LEAN MANAGEMENT APPROACH IN EMERGENCY MEDICAL TRAUMA SERVICE USING ANALYTIC HIERARCHY PROCESS

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Abstract - The effectiveness of the Emergency Medical Trauma Services (EMTS) is dependent on a diverse range of decision making, planning and operational phases, such as ambulance locations and dispatching protocols. An important indicator of the quality of care and service delivery in the Emergency and Trauma Department (ETD) is the satisfaction of the patients. The objective of this study was to evaluate the patients' satisfaction factors towards ambulance and ETD services. This study was carried out with the aid of questionnaires, followed by descriptive and analytical statistics using Analytic Hierarchy Process (AHP). Respondents of 150 patients were randomly selected. Based on the overall priority scores of satisfaction factors of patients in the ambulance services, for the domain priority, it was found that the efficiency of services was ranked the highest at 34.3% and lowest ranking for vehicles at 5.24%. Based on the overall priority scores of satisfaction factors of patients in the emergency department, for the domain priority, it was found that the staff performance was ranked highest at the 39.41% and lowest ranking for efficiency of services at 13.28%. From the analysis, it was found that the most important satisfaction factor in EMTS is the speed of admittance of patients to the hospital, and the length of waiting period before admittance into the examination room. From the calculations of the priorities of the EMTS, the satisfaction factors could be used to develop a lean management approach and thus, further research can be conducted on AHP analysis and operational decision making in order to improve the quality of the EMTS system.

Index Terms - Emergency Medical Trauma Services (EMTS), satisfaction factors, lean management approach, operational decision making.

I. INTRODUCTION

Emergency medical and trauma care service (EMTS) is the most important service present in the hospital compared to any other hospital services because it is a 24-hours non-stop service providing unit throughout the year. It is also known as emergency ambulance service or pre hospital care in Malaysia. Emergency medical and trauma care service (EMTS) is also one of the public safety systems which acts as the first responder to the patient, in which is the first point of contact between healthcare providers and the patients [1], [2]. The emergency medical and trauma services (EMTS) in Malaysia is divided into two parts, which are the ambulance services or pre-hospital care, and the emergency department. Emergency medical and trauma services (EMTS) is important for the support of emergency and accident cases, in which it will promote early recovery, prevent serious complications and ensuring quality health care. There were various types of ambulance services in Malaysia; namely, they were the land ambulance, air ambulance, water squad, motorcycle and bicycle squad. According to [3], there were several agencies in Malaysia that provide emergency ambulance services such as the government and private hospitals, Malaysian Civil Defense Department, St. John Ambulance Malaysia, Malaysia Red Crescent Society, and etc. Following the ninth Malaysia Plan, in 2011 the tenth Malaysian Plan was launched with the theme of "Ensure Access to Quality Healthcare and Promote Healthy Lifestyle", was for the purpose to increase the efficiency and effectiveness of the delivery system. This was done by transforming the health sector delivery system [4]. It was important for the administration to be identified with the reaction time of an emergency call. This was important that the rescue vehicle was dispatched to the closest station to ensure that the patients can get the treatment in the most limited period [5]. In accordance with the Tenth Malaysia Plan, the Ministry of Health Malaysia had focused to have emergency physicians in all specialist hospitals. This was caused by the annual expansion of the quantity of patients looking for administrations from the Emergency Department. For example, there is an expansion of 29.08% in the number of patients getting treatment in the year 2009, compared to the year before, that was, from 5,225,798 to 6,745,721 patients [6]. Besides that, with the help of Telekom Malaysia, a project named "Medical Emergency Response System 999 (MERS 999) was launched in the year 2007. Similar to the Medical Emergency Coordinating Centre, MERS 999 functions as one of the authorities to manage the emergency calls, and thus, had improved the response time [6]. However, this project did not solve the problems of emergency services as there was an average 0.324 fake calls reported by the four agencies involved, which included the Royal Police Department, Fire Rescue Department, Ministry of Health and Civil Defence Department [7]. This study was thus carried out on the patients' perception on the Emergency Medical and Trauma Services (EMTS)

which was on the ambulance services and the emergency department of government hospitals in Kota Kinabalu, and further determining the main criteria and sub-criteria in the selection of ambulance services and emergency department at the hospital via the analytic hierarchy process.

