih dapat ditingkatkan. Menentukan tingkat utilisasi dengan simulasi Monte Carlo memberikan informasi lebih lengkap kepada manajer rumah sakit dalam proses pengambilan keputusan.

Kata kunci: kamar operasi, utilisasi, simulasi monte carlo, pelayanan kesehatan

INTRODUCTION

One significant part of service sector in Indonesia is health care industry. In their earlier research, Li *et al.*¹ acknowledged that health care service is a patient-oriented service that requires continues interaction with patients, and utilizes facilities, equipment, and also consumes a large volume of resources. Therefore, it becomes increasingly important to health care stakeholders to recognize and decide their critical resources flow to achieve the goal in providing excellent health care services at reasonable cost.² Health care industry face the challenge in reducing cost, and improving operational quality, including service quality and patient satisfaction.³ Furthermore, health care industry deals with person's life and safety which is increasing management complexity. A failure in health care service could be a disaster for entire system of organization.

The most outsized service in health care industries can be found in hospital as it utilized a huge volume of resources. One specific unit that consumed

the largest volume of resources in hospital is operating theatre. The operating cost of a surgery department is the one of the largest hospital cost category, approximately one-third of the total cost.³ Not only consumed the largest volume of resources, but operating theatre also generates revenue and admission to hospital.⁴ Therefore, managing operating theatre in purpose for optimizing its usage and performance will give a lot of benefits to hospital.

Operating theatre performance often described as utilization which means optimum utilization that may achieved will result in more efficient operating theatres.^{5,6} In general, Hospital Operating theatre was designed with 3 types of surgery activity i.e. elective surgery, emergencies (24-hours) surgery, and one-day surgery. Elective surgery represent the surgery which is well planned.⁴ The patients of this surgery may need recovery in the hospital for some time. They cannot go home directly after surgery finished. Emergencies surgery means that surgery has to be performed as soon as possible because of emergencies situation.⁴ One-day surgery means that patient came at surgery time; pre-operation preparation has been done at home. After surgery finished, they can go home at the moment. We cannot analyze the operating theatre planning, scheduling and utilization without considering the type of surgery.

In general, utilization is the sum of time it takes to perform each surgical procedure plus the total turnover time divided by the time available.⁷ However, our interview revealed that there is different formulation used by the hospital understudy. They calculated utilization based on how many surgeries can be done each day. The use of this formulation needs to be reassessed. Since it only measured the number of operations, this measurement may mislead decision making process. Moreover, hospital management admitted low utilization rate while they also see long patient waiting list. This contradictory condition becomes trigerring factor that operating theatre in this hospital must be analyzed.

Researchers in many countries have conducted study on this topic in order to help the hospital to achieve optimum level of service in operating theatre. Improvement in planning and scheduling surgery activity became a critical point to optimize operating theatre's service level. On the contrary, there are only a few references discuss operating theatre in Indonesia. Therefore, this study will provide a lot of benefits to hospital management or other researchers for giving an overview about operating theatre management. Furthermore, applying previous researchers' works at different places into hospitals in

Indonesia is not that easy. Health care industry is an industry that directly involve people with different characters, habits, and cultures. This study aims to validate the low utilization rate and to identify causes of unutilized capacity of operating theatre in Indonesia.

Operating theatre study had been studied since a long time ago. Our study began with a research result from Schmitz and Kwak¹⁰ about Monte Carlo simulation in determining the numbers of operating theatre to open. Dexter *et al*⁵ conducted his research in low a health care about scheduling elective surgery using two typical heuristic methods.

Weinbroum *et al.*¹¹ has done his research in teaching public medical centre in Israel about evaluating the possible existence of periods of operating theatre inactivity. His research aimed to analyze the impact on operating theatre related performance and cost. While Hans *et al.*¹² already mentioned about block-booking concept in scheduling which he proposed as the model and technique in surgical planning and scheduling at Erasmus Medical Centre in Rotterdam. Similar with Hans *et al.*¹² research, Houdenhouven *et al.*⁹ also conducted his research in Erasmus Medical Centre in Rotterdam to improve the operating theatre efficiency by applying mathematical algorithm and lowering organizational barrier. The detail concept can be seen at Table 1.

