Application of the PROMETHEE II Method in Overcoming the Bottleneck Problem in An Emergency Department

Sharifa Amalina Binti Sadikon & Dr. Zaitul Marlizawati Binti Zainuddin

ABSTRACT

Emergency department (ED) is a primary healthcare department and a key component of the whole healthcare system. The original mission of ED is to primarily handle only emergent situations. However, ED visits include a wide range of illnesses and injuries that is truly emergencies, urgent, semi-urgent, and non-urgent cases.As a result of this, EDs are overcrowded and the length of stay (LOS) of patients has increased, whereas quality of service has decreased. The decision maker (DM) should analyze and eliminate this problem in order to allocate and optimize the hospital resources more efficiently. This work discusses the application of PROMETHEE II method in solving the bottleneck problem in an ED. PROMETHEE II is a prominent method for multi criteria decision aid (MCDA) that builds a complete ranking on a set of potential actions. Microsoft Excel 2010 and Visual PROMETHEE software are used to implement the method. The emergency department in Hospital Universiti Sains Malaysia, Kubang Krian is taken as the case study in our work. The result shows that improve the time taken to deliver test result ranked first in improving the patient flow and the most sensitive criterion are to reduce the hospital infections.

Keyword: Emergency Department, PROMETHEE, bottleneck

1. INTRODUCTION

An emergency department (ED), also known as emergency room (ER) is a medical treatment facility specializing in acute care of patients who present without prior appointment, either by their own means or by ambulance [1]. ED is a primary healthcare department [2], usually it will be the main entrance to the hospital, and a key component of the whole healthcare system. ED is a semi-autonomous unit that is open and staffed 24 hours per day, 365 days per year including holidays. ED is the busiest department in hospital and we need to improve the management of the department and the quality of health care services provided to the community [3].

The situation of emergency department is very dynamic and no control condition over what type of patients that are coming or how many often they come. This situation causes bottlenecks in ED and needs to be overcome to avoid the long waiting time among the patients. Every hospital with an emergency department aims to provide the patients with high quality care as efficiently as possible. Patients present in ED need emergency care and their needs are unpredictable and require many of hospital resources. Doctors in ED will ensure everybody receives their treatment according to the severity of their illnesses. Therefore, it is important for the public to know that emergency services are only for patient who need treatment that smaller hospitals or clinics cannot offer. This is important to ensure there is no backlog of patients in the hospital with non-emergency or non-critical illnesses that can possibly delay treatment for others who need it more [4].

The original mission of ED is to primarily handle only emergent situations. However, ED visits include a wide range of illnesses and injuries that is truly emergencies, urgent, semi-urgent, and non-urgent cases.ED need to increase their resources to attend to all these cases, therefore is becoming large, complex and dynamic unit. As a result of this, ED is overcrowded and the length of stay (LOS) of patients has increased, whereas quality of service has decreased. Therefore, new techniques and paradigms should be found in order to deal with such overcrowded condition.

ED managers require different and fresh solutions, because society demands not only care, quality and service, but also the best. Decisions in an ED environment can have huge consequences on patients' lives and can affect the overburdened working staff, causing low throughput, delay in treatment and the Length of Stay (LOS). Therefore, making decisions in an ED is a complex process and different objectives have to be taken into account and rationally structured. The decision maker (DM) should analyze and eliminate bottlenecks to allocate and optimize the hospital resources more efficiently [2].

Sincedecisions in an ED environment can have huge consequences on patients' lives and can affect the overburdened working staff, causing low throughput, delay in treatment and the Length of Stay (LOS), many researches have been done in finding the solution to the bottleneck problem in ED. It can be seen that many researchers are concerned on the way ED is managed and tried to find the alternatives to make the ED management more effective since ED is an important part in a hospital.

There are many methods in Operational Research (OR) that can be implemented to structure decision-making and improve the efficiency of management in ED. OR methods have grown to concern problems in a variety of industries that facing complexity of their activities since World War II due to the newly invented technologies [5]. PROMETHEE II method is one of them. PROMETHEE II provides a complete ranking of alternatives from the best to the worst one. This method is able to balance actions with qualitative and quantitative criteria. This work considers the allocation of finite hospital resources considering different criteria in an ED to improve the quality of health care services provided to the community by using an outranking approach. One of the significance of this research is the information gained on the operation of ED. The appropriate data needs to be obtained so that the efficiency can be improved. The finding of this study could be implemented in order to improve the operation of an ED and thus better service can be given to the patients.