II. LITERATURE REVIEW

Emergency Medical and Trauma Care Service (EMTS) is one of the popular points for Operations Research [8]. The ambulance and the ambulance staff are the main sources of Emergency Medical and Trauma Care Service (EMTS). However, the sources are always in scarce because of its high operation cost. Therefore, the coordination of sources of Emergency Medical Trauma Service (EMST) is important to achieve the main goal, which is to increase the survival rate of patients. It is known that every emergency is a timely manner, that is, the faster the response time, the less the impact of the incident. Hence, the minimum maximal response time to the emergency caller is one of the goals for the ambulance service worldwide. In order to overcome the problem, the Decision Support System (DSS) is a must for the modern Emergency Medical Trauma Service (EMTS) providers to learn and apply. For example, the deployment of ambulances and the crew shift scheduling in the sector of Emergency Medical Trauma Service (EMTS). There are three types of logistics decisions regarding ambulances which are associated with the response time. First, the location of the ambulance's station needs to be optimized in terms of coverage. Next is the relocation plan to maximize the coverage area. Lastly, the strategy of ambulance dispatching the patients in order to assign ambulance to the patients [9]. [10] used an integer linear programming model to solve the allocation problem for Emergency Medical and Trauma Care Service (EMTS). In Malaysia, the coordination between ambulance services' providing agencies is weak in terms of deployment strategy. For instance, the deployment of ambulance is not standardized. The coordination problem of ambulance service is the primary focus of EMTS Malaysia. The ambulance coordination problem is known as a Complex Event Processing (CEP) problem.Complex Event Processing (CEP) is a model to solve a complex event by indentifying and transmitting the changes occurs during an operation. In the case of the ambulance service, it reviews the performance of ambulances' service operation stages [11]. The performance of Emergency Medical Trauma Service (EMTS) in terms of ambulance service in Malaysia is reviewed by the Key Performance Indicators (KPIs). The main criterion of the Key Performance Indicator (KPI) for ambulance service is to response to cases within five minutes although the target response time set by the Ministry of Health Malaysia is within 15 to 30 minutes [6], [12]. According to [13], the Emergency Medical Trauma Service (EMST) can be evaluated using simulation. The evaluation process is initiated with the ambulance dispatching and ends with selection of hospitals.

III. METHODOLOGY

The study was conducted at three different government hospitals in Kota Kinabalu, Sabah, which were namely, the Sabah Women and Children's Hospital (SWCH), Queen Elizabeth I Hospital and Queen Elizabeth II Hospital. They were selected as the study sites because these hospitals provided Emergency Medical and Trauma Services (EMTS). A questionnaire was used in this study as the research instrument for data collection. The questionnaire was adapted from a study on patient's perception of the ambulance services from Universiti Sains Malaysia Hospital [14], and from the emergency department patient satisfaction survey in Imam Reza Hospital, Tabriz, Iran [15]. It was consisted of three sections, namely, were; Section A: Includes the background of the respondents, Section B: Includes the patients' perception on ambulance services , and Section C: Includes the patients' perception on emergency department at the Emergency Medical and Trauma Services (EMTS). Pilot test and reliability test of 30 respondents were conducted before the questionnaires were fully distributed. The questionnaires were then distributed on the sample showing the considerations regarding the design criteria used in this questionnaire. For the total survey, 150 questionnaires were then distributed to the patients of the three selected hospitals in this study. According to [16], a minimum acceptable reliability test value is 0.60. The data obtained from Section A of the questionnaire forms was statistically analysed for descriptives statistics using the IBM tools Statistical Package for Social Science (SPSS) version 22.0. AHP is one way of decision-making process which involves setting a higher priority, and identifying the location of the various criteria with a weighting of comparisons in pairs. This can be done by using a hierarchical structure, allowing decision-makers to draw up criteria, sub-criteria and the alternatives involved, and thus a special matrix is used for a better assessment [17], [18]. Hierarchical structure was constructed so as to make it easier for any researcher to look at the arrangements and priorities in making the pairwise comparison matrix. It was divided into three phases, which were objective or purpose (Phase 1), the selected criteria (Phase 2), and sub-criteria (Phase 3) respectively as shown in Figure 1.