However, we used literature review from Cardoen *et al.*⁴ that identify and specify topics in operating theatre planning and scheduling and also literature review from Erdogan and Denton⁶ provide a bright overview of surgery planning and scheduling. This study also provides general terms in operating theatre.

METHOD

Data Collection

The study was conducted in one hospital in Bandung and focused on four elective rooms. Each room is dedicated for certain surgery cases; it means that this hospital followed block planned scheduling method. Data used in this study is all the elective cases performed at surgical suites in November 2011 that consist of 419 data. The study period excludes weekend and holidays, and official operating theatres work hour is from 8.00 am – 16.00 pm. Collected data is scheduled surgery and surgery duration. Surgery duration was defined as the time from when the doctors starting the surgery until they finished, and patient move to post anaesthesia care unit (PACU). Initial planning of this operating theatre is three scheduled surgeries per day in each room.

Table 1. Research Comparison of Operating Theatre Management

Factors	Schmitz and Kwak (1972) ¹⁰	Dexter et.al (2002) ⁵	Tyler et.al (2003) ⁷	Weinbroum et.al (2003) ¹¹	Harders et.al (2006) ⁸	Houdenhaven et.al (2007) ⁹	Hans et.al (2007) ¹²	Ogulata and EroI (2003) ¹³
Research place	Deaconess Hospital, Missouri	Iowa Health Care	Children Hospital Philadelphia	Public Medical centre, Israel	Metro Health Medical Centre, Cleveland	Erasmus MC, Rotterdam	Erasmus MC, Rotterdam	Cukurova University Research Hospital, Turkey
Topics	Determine the numbers of OR to open a day and the impact of increasing the usage of OR and recovery room	Scheduling cases to maximize the efficiency of OR	Examine how factors such as case duration and variability of case duration affect OR utilization	Evaluate possible factors affecting OR inactivity	Redesigning Non-operative Time to increase OR efficiency	Examine the effects of organizational barrier in OR efficiency	proposes models and technique to schedule OR in order to raise efficiency	Propose surgery scheduling technique of multiple OR, surgeon groups
Patient characteristics	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective and emergency
Method	Monte Carlo Simulation	Using heuristic method to schedule OR: Earliest start time and latest start time	Simulation with Arena	observed OR activity and measured its utilization	Experimental studies with process redesign	Advanced Mathematical Technique	Programming Model for block-booking and cyclic planning (Master Surgical Schedules)	Simulation with MPL optimization package
Result	The maximum number of recovery room in use is 12, and the number of surgical activity a day is 27.	They showed how cases should be scheduled to maximize OR efficiency	Decreasing variability of case duration will increase utilization	Find factors that cause "time waste" and recommend new guidelines to minimize "time waste"	Coordinated multidisciplinary process redesign can significantly reduce NOT	Lowering organizational barriers and applying mathematical algorithms can increase utilization by 4.5%	Cyclic planning can increase OR utilization	Current scheduling models can be extended to consider other related resources and simultaneous consideration with emergency operations

Manual Utilization Calculation and Existing Performance Analysis

Manual utilization calculation means that utilization is manually calculated for each room using equation (1). We calculate actual utilization for each day, average during the collected period and its standard deviation. This utilization calculation is different from the current method used by the hospital. The difference will be discussed later in the result section.

$$Utilization = \sum_{i=1}^n \frac{Actual\ hours\ for\ surgery}{Available\ time} \dots\dots\dots (1)$$

Before we headed to Monte-Carlo Simulation, we need to know factors that may affect unutilized capacity. In order to find these factors, we perform existing performance analysis of operating theatre. Those performance analyses will be based on equation (2) to (6).