This paper presents a real application of PROMETHEE II with a view to improving decision-making and resource management in an ED. The method is used to rank possible alternatives to solve a specific bottleneck in an ED. This paper is structured as follows: first the PROMETHEE II method is presented. Then emphasis is given to an application in Hospital Universiti Sains Malaysia, Kubang Kerian (HUSM) for validation purpose. The paper concludes with a discussion of the method applied recommended for the future study.

1.0 The PROMETHEE II method

PROMETHEE II is a prominent method for multi criteria decision aid (MCDA) that builds a complete ranking on a set of potential actions by assigning each of them a so-called net flow score. However, to calculate these scores, each pair of actions has to be compared, causing the computational load to increase quadratically with the number of actions, eventually leading to prohibitive execution times for large decision problems. For some problems, however, a trade-off between the ranking's accuracy and the required evaluation time may be acceptable [6]. PROMETHEE II method is able to classify the alternatives which are complex and difficult to compare. Inaddition, it has other characteristics such as simplicity, clarity and stability. It is based on the multi-criteria net flow and includes preferences and indifferences [7].

PROMETHEE II also provides a complete ranking. The large data sets must be handled fast because providing the decision maker with an outranking-based evaluation on *n* actions comes at a cost of $O(n^2)$ pairwise action comparisons. The computation time increases accordingly, eventually reaching the limit of evaluation time that is considered as acceptable [6].

The principle of PROMETHEE II is based on a pair-wise comparison of alternatives for each criterion [8]. The alternatives are evaluated according to different criteria which have to be maximized or minimized. Each criterion should be able to distinguish all the alternatives, regardless of how the alternatives behave under other criteria. Basically, PROMETHEE II provides complete ranking of alternatives, so, the decision maker has to identify the alternatives, assign weights to each alternatives, scoring the criteria and should understand the outranking relationships.

The PROMETHEE II method can be described in seven steps:

Step 1 : Normalize the decision matrix.

$$R_{ij} = \frac{[X_{ij} - min_j(X_{ij})]}{[max_j(X_{ij}) - min_j(X_{ij})]} \qquad (1)$$

$i = 1,2,3, \dots, n$ and $j = 1,2,3, \dots, m$

where X_{ij} is the DM's evaluation of the i^{th} alternatives with respect to the j^{th} criteria.

Step 2: Evaluate the differences of the i^{th} alternatives with respect to the other one. This means that the differences in criteria values between different alternatives should be determined pair-wise.

Step 3: Choose and calculate the preference function, $P_j\ (i\ , i)$ where i is a set of alternatives. The PROMETHEE method induces a preference function to describe the DM's preference difference between pairs of alternatives on each criterion. There are six distinct types of generalized preference functions that range from 1 to 0. It is possible to choose a different function for each criterion. The criterion function used in this study is defined by

$$P_j\ (A_i\ , A_i{}') = 0 \ \ if \ \ R_{ij} \ \le \ R_{i'j} \qquad (2)$$

$$P_j\ (A_i\ , A_i{}') = 1 \ \ if \ \ R_{ij} > R_{i'j} \qquad (3)$$

Step 4: Determine the aggregated preference function incorporating the weights:

$$\pi\ (A_i\ , A_i{}') = \sum_{j=1}^{m} P \ \ (A_i\ , A_i')w_j \qquad (4)$$

where W_j is the weight of relative important of the j^{th} criterion.

Step 5: Each alternatives can be related to $(n - 1)$ alternatives resulting in a positive or negative outranking flow. Thereafter, it is necessary to calculate the leaving and entering outranking flow which are given by

The leaving flow: $\emptyset^{+}(A_i\ ) = \frac{1}{n-1} \sum_{i'=1}^{n} \pi\ (A_i\ , A_i{}')\ , \quad (i \neq i')$ (5)

The entering flow: $\emptyset^{-}(A_i) = \frac{1}{n-1}\sum_{i'=1}^{n} \pi\,(A_i{}', A_i)\,, \quad (i \neq i')$ (6)

where n is the number of alternatives. The entering flow is a measure of the weakness of the alternatives while the leaving flow is a measure of the strength of the alternatives.