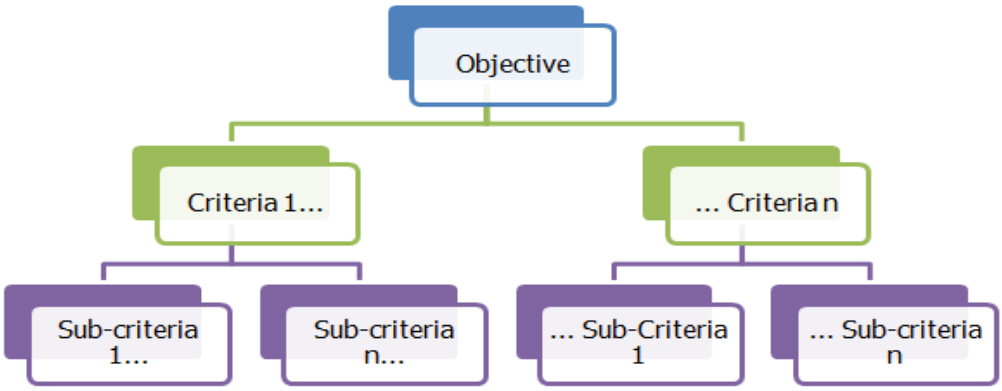

Figure1. Analytic Hierarchy Process Structure [17].

Matrix (size: n x n) for pairwise comparison was then built for each level in the hierarchy. The value used in pairwise comparison matrix was assigned with Saaty scale of 1-9 by [18], as shown in Table 1.

Table 1. Saaty 1-9 scale [18]

The importance of scale	Description
1	Criteria A and criteria B is equally important
3	Criteria A slightly important than criteria B
5	Criteria A more important than criteria B
7	Criteria A strongly more important than criteria B
9	Criteria A absolutely more important than criteria B

The value of the weights were identified and the criteria involved were then be determined. The arrangement, number, and size of the matrix would depend on the number of elements for each level of the hierarchy [19].

$$A = (a_{ij})_{nxn} = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{pmatrix}$$

For all i,j = 1,2,3.....,n and aij> 0

The comparison of each stage can be identified by using the formula: $\frac{n(n-1)}{2}$

……..(1)

The pairwise comparison matrix should then be normalized, by calculating the sum of each column of the matrix divided by the number of pairwise comparisons element, n, and is given by the formula (2) below:

$$\frac{\text{(The sum of each column in the matrix of pairwise comparison)}}{n}$$

…(2)

Computation of the weights is given by [18] in formula (3):

$$\frac{\text{(the sum of each row in the matrix normal)}}{n}$$

…(3)

The inconsistency of AHP was done by comparing the data with a set of decision-making random decisions, assuming that the data were of the same matrix size with random certainty [19]. According to [17], a calculation was carried out using a ratio of inconsistency, and the accepted value of the ratio should be less than 0.10. The calculations of the consistency analysis were as follows:-

1) Calculate the Principal Eigenvalues

[20] had shown that λ_{max} is always greater than or equal to n. λ_{max} can be calculated by adding each result from column in the matrix of pairwise comparisons after multiplied by the weighting of each. The principal eigenvalues formula is given by:

λ_{max} = [(Number of pairwise comparison matrix column 1)] x weight (1) +……+[(Number of pairwise comparison matrix column n)] x weight (n)

…….(4)

2) Calculate the Consistency Index (CI)

Next, calculate the value of the consistency index (CI) introduced by [17], given by the formula:

$(CI) = \frac{\lambda_{max} - n}{n}$ ……..(5)

where n is the number of elements that been compared.

