IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received January 18, 2019, accepted February 3, 2019, date of publication February 11, 2019, date of current version April 3, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2898214

Based Multiple Heterogeneous Wearable Sensors: A Smart Real-Time Health Monitoring Structured for Hospitals Distributor

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ABSTRACT This paper proposes a smart real-time health monitoring structured for hospitals' distributor based on wearable health data sensors. Health data were received from multiple heterogeneous wearable sensors, such as electrocardiogram (ECG), oxygen saturation sensor (SpO2), blood pressure monitor, and non-sensory measurement (text frame), from 500 patients with different symptoms. Triage level and healthcare services were identified based on the new four-level remote triage and package localization (4LRTPL). The numbers of healthcare services that represent hospital status were collected from 12 hospitals located in Baghdad city. This study constructed a decision matrix based on the crossover of ''multi-healthcare services'' and ''hospital list'' within Tier 4. The hospitals were then ranked using multi-criteria decision-making (MCDM) techniques, namely, integrated analytic hierarchy process (AHP) and vlsekriterijumskaoptimizacija i kompromisnoresenje (VIKOR). Mean ± standard deviation was computed to ensure that the hospital ranking undergoes systematic ranking for objective validation. This research provided scenarios and checklist benchmarking to evaluate the proposed and existing health recommender frameworks. Results corroborated that: 1) the integration of AHP and VIKOR effectively solved hospital selection problems; 2) in the objective validation, significant differences were recognized between the scores of groups, indicating that the ranking results were identical; 3) in evaluation, the proposed framework exhibited an advantage over the benchmark framework with a percentage of 56.25%; and 4) hospitals with multiple healthcare services received the highest ranks, whereas hospitals with fewer healthcare services received low ranks.

INDEX TERMS Real-time remote monitoring, hospital management, hospital selection, chronic heart, healthcare services, triage, wearable health sensor.

I. INTRODUCTION

Numerous diseases are fatal; of which, cardiovascular diseases are the main cause of death [1], [2]. The World Health Organization estimated that heart diseases are responsible for 12 million deaths annually worldwide [3]. Chronic heart disease accounts for approximately 55% of deaths amongst patients according to the American Heart Association [4]. Automatic diagnosis of heart disease is considered a significant medical problem because it affects the working performance and health of patients, especially the elderly [3]. E-health is a relatively modern health-care

The associate editor coordinating the review of this manuscript and approving it for publication was Bo Jin.

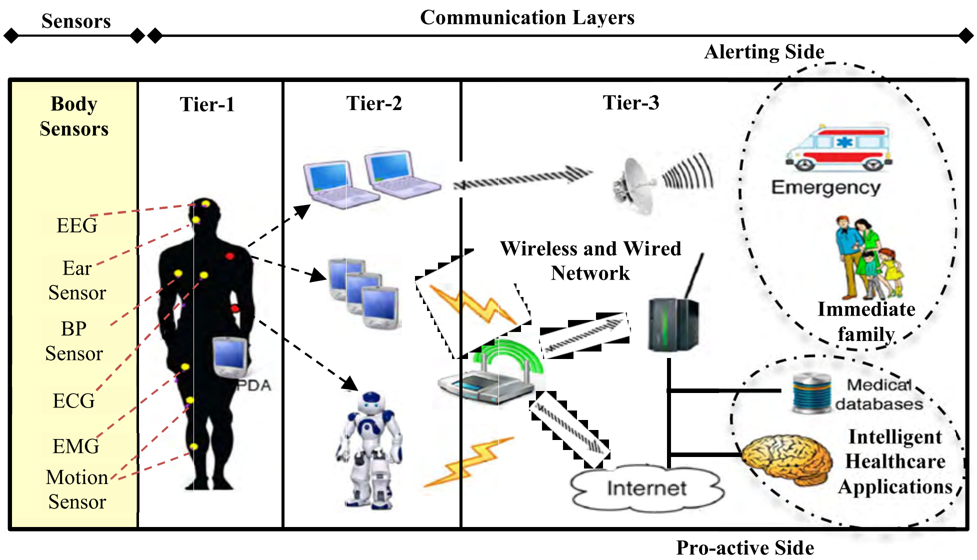


FIGURE 1. Architecture of real-time remote health-monitoring system.