Step 6: PROMETHEE II provides a complete preorder determined by the net outranking flow of decision alternatives:

The net flow : $\emptyset\,(i) = \emptyset^{+}\,(i)$ - $\emptyset^{-}\,(i)$ (7)

Step 7: Determine the ranking of alternatives considering the net outranking flow. The highest $\theta(i)$ is the best alternatives. Another advantage of using PROMETHEE II is that is incomparability among alternatives.

The case study to demonstrate the applicability of PROMETHEE II was carried out in Hospital Universiti Sains Malaysia, Kubang Kerian. Real data were used to test and validate the method. The following section will elucidate how PROMETHEE II can be applied to improve the decision-making and to solve productive bottlenecks in an ED more efficiently.

3. Application and results

The goal of most emergency department in hospital is to provide treatment for those who need the urgent medical care, with the goal of satisfactorily treating the presenting conditions, or arranging for timely removal of the patient to the next point of definitive care.

In order to improve the medical services in ED, the hospital manager or the DM who is in charge of managing resources had evaluated the alternatives taking into consideration six criteria. The weights of the six criteria were obtained from the DM in which he indicated the relative importance of each criterion based on the situation in ED and his experience.

All the alternatives suggested may lead to improve some criteria. In this work, the criteria are considered to be maximized. The expectation of the decision-maker is to identify an alternative optimizing all the criteria. Usually this is an ill-posed mathematical problem as there exist no alternative optimizing all the criteria at the same time. However, most human problems have a multi criteria nature.

According to the various human aspirations, it makes no sense and unfair to select a decision based on one evaluation criterion only. In most cases, at least technological, economic, environmental and social criteria should always be taken into account. Multi criteria problems are therefore extremely important and request an appropriate treatment.

The possible alternatives considered in this study to solve the bottleneck are discipline the medical staff (A_1), relocate one physician from the outpatients departments to the emergency department during peak hours (A_2), relocate two physicians during peak times (A_3), develop an information system for queue management (A_4), change the ED layout (A_5), relocate an administrative assistant to support the physician (A_6) and improve the time taken to deliver test results (A_7).

In this research, the DM evaluated the alternatives taking into consideration six criteria. The criteria were to improve Patient Throughput (PT), Quality (Q), Operational Control (OC), Motivation of Healthcare Staff (MHS), to reduce Operational Expenses (OE) and Rate of Hospital Infection (HI) [8]. The DM needs to indicate the relative importance of each criterion to the alternatives. The relative weight assigned by the DM were W_{PT} = 0.35, W_{OE} = 0.125, W_Q = 0.175, W_{OC} = 0.25, W_{HI} =0.025 and W_{MHS} = 0.075.

Several methods have been devised to transform verbal statements into quantitative outcomes. A well-known approach is the seven-point scale. Instead of seven-point scale, a five-point scale may be used also [9]. A fuzzy verbal scale was used during the evaluation to express the decision maker's subjectivity. The fuzzy verbal scale that is used to assign the score were as follow : Very high (VH) - 0.9, High (H) - 0.7, Average (A) - 0.5, Low (L) - 0.3, Very Low (VL) - 0.1.

Once the alternatives and criteria were defined, the DM evaluated the alternatives on each criterion. Table 1 illustrates the evaluation of alternatives as judged by DM. The DM evaluation as shown in Table 1 is converted into crisp scores using the fuzzy scale mentioned in above. Then, a decision matrix as shown in Table 2 was formed. After the evaluation, the maximum and minimum values need to be identified.

Table 1 The DM evaluation

Alternatives (*i*)	**Criteria (*j*)**					
	PT	**OE**	**Q**	**OC**	**HI**	**MHS**
A_1	H	L	VH	H	H	VH
A_2	VH	L	A	VH	VL	H
A_3	VH	VL	A	VH	VL	H
A_4	VH	A	VH	VH	VL	H
A_5	H	VL	A	H	VL	A
A_6	H	A	A	H	A	H
A_7	VH	H	VH	VH	VL	H