3) Calculate the Ratio of Consistency

RI is a random index which is the average number of the CI matrix generated randomly (as shown in Table 2). The ratio of the probability calculations for consistency would generate a randomly filled pairwise comparison matrix. Consistency ratio (CR) of between 0 and 0.10 or in the range of 10% to an output of a random justification is acceptable. When the CR more than 10% the third step is to build a comparative matrix should be repeated [18]. By using formula (6) below,the consistency ratio can be calculated.

$CR = \frac{CI}{RI}$ ……...(6)

Table 2. Random Indeks [18]

n	1	2	3	4	5	6	7
IR	0	0	0.58	0.9	1.12	1.24	1.32

The 8-Steps using pairwise matrix of the AHP methodology can be summarized as shown in Figure 2.

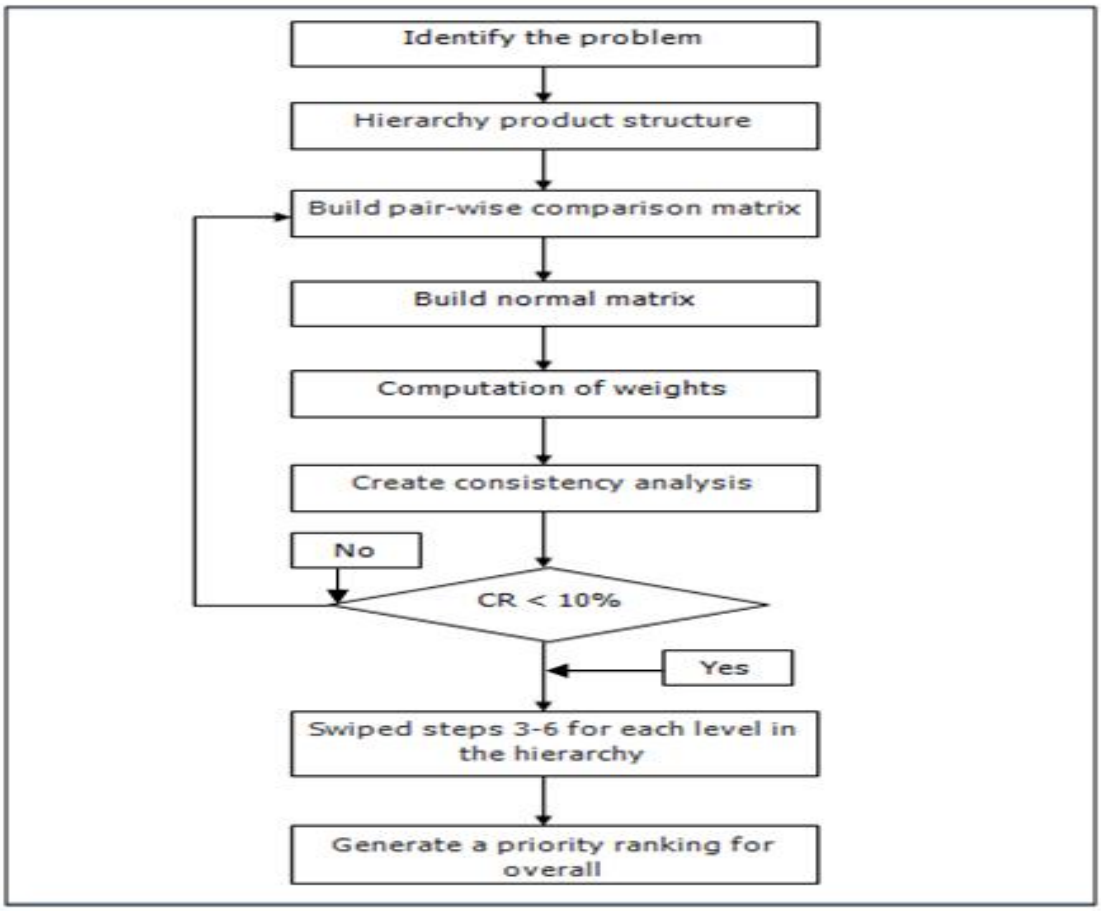

Figure 2. AHP Methodology [20].