practice supported by electronic processes and communication; this tool has been widely used [109]–[116]. Telemedicine plays a key role in the efficient delivery of health care to patients suffering from different types of cardiovascular diseases [5], [117]–[119]. E-health-care techniques exhibit considerable effects on chronic heart failure care [6]. Patients in isolated communities can benefit the most from remote health-care services because remote technology allows patients to receive medical care without traveling [1]–[6]. Systems used in remote health-care services have drawn considerable attention because of their importance in the lives of peoples [8], [9], [87], [88]. Regular monitoring of patients from a distance is ideal to ensure that they receive proper care and suitable guidelines for proper medication [10], [120], [121]. The concept behind telemedicine is to remotely supply medical services with the aid of telecommunication technologies [11], [89]. Data processing in existing telemedicine systems occur through three main tiers, including wearable sensors (Tier 1), gateway (Tier 2) and medical center server (Tier 3) [8], [12] (Figure 1). Tier 1 involves collecting the vital signs of patients by using interoperable wearable medical devices. Some devices include electrocardiogram (ECG), blood oxygen saturation level (SpO2) sensors and blood pressure (BP) monitors. These devices transfer the gathered data to Tier 2. After the collection of data from all monitoring devices, Tier 2 aggregates and transfers them to a remote server via external gateway to ensure long-range communications. Tier 3, or the medical center server, represents a remote computer that is located in a medical institution to monitor the data at real-time and provides health recommendations for patients. Monitoring is done by physicians or a database for post-processing [83], [84].

Scalability is the expansion capability of health-care systems to satisfy the demands of an increasing number of users. As the number of patients increases, the need for scalability

TABLE 1. Example of a multi-attribute problem.

Yi/Xj	X1	X2	X3	X4	X5	Xm
Y1	7	3390	8844	3.3	9	8
Y2	89	2836	99	2	2	2
Y3	1.5	2000	1000	4	5	6
Ym	7.3	4444	7881	8	88	1

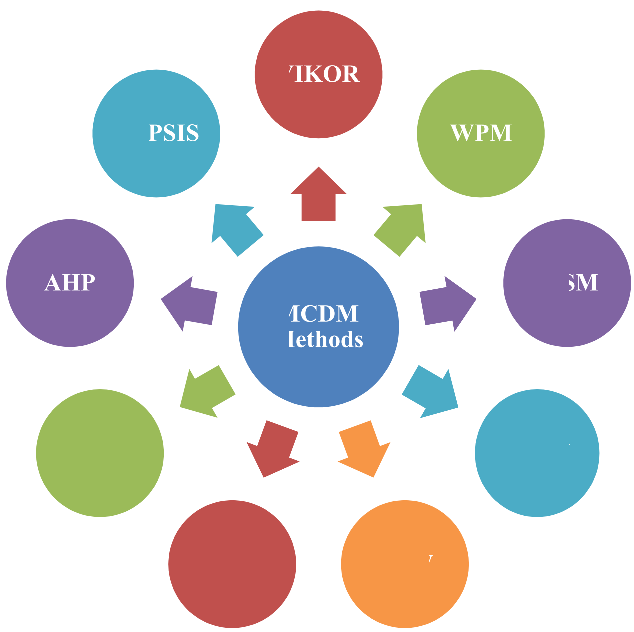


FIGURE 2. MCDM methods.

also increases. The increase can occur due to different reasons, including population aging, disasters and mass casualty incidents [8], [13], [15], [78]. As the number of users