Number of scheduled surgery (i) will be used as a standard to achieve. Let we define number of actual surgery (ii); number of emergency cases (iii); number of surgery cancellation (iv); and number of switching room (v). Then the hospital defines some measurement as follows:

$$Percentage\ of\ Actual\ surgery = \frac{ii}{i} \dots\dots\dots (2)$$

$$Percentage\ of\ Emergencies\ cases = \frac{iii}{i} \dots\dots\dots (3)$$

$$Percentage\ of\ surgery\ cancellation = \frac{iv}{i} \dots\dots\dots (4)$$

$$Percentage\ of\ switching\ room = \frac{v}{ii} \dots\dots\dots (5)$$

$$Percentage\ of\ completed\ scheduled\ surgery = \frac{ii - (iii + v)}{ii} (6)$$

Monte Carlo Simulation

The next step is to do Monte Carlo simulation in order to explore the system characteristic. At the end, we need to find what factors affecting unutilized capacity. This simulation consists of three sequential processes, i.e. pre-surgery, surgery and post-surgery.

Pre-surgery means process where patient is prepared for surgery after entering operating theatre. Surgery means process where doctors do the main activity. Post-surgery is process after surgery where the patient recovered after surgery before leaving operating theatre. Although there are three processes in operating theatre system, we performed utilization calculation in each room.

In this research, processes in operating theatre can cause two situations i.e. utilized capacity and unutilized capacity. Utilized capacity consists of

operative factor and sterilization activity. Whereas in this study, we describe unutilized capacity is consist of cancellation rate, waiting and idle time. Waiting time represents the time where patient must wait for the surgery because of unavailable facilities, while idle time represents the time where there are no scheduled activities in operating theatre. The time besides surgery activity is defined as non-operative time.⁸ These explanations can be described by Figure 1.

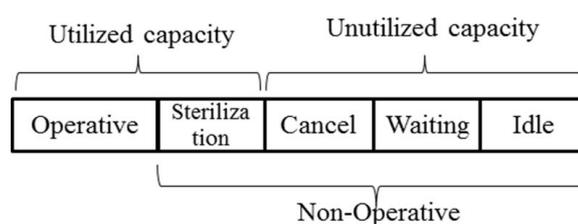


Figure 1. Time Terminology in This Research

The simulation was done with several scenarios and each scenario was run up-to 1000 simulation. First scenario that we built was Monte Carlo simulation with no cancellation, the second scenario was Monte Carlo simulation with cancellation factor, and the last scenario was Monte Carlo simulation with waiting and idle time.

RESULT

Operating Theatre Utilization

We calculate four out of nine operating theatres utilization because based on our observation, these four rooms applied the block-booking method. Advantage of this method is we can easily determine the time needed for each type of surgery, thus we can make an evaluation about surgery activity performance. The result is presented in second and third row of Table 2, while the last row shows utilization rate based on hospital perspective. Table 2 shows that operating theatres utilization have not achieved their optimum utilization, where Weinbroum *et al.*¹¹ mentioned that optimal consideration of operating theatre is 97%.

Table 2. Operating Theatre Utilization

Room	Mean (%)	Standard Deviation (%)	Perceived Utilization (Surgery Per Day)
1	55.5	23.2	1.55
2	74.5	41.8	2.05
3	82.5	46.8	2.23
4	84.8	38.5	1.14

It is important to note about the difference of utilization formulation. In current hospital calculation, the focus is number of surgery rather than time duration of surgery. This method has weaknesses in practice. They do not consider the time that surgeon spent in the operating theatre. In addition, with the different type of surgery, number of surgery has less meaningful information for management to decide on their performance. Furthermore, by using time duration, we can trace factors affecting low utilization.

Based on the collected data, there are some inhibiting factors that may affect surgery activity. Some of these inhibiting factors can be found in surgery activity profile (Table 3). However, we still need to confirm what factors that contribute on unutilized time. In this research, we used Monte Carlo Simulation to validate the impact of those factors.