IV. RESULTS AND DISCUSSIONS

4.1 Descriptive Statistics

A total of 150 responses had been obtained from the questionnaires. Majority of the respondents were of mixed-Malay ethnicity (36.0%), and only 3.0% were Iban, while the others were of mixed ethnicity. This had essentially reflected the demographical proportion of the urban population who went to the government hospitals in Kota Kinabalu for treatment. In terms of age groups, the highest number of Sabah Hospital ambulance service users was from the age group between 18-24 years (68.0%). The lowest number of users was more than 74 years age group which was 0.3%. In terms of educational level, 94 respondents were with a university degree-level education (62.7%), and the smallest group of 2 respondents (1.3%) was with a PhD-level in Education. In terms of marital status, 114 respondents (76.0%) were single, and 2 respondents (1.3%) were divorced.

4.2 Hierarchical Structure

The hierarchical structure was generated at three levels. They were namely, Phase 1: objective, Phase 2: criteria chosen, and Phase 3: sub-criteria for each criterion chosen. In this study; the objective, criteria and sub-criteria for the ambulance services and emergency department were as indicated in Figure 3 and Figure 4 respectively.

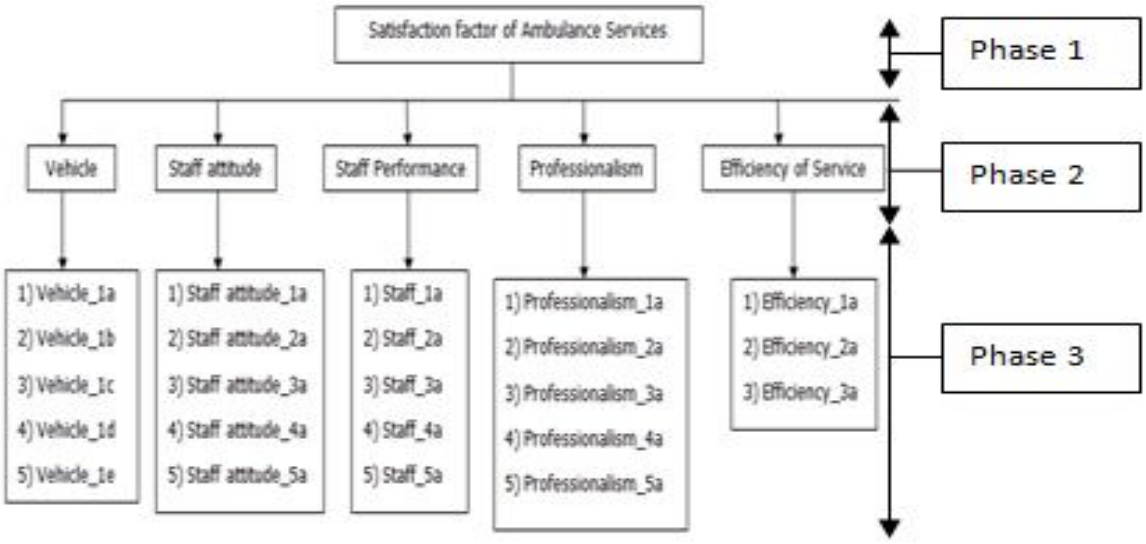

Figure 3. Hierarchy Structure of Section B of Questionnaire

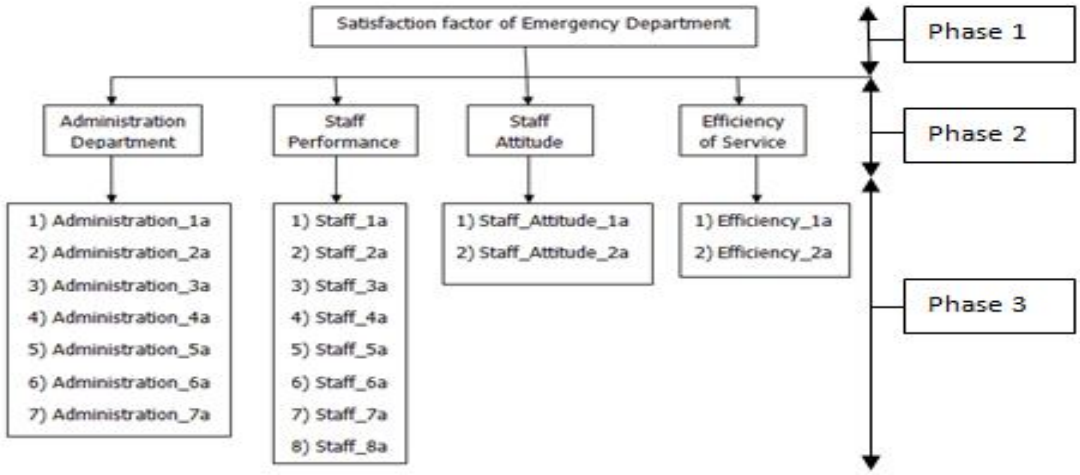

Figure 4 Hierarchy Structure of Section C of Questionnaire

4.3 Reliability Tests

The pilot test was randomly selected using a sample size of 30 respondents. The reliability of the questionnaires was analysed by using the Cronbach's Alpha reliability test. The result of Cronbach's Alpha value in the pilot test was shown in Table 2 as 0.973, and the overall Cronbach's Alpha value for 150 respondents of the survey was shown as 0.974. This meant that, all the items used in this study were standardized, and thus would provide a stable and consistent result.

Table 3. Reliability Tests

TESTS	Cronbach's Alpha	No. of Respondents
Pilot Test	0.973	30
Total Survey	0.974	150