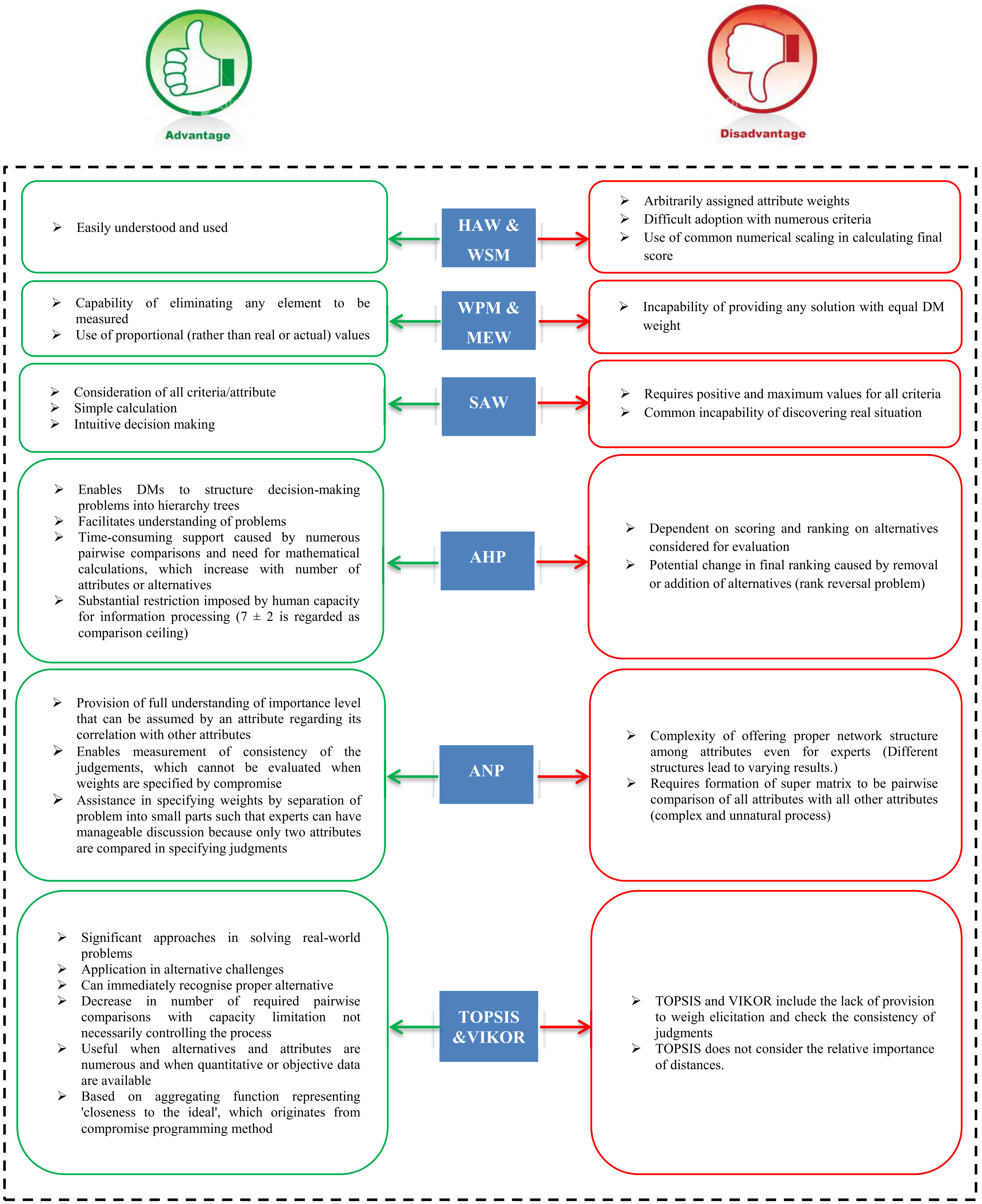


FIGURE 3. Advantages and disadvantages of MCDM techniques.