Table 2 Decision matrix

Alternatives (*i*)	Criteria (*j*)					
	PT	**OE**	**Q**	**OC**	**HI**	**MHS**
$\mathbf{A_1}$	0.7	0.3	0.9	0.7	0.7	0.9
$\mathbf{A_2}$	0.9	0.3	0.5	0.9	0.1	0.7
$\mathbf{A_3}$	0.9	0.1	0.5	0.9	0.1	0.7
$\mathbf{A_4}$	0.9	0.5	0.9	0.9	0.1	0.7
$\mathbf{A_5}$	0.7	0.1	0.5	0.7	0.1	0.5
$\mathbf{A_6}$	0.7	0.5	0.5	0.7	0.5	0.7
$\mathbf{A_7}$	0.9	0.7	0.9	0.9	0.1	0.7
Min	0.7	0.1	0.5	0.7	0.1	0.5
Max	0.9	0.7	0.9	0.9	0.7	0.9

Table 3 Normalized decision matrix

Alternatives (*i*)	Criteria (*j*)					
	PT	**OE**	**Q**	**OC**	**HI**	**MHS**
$\mathbf{A_1}$	0	0.3333	1	0	1	1
$\mathbf{A_2}$	1	0.3333	0	1	0	0.5
$\mathbf{A_3}$	1	0	0	1	0	0.5
$\mathbf{A_4}$	1	0.6667	1	1	0	0.5
$\mathbf{A_5}$	0	0	0	0	0	0
$\mathbf{A_6}$	0	0.6667	0	0	0.6667	0.5
$\mathbf{A_7}$	1	1	1	1	0	0.5

After the evaluation, the data need to be normalized. Normalization is the process of reorganizing data in a database so that there is no redundancy of data and the data dependencies are logical. Normalization is important because it is a process of analyzing the given relation schemas based on their functional dependencies. The matrix was normalized using equation (1). The normalized decision matrix is given in Table 3.

To find the evaluative differences of i^{th} alternative with respect to other alternatives, the preference function, $P_j(A_i, A_i{'})$ was calculated. This step involves the calculation of differences in criteria values between different alternatives pair-wise. The preference functions require the definition of some preferential parameters, such as the preference and indifference thresholds. However, in real time applications, it may be difficult for the decision maker to specify which specific form of preference function is suitable for each criterion and also to determine the parameters involved. To avoid this problem, the following simplified preference function is adopted using equations (2) and (3). The function assumes values of 1 if the performance difference is positive and has strong preference or 0 if the difference is negative and has weak preference. Table4 exhibits the preference matrix using the usual preference function after all the 42 pairs of alternatives.

Table 4 Preference functions for the pairs of alternatives

	PT	OE	Q	OC	HI	MHS
P(A1,A2)	0	0	1	0	1	1
P(A1,A3)	0	1	1	0	1	1
P(A1,A4)	0	0	0	0	1	1
P(A1,A5)	0	1	1	0	1	1
P(A1,A6)	0	0	1	0	1	1
P(A1,A7)	0	0	0	0	1	1
P(A2,A1)	1	0	0	1	0	0
P(A2,A3)	0	1	0	0	0	0
P(A2,A4)	0	0	0	0	0	0
P(A2,A5)	1	1	0	1	0	1
P(A2,A6)	1	0	0	1	0	0
P(A2,A7)	0	0	0	0	0	0
P(A3,A1)	1	0	0	1	0	0
P(A3,A2)	0	0	0	0	0	0
P(A3,A4)	0	0	0	0	0	0
P(A3,A5)	1	0	0	1	0	1
P(A3,A6)	1	0	0	1	0	0
P(A3,A7)	0	0	0	0	0	0
P(A4,A1)	1	1	0	1	0	0
P(A4,A2)	0	1	1	0	0	0
P(A4,A3)	0	1	1	0	0	0
P(A4,A5)	1	1	1	1	0	1
P(A4,A6)	1	0	1	1	0	0
P(A4,A7)	0	0	0	0	0	0
P(A5,A1)	0	0	0	0	0	0
P(A5,A2)	0	0	0	0	0	0
P(A5,A3)	0	0	0	0	0	0
P(A5,A4)	0	0	0	0	0	0
P(A5,A6)	0	0	0	0	0	0
P(A5,A7)	0	0	0	0	0	0
P(A6,A1)	0	1	0	0	0	0
P(A6,A2)	0	1	0	0	1	0
P(A6,A3)	0	1	0	0	1	0
P(A6,A4)	0	0	0	0	1	0
P(A6,A5)	0	1	0	0	1	1
P(A6,A7)	0	0	0	0	1	0
P(A7,A1)	1	1	0	1	0	0
P(A7,A2)	0	1	1	0	0	0
P(A7,A3)	0	1	1	0	0	0
P(A7,A4)	0	1	0	0	0	0
P(A7,A5)	1	1	1	1	0	1
P(A7,A6)	1	1	1	1	0	0