4.4 Pairwise ComparisonMatrices

Table 4 and Table 5 showed the pairwise comparison matrices on the five main criteria for the ambulance services with 23 sub-criteria, and four main criteria with 19 sub-criteria of the emergency departments of the hospitals.

Table 4. Pairwise Comparison Matrix of Criteria for Ambulance Services (Section B)

	Vehicle	Staff Attitude	Staff performance	Professionalism	Efficiency of Services
Vehicle	1	0.33	0.33	0.25	0.33
Staff Attitude	3	1	0.33	0.25	0.33
Staff performance	3	3	1	1	0.50
Professionalism	4	4	1	1	0.25
Efficiency of Services	3	3	2	4	1

Table 5. Pairwise Comparison Matrix of Criteria for Emergency Department (Section C)

	Admistrative Department	Staff Performance	Efficiency of Services	Staff Attitude
Admistrative Department	1	0.33	3	3
Staff Performance	3	1	3	3
Efficiency of Services	0.33	0.33	1	1
Staff Attitude	0.33	0.33	1	1

Further five pairwise comparison matrices of the subcriteria (Vehicle, Staff attitude, Staff performance, Professionalism, and Efficiency of Servise) of the ambulance services were as shown below in Table 6.

Table 6. Pairwise Comparison Matrices of Sub-Criteria

Pairwise Comparison Matrix on Vehicle					
	V1	V2	V3	V4	V5
V1	1	0.25	0.5	0.25	0.33
V2	4	1	4	0.5	0.33
V3	2	0.25	1	0.25	0.33
V4	4	2	4	1	1
V5	3	3	3	1	1

Pairwise Comparison Matrix on Staff Attitude					
	SA1	SA2	SA3	SA4	SA5
SA1	1	1	1	4	4
SA2	1	1	4	4	4
SA3	1	0.25	1	4	4
SA4	0.25	0.25	0.25	1	0.33
SA5	0.25	0.25	0.25	3	1

Pairwise Comparison Matrix on Staff Performance					
	SP1	SP2	SP3	SP4	SP5
SP1	1	1	0.33	0.2	3
SP2	1	1	0.33	0.33	3
SP3	3	3	1	1	3
SP4	5	3	1	1	3
SP5	0.33	0.33	0.33	0.33	1

Pairwise Comparison Matrix on Professionalism					
	P1	P2	P3	P4	P5
P1	1	0.25	0.25	0.2	0.25
P2	4	1	1	0.25	0.33
P3	4	1	1	0.2	0.25
P4	5	4	5	1	1
P5	4	3	4	1	1

Pairwise comparison on Efficiency of Service			
	E1	E2	E3
E1	1	0.33	0.25
E2	3	1	0.33
E3	4	3	1

For illustrative purposes, only normalized matrix on efficiency of service criteria of ambulance services, and on staff performance of the emergency department are shown as in Table 7, and Table 8 respectively.