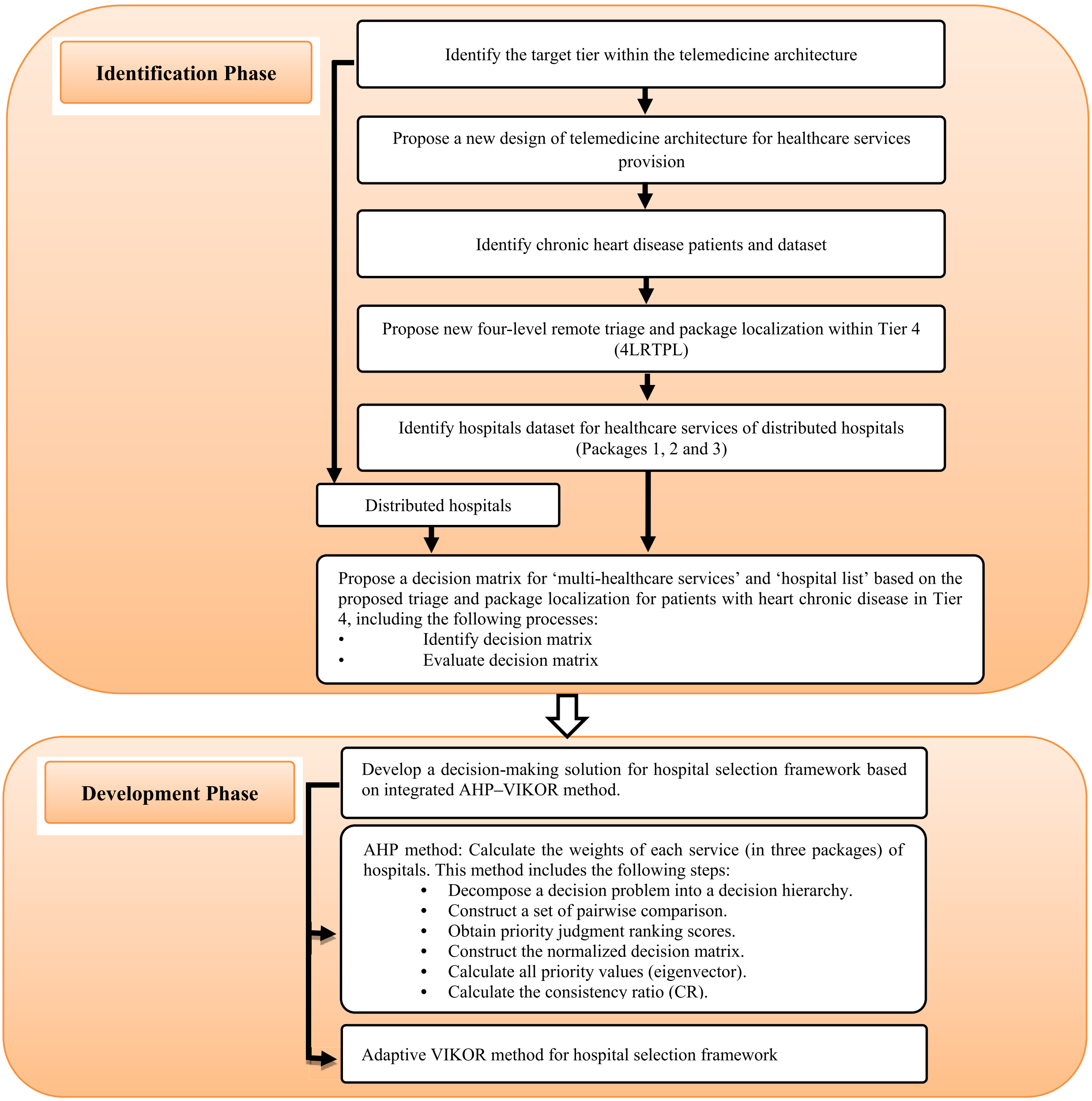


FIGURE 4. Two-phase methodology of the smart real-time health recommender framework for hospital selection.

increases, the demand for health-care services also increases, which is a major issue in medical centers [8], [16]. The issues of scalability can be responsible for acute shortage of health-care services and medical resources with increasing health-care demand [8], [13]. Therefore, the availability of hospital services can decrease due to the demands of patients, leading to limited health-care services and inadequate management of medical resources [17], [18]. These challenges increase if the patient is located far from health-care services and utilizes remote health-care services [8]. Given the increased demands of health-care services, scholars must develop effective and scalable health-care services [4], [16]. Any developed system must be utilized by medical centers to manage and accommodate such systems with growing demand [8]. Thus, managing and controlling the loading of health-care services among health-care providers and providing health-care services through distributed hospitals can help avoid the limitations of services in hospitals and support the continuous care of remote patients in a pervasive environment [13], [19]–[21]. The management and control of health-care services loading amongst hospitals and the provision of quality services to patients from suitable hospitals are important aspects that must be measured or evaluated [13], [22]–[27]. Hospital selection is required to avoid limitation and reduce the number of health-care services in hospitals, but it remains challenging [13], [25]. This study provides benefits