The simplicity is the main advantage of these preference functions. There are not more than two parameters at a time, each having a clear chronological significance. The usual criterion function is indicated for qualitative criteria. This means that any difference between the evaluations of alternatives for a given criterion implies in a situation of strict preference. For example, when the DM compares the alternatives A_1 and A_2 in the first row, it means that A_1 is not preferred to A_2 considering the PT criterion. This implies that the difference between A_1 and A_2 on PT is negative and has a weak preference. When comparing A_1 and A_2 in the first row considering the Q criterion, it means that A_1 is preferred to A_2 and the difference between the two alternatives is positive and has a strong preference.

A multi criteria preference index, $\pi(A_i, A_i')$ can then be defined considering all the criteria by using equation 4. This index also takes values between 0 and 1 and represents the global intensity of preference between the couples of alternatives. The aggregate preference functions are calculated and Table 5 shows the aggregate preference functions for the paired alternatives and represents how A_1 is preferable to A_2 considering all the six criteria after all the aggregated functions were calculated.

Value of $\pi\ (A_i, A_i')$ that is approximately 0 implies a weak global preference of A_i over A_i' whereas value of $\pi\ (A_i, A_i')$ that is approximately 1 implies a strong global preference. For example, $\pi\ (A_4, A_5) = 0.975$ implies that A_4 over A_5 have a strong global preference considering all six criteria. But, for A_2 over $A_{4,}$ the alternatives have a weak global preference considering all six criteria since $\pi\ (A_2, A_4) = 0$.

After considering the aggregate preference function, next, leaving, entering and net flow need to be calculated using equations (5) and (6). The positive outranking flow expresses how an alternative $A_i$outranking all the others. It is its power, its outranking character. The higher $\emptyset^{+}(A_i)$is thebetter alternative (Figure 1a). The negative outranking flow expresses how an alternative A_i is outranked by all the others. It is its weakness, its outranked character. The lower the $\emptyset^{-}(A_i)$is the better alternative (Figure 1b) [10].

a) The$\emptyset^{+}(A_i)$ outranking flow   b) The $\emptyset^{-}(A_i)$ outranking flow

Figure 1 The PROMETHEE outranking flow

The leaving, entering and net flow as well as the ranking of the alternatives are shown in Table 6. The last column exhibits the ranking of the best alternative depending on the values of $\emptyset$ (A_i). The higher the value of $\emptyset$ (A_i) is the better alternative. Thus, the best alternative is improving the time taken to deliver test result ($A_{7)}$ with the net flow of 0.533. While the least encouraged alternatives is change the ED layout (A_5) that can cause a high financial implication.

Table 5 Aggregate preference function

	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
A1	-	0.275	0.400	0.100	0.400	0.275	0.100
A2	0.6	-	0.125	0.000	0.800	0.600	0.000
A3	0.6	0.000	-	0.000	0.675	0.600	0.000
A4	0.725	0.300	0.300	-	0.975	0.775	0.000
A5	0	0.000	0.000	0.000	-	0.000	0.000
A6	0.125	0.150	0.150	0.025	0.225	-	0.025
A7	0.725	0.300	0.300	0.125	0.975	0.900	-

Table 6 Leaving, entering and net flow and ranking of the alternatives.

Alternatives	Leaving Flow	Entering Flow	Net Flow	Ranking
A1	0.258	0.463	-0.204	**5**
A2	0.354	0.171	0.183	**3**
A3	0.313	0.213	0.100	**4**
A4	0.513	0.042	0.471	**2**
A5	0.000	0.675	-0.675	**7**
A6	0.117	0.525	-0.408	**6**
A7	0.554	0.021	0.533	**1**

Many MCDA models and methods are available for decision making. Apart of using Microsoft Excel, Visual PROMETHEE Software is one of the most widely used and scientifically recognized methodologies that can be used to evaluate the ranking of alternatives. The ranking of the alternatives can be determined using PROMETHEE Rankings module in the software by clicking PROMETHEE-GAIA. The result given by Microsoft Excel 2010 and Visual PROMETHEE Software are the same with the best alternative is improving the time taken to deliver test results ($A_{7)}$ with the highest net flow of 0.5333.