Table 7. Normalized Matrix on Efficiency of Service

Normalized matrix on Efficiency of Service					
	E1	E2	E3	weight	Consistency Measure
E1	0.125	0.076	0.158	0.120	3.018
E2	0.375	0.231	0.209	0.272	3.063
E3	0.500	0.693	0.633	0.609	3.126
sum	1	1	1	CI=	0.0350
				RI=	0.52
				C. Ratio =	0.0673

Table 8. Normalized Matrix on Staff Performance

Normalized matrix of Staff Performance										
	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	weight	Consistency measure
SP1	0.109	0.142	0.200	0.215	0.171	0.143	0.115	0.063	0.1448	9.408
SP2	0.109	0.142	0.200	0.215	0.171	0.143	0.192	0.104	0.1595	9.243
SP3	0.036	0.047	0.067	0.172	0.114	0.036	0.154	0.104	0.0911	8.952
SP4	0.022	0.028	0.017	0.043	0.057	0.036	0.154	0.104	0.0575	8.365
SP5	0.036	0.047	0.033	0.043	0.057	0.036	0.077	0.104	0.0541	8.677
SP6	0.109	0.142	0.267	0.172	0.229	0.143	0.154	0.104	0.1648	9.252
SP7	0.036	0.028	0.016	0.011	0.029	0.036	0.038	0.104	0.0372	8.534
SP8	0.544	0.425	0.200	0.129	0.171	0.429	0.115	0.314	0.2910	9.304
sum	1	1	1	1	1	1	1		CI =	0.1382
									RI =	1.4
									C. Ratio =	0.0987

Table 9 and Table 10 showed the overall priority scores of the satisfaction factors of the ambulance services and the emergency departments of the hospitals. The consistency ratios (CRs) for all the domain comparisons were of between 0 and 0.10, thus indicated that the possibility of relying on judgments that had been adopted in the pairwise comparisons for the main criteria and sub-criteria were acceptable. The AHP analysis results in Table 9 indicated that quickness/speed of admittance of the patients to hospital was the most important issue related to the patients' satisfaction factor in the ambulance services provided by the hospitals, of which the score was 0.6086 (60.86%), and followed by other sub-criteria's according to the priority values, namely, staff level of competence (37.71%), staff attentiveness (36.30%), staff efficiency (35.18%), and the feeling of security by patients when in the ambulance (31.60%).

Table 9. Overall Priority Scores of Satisfaction Factors of Ambulance Services.

Domain	Domain Priority	Item	Item Priority (weight)	Rank
Vehicle (CR = 0.0598)	0.0524	General appearance of the ambulance	0.0680	5
		Cleanliness of the ambulance	0.2080	3
		Comfort of ride in the ambulance	0.0900	4
		Feeling of security in the ambulance	**0.3160**	**1**
		Adequacy of ambulance equipment	0.3140	2
Staff Attitude (CR = 0.0879)	0.0769	Helpfulness of staff	0.2707	2
		Attentiveness of staff	**0.3630**	**1**
		Empathic nature of staff	0.2161	3
		Friendliness of staff	0.0576	5
		Gentleness of staff	0.0927	4
Staff Performance (CR = 0.0601)	0.1886	Ensuring of patient's comfort	0.1256	4
		Calmness of staff	0.1347	3
		Adequacy of explanation by staff of their actions	0.3131	2
		Efficiency of staff	**0.3518**	**1**
		Feeling of safety when staff arrive	0.0748	5
Professionalism (CR = 0.0633)	0.1724	Perceived level of training of staff	0.0537	5
		Professional look of staff	0.1260	3
		Level of trust in staff	0.1166	4
		Level of competency of staff	0.3771	**1**
		Confidence of staff to keep me alive until reaching the hospital	0.3266	2
Efficiency of Service (CR = 0.0673)	**0.3430**	Availability of staff at all times	0.1198	3
		Response time of ambulance to an emergency	0.2716	2
		Speed of admittance to hospital	**0.6086**	**1**

Note: Questionnaire adapted from Patient's perception of the ambulance services at Hospital Universiti Sains Malaysia [14].