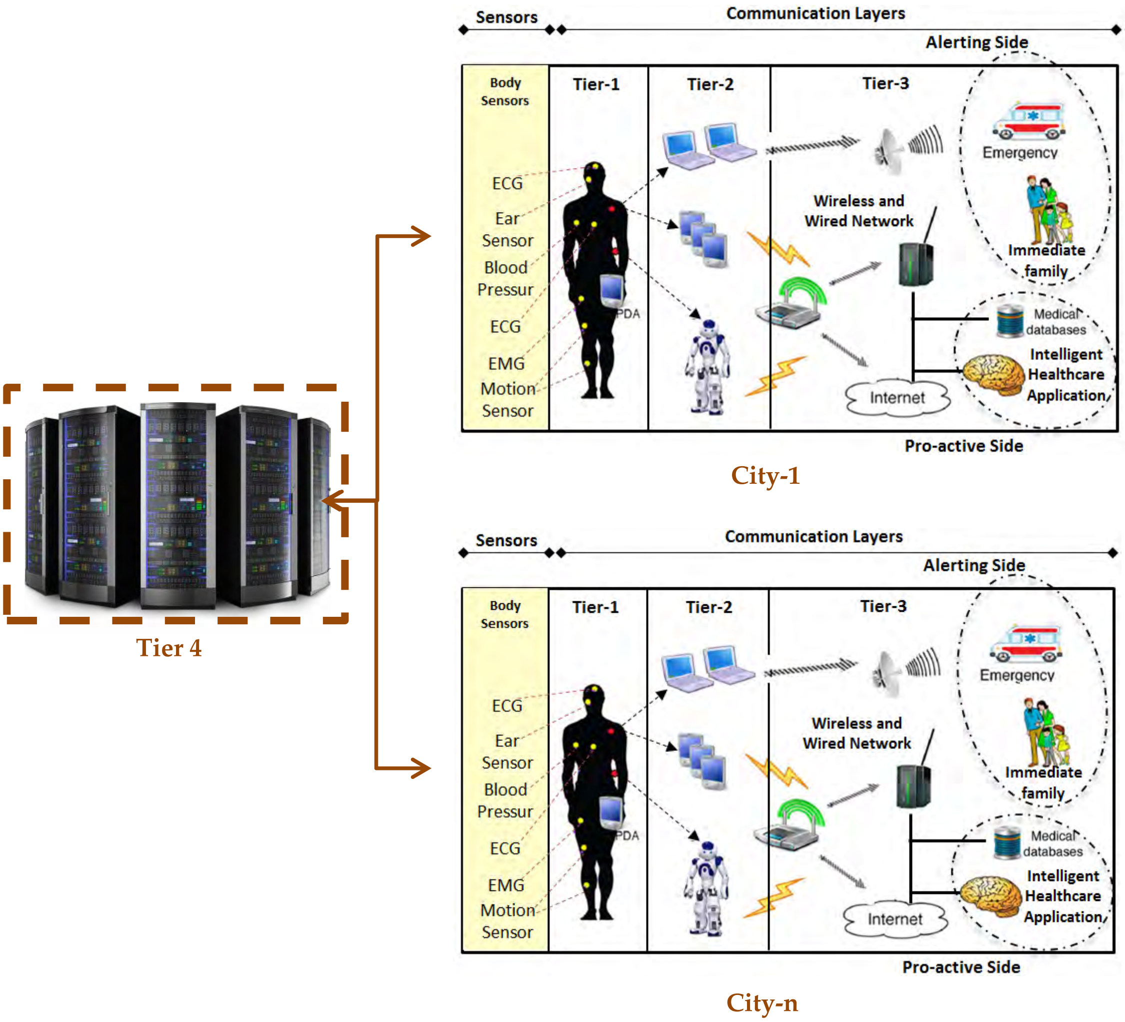


FIGURE 5. New design of telemedicine architecture for providing health-care services.

TABLE 2. Triage levels linked with health-care service packages.

TC Indication		Triage level	Hospital Services	Health-care Service Packages
Colour	TC value			
Red	66–100	Risk	Prepare Surgery Room, Prepare Surgery Team, Prepare Doctor, Prepare O_2 Supplier, Send Ambulance and Provide Medications.	Package 1
Orange	51–65	Urgent	Prepare Emergency Room, Prepare Consultant Section, Prepare Doctor, Prepare O_2 Supplier, Send Ambulance and Provide Medications.	Package 2
Yellow	26–50	Sick	Prepare Consultant Section, Prepare O_2 Supplier, Prepare Doctor and Provide Medications.	Package 3
Green	0–25	Normal	Message: 'You are in good health. You do not need a hospital ☺.'	Package 4

to medical organizations to manage and balance health-care services amongst hospitals in cases of scalability challenges. This study also provides a method for improving the triage and process of providing health-care services for health-care organizations that constantly make difficult resource decisions. Moreover, this study is significant for doctors in