When applying the PROMETHEE II method, it is important to study the sensitivity of the ranking due to modifications in the weights of each criterion. Sensitivity analysis can be determined by the correlation between the criteria and through the computation of the intervals of stability [11]. The weightage of the criteria is known to play a major role in MCDA. By carrying out the sensitivity analysis, the decision maker is able to see to what extent changes of the weights of the criteria will impact the rankings provided by a multi criteria method [12]. In this work, the interval of stability is obtained by varying the weight of one criterion at a time keeping the other criteria fixed. The interval shows the limits to the weight of each criterion to keep the ranking unchanged when the other weights are kept at their initial levels. Table 7 shows the upper and lower limits of the range of stability for each of the criterion.

Table 7 Range of stability

Criterion	Lower bound	Upper bound	Sensitivit y
Patient throughput (PT)	0.09	1	0.91
Operational expenses (OE)	0.01	0.43	0.42
Quality (Q)	0.01	0.43	0.42
Operational control (OC)	0	1	1
Hospital infections (HI)	0	0.25	0.25
Motivation (MHS)	0	0.37	0.37

Once the lower boundaries and upper boundaries have been identified, the difference of the two aspects determines the most sensitive criterion. Based on Table 7, to reduce the hospital infection (HI) is the most sensitive criterion and to maximize the operational control (OC) is the least sensitive criterion.

4.0 Discussion

From Table 6, the ranking shows that alternatives A_7 was the best alternative to improve the patient flow since it has the highest $\emptyset(A_i)$of all the six criterion considered. In addition, the net flow column shows a small difference between A_2 and A_3. Based on the best alternatives in the ranking, the DM decided to improve the time taken to deliver the test results to avoid the delay of patients' test result and to make the "Blue Room" more productive, the DM will develop an information system for queue management for the physician as it is the second alternative ranked so that the waiting time can be reduced when the numbers of patients waiting to be diagnosed and treated in emergency department is at its highest. However, the least satisfactory alternative is A_5 which is change the layout in emergency department. This alternative is the most non-preferable because it could generate an extra cost to the hospital without necessarily solving the specific bottlenecks.

The most sensitive criterion shown in range of stability in Table 7 is to reduce the rate of hospital infection, HI. When the times taken to deliver the test result are improved, HI is the criterions that will be improved first. Hospital infection is a disease caused by micro-organisms like viruses, fungi, bacteria or parasites that are often called bugs or germs. All over the four micro-organisms, bacteria are the most common causes of healthcare-associated infections (HAI). HAI usually occurs two or three days after admission to the hospital. These infections occur at a cost to the community and the patient because they causes illness to the patient and give the higher cost associated with a longer stay in hospital and a longer recovery. ED is the one area of the hospital that is more likely to have the infection [13]. However, to improve the operational control (OC) is the least sensitive criterion since this criterion need use large physical facilities that lead to the higher cost.

5.0 Discussion

PROMETHEE II methodology can be utilized as a valuable decision-making process to evaluate the alternatives in a logical and consistent manner. We can identify the potential benefits of this method in a hospital environment. First of all, the value of measurement model for other MCDA required additional effort to calculate the weights because time needed to calculate interpret the swing weight but in PROMETHEE II, the weight need to satisfy the preferential independence of criteria and the trade-off requirement [14]. So, no extra time or conditions needed because the weight convey the relative importance of each criterion in the assertion that one alternative is better that others. Furthermore, not much effort is required to develop performance value scores because this method reflects the notion of the most acceptable compromise with respect to the preference structure by the DM.