The highest weight amongst the main criteria was indicated by the efficiency of service criterion in the ambulance services, of which was 0.3430 (34.30%), and this indicated that this criterion was of great importance in the ambulance services of EMTS provided. The next criterion of significantly moderate importance referred to the criterion of staff performance (18.86%), followed by prefessionalism of the ambulance services (17.24%). The criterion of staff attitude of the ambulance services (7.69%), which was a medium proportion, while the criterion of vehicle of the ambulance services obtained a low proportion of importance of about 5.24%, which indicated a lesser importance of this criteria for ambulance services of EMTS.

Table 10. Overall Priority Scores of Satisfaction Factors of Emergency Department.

Domain	Domain Priority	Item	Item Priority (weight)	Rank
Administration Department (CR = 0.0741)	0.2523	Courtesy of staff in the registration area	0.0494	7
		Comfort and pleasantness of the waiting area	**0.3070**	**1**
		Comfort and pleasantness during examination	0.0703	6
		Concern the nurse showed for doing medical orders	0.1059	5
		Courtesy of security	0.1888	2
		Friendliness/courtesy of the nurse	0.1592	3
		Courtesy of staff who transfer the patients	0.1196	4
Staff Performance (CR = 0.0987)	**0.3941**	Friendliness/courtesy of the care provider	0.1448	4
		Explanations the care provider gave you about your condition	0.1595	3
		Concern the care provider showed for your questions or worries	0.0911	5
		Care provider's efforts to include you in decisions about your treatment	0.0575	6
		Information the care provider gave you about medications	0.0541	7
		Instruction the care provider gave you about follow-up care	0.1648	2
		Degree to which care provider talked with you using words you could understand	0.0372	8
		Amount of time the care provider spent with you	**0.2910**	**1**
Efficiency of Services (CR = 0.0684)	0.1328	**Length of wait before going to an exam room**	**0.7509**	**1**
		Frequency of being visit by physicians	0.2491	2
Staff Attitude (CR = 0.0702)	0.1471	Overall cheerfulness of care provider practice	0.3000	2
		Overall cleanliness of care provider practice	**0.7000**	**1**

Note: Questionnaire adapted from Emergency department patient satisfaction survey in Imam Reza Hospital, Tabriz, Iran [15].

Meanwhile, the AHP analysis results in Table 10 indicated that the length of waiting period of patients before admittance to an examination room was the most important issue related to the patients' satisfaction factors in the emergency department services provided by the hospitals, where the priority values are 0.7509 (75.09%), and followed by the other sub-criteria according to ascending order of the priority values, namely, overall cleanliness of care providers (70%), comfort and pleasantness of waiting area (30.7%), and amount of time spent with patients by care providers (29.1%). Table 10 also showed that the highest weight was obtained by the staff performance criteria in the emergency department of the hospitals which scored 0.3941 (39.41%), and this indicated that this criterion was of vital in the emergency department. The second criterion of moderate importance was the administration department, which earned the weight of 25.23%, followed by criterion of staff attitude (14.71%), and efficiency of services in the emergency department (13.28%) of medium importances.

CONCLUSION

In this paper, we had determined the significant satisfaction factors aligned to the Emergency Medical Trauma Service (EMTS) and Emergency Departments with the Analytic Hierarchy Process (AHP) techniques. According to the AHP analysis, the most important satisfaction factors identified for the Emergency Medical Trauma Service (EMTS) were the speed of admittance of patients to the hospital, and the length of waiting period of the patients before going into the examination room. By calculating the priorities of the Medical Trauma Service (EMTS) satisfaction factors, a lean management approach could be developed. Additionally, this study's results can be used for the construction of a set of appropriate strategy alternatives for the hospital administration

and staff organization. Future researches are suggested to be conducted so as to improve the EMTS departments of hospitals, such that risk and uncertainty cases can be handled more effectively efficient.

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