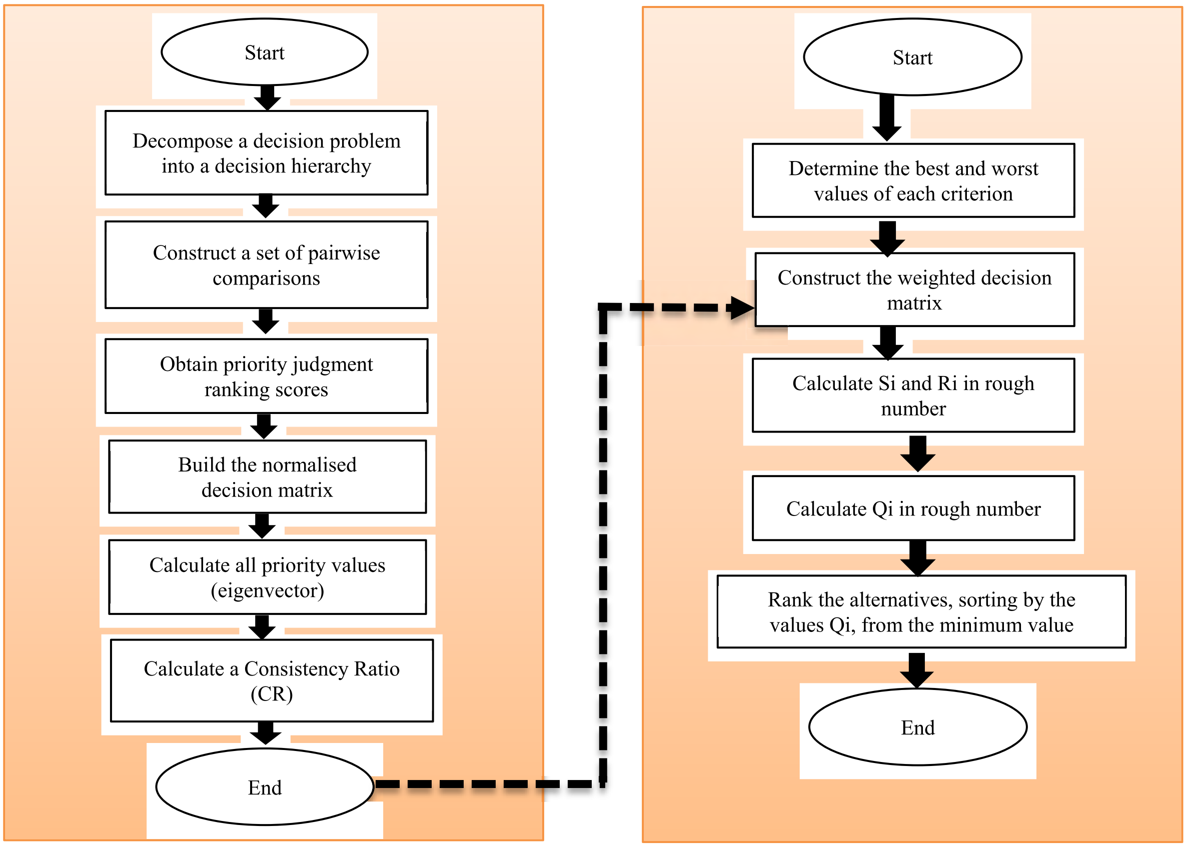


FIGURE 6. Integrated AHP–VIKOR methods for ranking hospitals.

TABLE 3. DM for package 1.

H/S	PSR	PST	PSD	POS	SA	PM
H 1	R1/H1	R2/H1	R3/H1	R4/H1	R5/H1	R6/H1
H 2	R1/H2	R2/H2	R3/H2	R4/H2	R5/H2	R6/H2
H 3	R1/H3	R2/H3	R3/H3	R4/H3	R5/H3	R6/H3
H 4	R1/H4	R2/H4	R3/H4	R4/H4	R5/H4	R6/H4
H 5	R1/H5	R2/H5	R3/H5	R4/H5	R5/H5	R6/H5
.	.	.	.	.	.	.
.	.	.	.	.	.	.
H 12	R1/H12	R2/H12	R3/H12	R4/H12	R5/H12	R6/H12

H= Hospital

R1=Number of Services

TABLE 4. DM for package 2.

H/S	PER	PCS	PD	POS	SA	PM
H 1	U1/H1	U1/H1	U1/H1	U1/H1	U1/H1	U1/H1
H 2	U1/H2	U2/H2	U3/H2	U4/H2	U5/H2	U6/H2
H 3	U1/H3	U2/H3	U3/H3	U4/H3	U5/H3	U6/H3
H 4	U1/H4	U2/H4	U3/H4	U4/H4	U5/H4	U6/H4
H 5	U1/H5	U2/H5	U3/H5	U4/H5	U5/H5	U6/H5
.	.	.	.	.	.	.
.	.	.	.	.	.	.
H 12	U1/H12	U2/H12	U3/H12	U4/H12	U5/H12	U6/H12

H= Hospital

U=Number of services

terms of assisting medical teams by providing a decision-making support for triage, providing health-care services and performing timely and accurate treatments and recommendations for their patients. The improved quality of health-care in large centers and the delivery of these services to unserved or underserved areas are the benefits for patients. This research ensures the provision of continuous health-care services for patients by balancing and controlling such services amongst hospitals in case of natural disasters and for the aging population. The current research aims to (i) propose a new design of telemedicine architecture for health-care service provision; (ii) propose a new four-level remote triage and package localisation based on the proposed architecture for patients with chronic heart disease; (iii) identify a decision matrix (DM) for 'multi-health-care services' and 'hospital list' based on the proposed triage and package localisation;

TABLE 5. DM for package 3.