Table 3. Surgery Activity Profile

Profile	No.	(%)
Number of scheduled surgery	419	100
Actual surgery	354	84
Number of completed scheduled surgery	341	96
Emergencies cases added	3	1
Switching room	10	3
Surgery cancellation	68	16

Monte Carlo Simulation

The aim of this simulation is to make a model of operating theatre system. The first step, we simulate an ideal system. The ideal system means the surgery activity do not encounter ineffective scheduling procedures, the number of insertions emergency surgery, the number of operations that changing room, and the cancellation of the operation. The ideal model is able to estimate the maximum utilization that hospital may achieve. The simulation results shows maximum utilization for room 1,2,3 and 4 are 99,4%, 99,9%, 99,7%, and 99,9%. After we are confidence with the ideal model, then we develop scenarios to discover factors that affect low utilization.

Impact of Cancellation Rate

From surgery activity profile (Table 3), one factor that clearly affecting utilization is cancellation rate. Based on data, cancelled surgery is incorporated into simulation model. In this case, 16% cancellation rate is simulated. The result shows that at 16% cancellation rate in room 1 decrease utilization level to 83.7%. The similar results have been found for the other rooms with 83.1%, 83.7% and 84.8% consecutively. Yet, from this result we cannot directly draw conclusion about impact of cancellation

rate on utilization. To confirm the impact, different levels of cancellation rate are simulated. The result can be seen in Figure 3. This figure indicates that linear relationship exist between cancellation rate and utilization. It can be concluded that 1% of cancellation rate will reduce 1% of utilization.

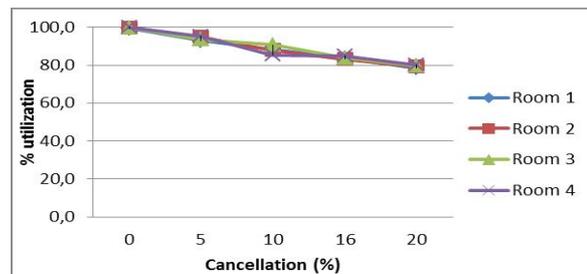


Figure 3. Impact of Cancellation Rate on Utilization

This important finding is very useful for hospital manager. It can be used to estimate further impact of cancellation on financial aspect. The hospital manager has responsibility to manage this operating theatre in order to achieve optimum level. Having this information, acceptable level of cancellation rate can be decided.

Impact of Waiting and Idle Time

In addition to cancellation rate, there are another two factors that reduce utilization of operating theatre i.e. waiting time and idle time. Waiting time occurs when patients had been prepared in pre-surgery room but must wait for surgery due to unavailability resources. Idle time occurs if the surgery of the day ended before the working hour is finished. Figure 4 illustrates both situations.

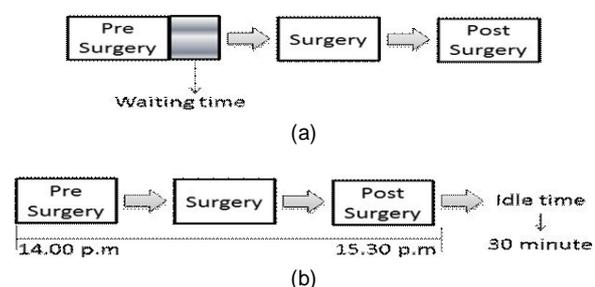


Figure 4. Illustration of Waiting Time and Idle Time

As illustrated in Figure 4 (a), the shaded area is showing that the patient needs to wait. It happened because the earlier surgery is longer than pre-surgery activity ended. Figure 4 (b) illustrates a situa-

tion where final surgery ended at 15.30 pm and working hours finished at 16.00 pm. If the next surgery will spend 60 minutes, then the surgery for that day will end and idle time will be 30 minutes.

Together with cancellation rate, both factors determine unutilized capacity. That is why this study should expose their impact on utilization. Simulation result has been able to reveal that both factors contribute to unutilized time about 24.7%, 18.6%, 23.1% and 2% consecutively for the rooms under study.

Through this simulation, we can breakdown factors affecting unutilized operating theatre capacity in the hospital. In addition, we get the comprehensive understanding about capacity utilization as presented in Table 4. The simulation result shows that room 4 has the biggest utilization rate. It has been confirmed that this room is allocated for neuro surgery activity, which consumed a lot of time in practice.