Taking the usual PROMETHEE preference parameters, such as weights and indifference or preference thresholds, an approximation of an action's net flow score is provided by a function that only depends on its evaluations. The approximated scores are then used to determine a complete ranking over the set of considered actions. However, using PROMETHEE II method in an ED has disadvantage including uncertainty in the analysis of variation on preferences of different alternatives. PROMETHEE suffers from the rank reversal problem when a new alternative is introduced. Besides, PROMETHEE does not provide the possibility to really structure a decision problem. In the case of many criteria and options, it may become difficult for the decision maker to obtain a clear view of the problem and to evaluate the results. Until now, PROMETHEE does not provide any formal guidelines for weighting, but assumes that the decision maker is able to weight the criteria appropriately.

Decisions on resource management in ED give implications to society because it can affect the quality of the emergency services provided and people's lives. PROMETHEE II proved to be a rational framework that can support the DM to rank the alternatives to solve the bottlenecks correlated to overcrowding in ED. The ranking and the stability interval help the manager to find the best alternatives to improve the throughput in ED where non-critically ill patients are diagnosed and treated thus, bringing new insights for the DM's decisions.

From the solution to the PROMETHEE II method on ED problem, the first ranking of the alternatives that bringing the new insights for the DM's decision is improving the time taken to deliver the test result that may give the improvement in reducing the hospital infections as the most sensitive criterion. As this alternative be improved, it can be implemented in order to improve the operation of an ED and thus give the better services to the patients.

From this study, some recommendations are suggested for future study. First, the ranking of the alternatives can be evaluated by using other variants of PROMETHEE method. Second, consider other alternatives that give more priority to solve the bottlenecks in ED and other criteria to be improved and the third is the peak hour must be determined exactly so that the time taken to deliver the test result can be improved, hence the blue room become more productive without the long waiting time and overcrowding.

References

1. NHS Choice. Emergency and Urgent Care Services. Available at:

   http://www.nhs.uk/NHSEngland/AboutNHSservices/Emergencyandurgentcareservices/Pages/AE.aspx. Retrieved on 2 October 2014.

2. Cabrera, E., Taboada, M., Iglesias, M. L., Epelde, F., and Luque, E., Simulation Optimization for Healthcare Emergency Departments. Procedia Computer Science 12 (2012) 1464 – 1473.

3. Selasawati, H. G., Naing, L., Aasim, W. A. W., Winn, T. and Rusli, B. N., *Inappropriate Utilization of Emergency Department Services in Universiti Sains Malaysia Hospital*,.Medical Journal of Malaysia 59 (1) (2004) 26-33.

4. Dr. Khoo Yoong Khean . *"Help! This Is An Emergency!", Or Is It?* Available at : http://www.mmgazette.com/help-this-is-an emergency-or-is-it-dr-khoo-yoong-khean/. Retrieved on 2 November 2014.

5. Taha. H.A. *Operations Research an Introduction*. 8th ed. Pearson Education Inc. (2007) 329-344.

6. Eppe, S. and Smet, Y. D., *Approximating PROMETHEE II's Net Flow Scores by Piecewise Linear Value Functions*, European Journal of Operational Research 233 (3) (2014) 651-659.

7. Amaral, T. M. and Costa, A. P. C. *Improving-Decision Making And Management Of Hospital Resources : An Application Of the PROMETHEE II Method In An Emergency Department*, Operations Research for Health Care 3 (1) (2014) 1- 6.

9. Nijkamp, P., Rietveld, P. and Voogd, H., *Multicriteria Evaluation in Physical Planning.* Amsterdam, Netherland : Elsevier Science Publisher (1990).

10. Brans, J.P., Vincke, P.H. and Mareschal, B., *How To Select And How To Rank Projects: The PROMETHEE Method*, European Journal of Operational Research 24 (2) (1986) 228-238.

11. D'Avignon, G. and Mareschal, B., *Specialization of Hospital Services in Quebec: An Application of The PROMETHEE and GAIA Methods*, Mathematical and Computer Modeling, 12 (10–11) (1989) 1393 – 1400.

12. Mareshal, B., *.PROMETHEE GAIA.net.* Available at: http://www.prometheegaia.net/methods.html. Retrieved on 13 May 2015.

13. Infections in Hospital - Reduce The Risk. Available at: http://www.betterhealth.vic.gov.au/. Retrieved on 10 June 2015.

14. Thokala, P. and Duenas, A., Multiple Criteria Decision Analysis for Health Technology Assessment. *Value in Health* 15 (8) (2012) 1172–1181.