H/S	PCS	POS	PD	PM
H1	S1/H1	S2/H1	S3/H1	S4/H1
H 2	S1/H2	S2/H2	S3/H2	S4/H2
H 3	S1/H3	S2/H3	S3/H3	S4/H3
H 4	S1/H4	S2/H4	S3/H4	S4/H4
H 5	S1/H5	S2/H5	S3/H5	S4/H5
.	.	.	.	.
.	.	.	.	.
H12	S1/H12	S2/H12	S3/H12	S4/H12

H= Hospital

S=Number of services

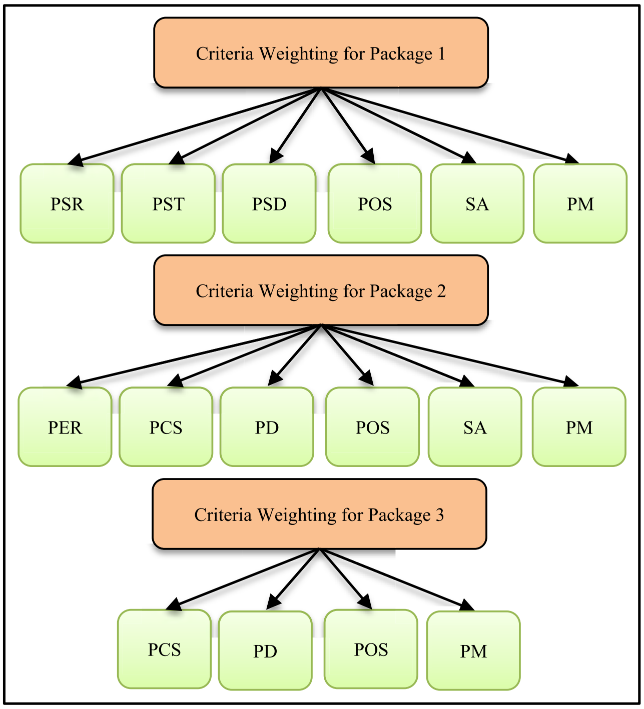


FIGURE 7. Hierarchy of AHP for each package.

(iv) develop a smart real-time health recommender framework based on wearable health data sensor for hospital selection; (v) validate the developed framework by using statistical methods; and (vi) evaluate the developed framework by using scenarios and checklist benchmarking. The remaining parts of this article are composed of eight sections: 'Introduction' introduces hospital selection. 'Literature review' presents the review of related studies. 'Methodology' reports the decision-making methodology for hospital selection. 'Results and discussion' presents the results and discussion. 'Validation and evaluation' deliberates the results of validating and evaluating the proposed framework. 'Limitations' highlights the limitations of the proposed framework. 'Recommendations for future work' presents several recommendations for future work. 'Conclusion' discusses the conclusion of the research.

II. LITERATURE REVIEW

As shown in Table 1, $Y_1, Y_2, \ldots, Y_m$ are suitable alternatives, in this case, hospitals that should be ranked by decision makers. In the same table, $X_1, \mathrm{X}, \ldots, X_n$ are the attributes/criteria against which the performances of all the alternatives are evaluated. In this research, these symbols represent health-care services. MCDM objectives include (1) prioritizing alternatives in a decreasing order of performance, (2) classifying the alternatives amongst other sets (3) and assisting data miners in the selection of suitable alternatives [43], [106]. The best and most suitable alternatives will be scored accordingly [100]–[104]. Through different MCDM techniques, health-care decision makers can promote their process of decision making. In this regard, the popularity of MCDM in the field of health care is not surprising [44]–[46]. Decision making can be done by systematically identifying suitable solutions [47]. Different MCDM theories have been explored, and the most frequently used MCDM techniques that utilize different notions are shown in Figure 2 [13].

Figure 2 shows the popular MCDM methods, and Figure 3 presents the advantages and disadvantages of such techniques [48]–[53].