Table 4. Operating Theatre Capacity (%)

Room	1	2	3	4
Cancellation Rate	16	16	16	16
(Waiting + Idle) Time	24,7	18,6	23,1	2
Utilization from Simulation	59,3	65,4	60,9	82
Total	100	100	100	100

Research Limitation

We limit the area of this research only in one hospital in Bandung. Thus, the result may hardly be generalized to other hospital. Our focus is on elective surgery and the model developed for elective surgery will not be applicable for emergencies and one-day surgeries. We also assumed that in each process there is only one bed. This assumption was made to reduce model complexity.

Another assumption that we made is that sterilization and transportation time had been included in the process duration, due to lack of data collected to address this matter. We do not consider that there are resources delays. In fact, delay that occurred by surgeons in particular is part of the hospital policy.

CONCLUSION AND RECOMMENDATION

This study has successfully confirmed that utilization of operating theatres in this hospital is low and there is a need for improvement. The relationship between cancellation rate and utilization shows that 1% cancellation rate will decrease 1% utilization. We also concluded that the impact of waiting and idle time in these operating theatres is fairly high except for neurosurgery. Finally, formulating

utilization with time spent to conduct surgery provides meaningful information rather than number of surgeries conducted per day.

This study is able to reveal the factors of unutilized capacity based on historical data in the hospital. Since this is very important to the hospital level of service and sustainability, hospital managers are expected to consider such information in order to optimize operational and financial advantages to the hospital.

Studies on managing the operating theatres through simulation are relatively rare in Indonesia. Therefore, future research on this similar issue in other hospitals will provide a common pattern on this issue. In addition, more comprehensive works should be done to address some assumption that have been made. Further research is suggested to not only include elective surgery but also emergency and one-day surgery and address different bed capacity for each room, open-booking system, scheduling method and delay in schedule.

REFERENCES

1. Li LX, Benton WC, Leong GK. The Impact of strategic operations management decisions. *Journal of Operations Management*. 2002;20: 389-408.
2. Gomes CF, Yasin MM, Yasin Y. Assessing operational effectiveness in healthcare organizations: a systematic approach. *Int J Health Care Qual Assur*. 2008;23:127-40.
3. Min D, Yuehwern Y. Scheduling elective surgery under uncertainty and downstream capacity constraints. *Eur J Oper Res*. 2010;206:642-52.
4. Cardoen B, Demeulemeester E, Belien J. Operating room planning and scheduling: A literature review. *Eur J Oper Res*. 2010;201:921-32.
5. Dexter F, Traub RD. How to schedule elective surgical cases into specific operating rooms to maximize the efficiency of use of operating room time. *Anesthesia & Analgesia*. 2002;94:933-42.
6. Erdogan S, Denton B. www.ise.ncsu.edu. [Online]; 2009 [cited 2011 May 20]. Available from: <http://www.ise.ncsu.edu/bdenton/Papers/pdf/Erdogan2009.pdf>.
7. Tyler CD, Pasquariello CA, Chen CH. Determining optimum operating room utilization. *Anesth Analg*. 2003;96:1114-21.
8. Harders M, Malangoni MA, Weight S, Tejbir S. Improving operating room efficiency through process redesign. In *The 63rd Annual Meeting of the Central Surgical Association; Kentucky: Surgery Online*. 2006: 509-516.

9. Houdenhoven MV, Oostrum JMv, Hans EW, Wullink G, Kazemier G. Improving operating room efficiency by applying bin-packing and portfolio techniques to surgical case scheduling. *Anesthesia & Analgesia*. 2007; 707-714.
10. Schmitz HH, Kwak NK. Monte carlo simulation of operating-room and recovery room usage. *Oper Res*. 1972;20(6):1171-80.
11. Weinbroum AA, Ekstein P, Ezri T. Efficiency of the operating room suite. *The American Journal of Surgery*. 2003;185:244-50.
12. Hans EW, Nieberg T, Oostrum JMv. Optimization in surgery planning. *MET*. 2007; 15:20-8.
13. Ogulata SN, Erol R. A hierarchial multiple criteria mathematical programming approach for scheduling general surgery operations in large hospital. *Journal of Medical System*. 2003; 27(3): 259-70.