Based on our analysis, all the mentioned and discussed approaches were not utilized in ranking distributed hospitals to control and manage health-care service provision in telemedicine system, which is considered a theoretical gap. Technique for order of preference by similarity to ideal solution (TOPSIS) and VIKOR are suitable for cases with numerous alternatives and criteria (Figure 3). Both methods are convenient to utilize when objective and quantitative data are given. The shortest distance towards the ideal solution is determined by TOPSIS, and the longest distance is derived from the negative-ideal solution; however, TOPSIS does not consider the relative importance of these distances [48]. VIKOR is functionally related to discrete-alternative problems [85] and considered the most practical approach for addressing real-world problems. The benefit of VIKOR is its capability to rapidly determine the best alternative. Therefore, VIKOR is suitable in situations involving many alternatives and attributes [48]. However, VIKOR lacks provision for weight elicitation and judgement consistency checking [48]. Therefore, VIKOR needs an effective technique to acquire the relative importance of various criteria regarding objectivity. Analytic hierarchy process (AHP) provides such technique. However, AHP tends to regulate the weights of the objects based on stakeholder preferences [54]. Moreover, AHP is highly restricted by the capacity of humans concerning information processing. Thus, 7 ± 2 would be the comparison ceiling [55]. The latest MCDM techniques trend is identified in integrating two or more techniques to compensate for the drawbacks of single techniques [56]–[58]. AHP and VIKOR

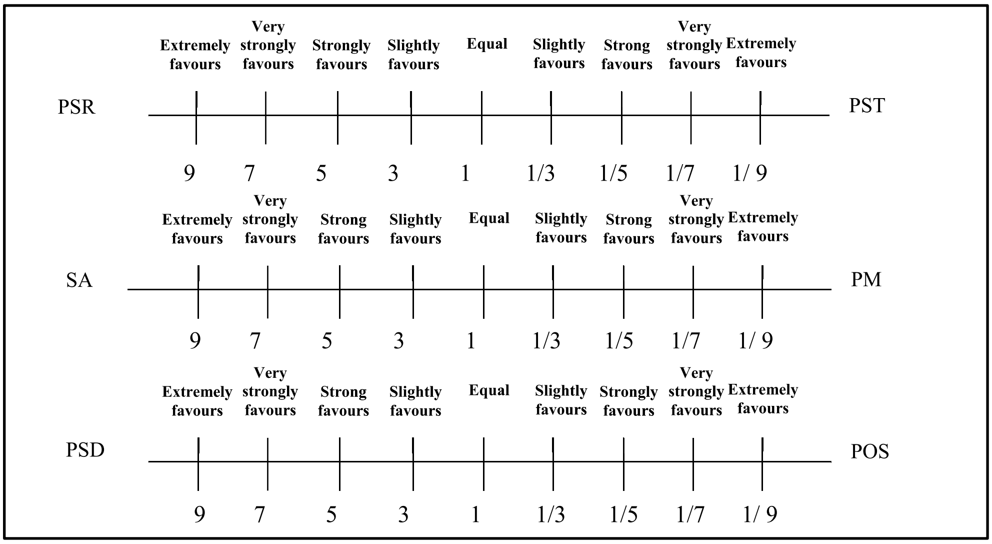


FIGURE 8. Sample evaluation form for package 1.

Each Evaluator	Criteria	Original matrix				Normalised matrix				Aggregation	Weight
		PCS	PD	POS	PM	PCS	PD	POS	PM		
	PCS	PCS (1)	PCS /PD	PCS/POS	PCS/PM	PCS(1)/ Sum1	(PCS /PD)/ Sum2	(PCS /POS) /Sum3	(PCS /PM) /Sum4	Sum-PCS	W1=Sum-PCS/n
	PD	PD/PCS	PD(1)	PD/POS	PD/PM	(PD/PCS) /Sum1	PD1/ Sum2	(PD/POS) /Sum3	(PD/PM) /Sum4	Sum-PD	W2=Sum-PD/n
	POS	POS/PCS	POS/PD	POS(1)	POS/PM	(POS/PCS) /Sum1	(POS/PD) /Sum2	POS1 / Sum3	(POS/PM) /Sum4	Sum-POS	W3=Sum-POS/n
	PM	PM/PCS	PM/PD	PM/POS	PM(1)	(PM/PCS) /Sum1	(PM/PD) /Sum2	(PM/POS) /Sum3	PM1/ Sum4	Sum-PM	W4=Sum-PM/n
	Sum	Sum1	Sum2	Sum 3	Sum 4						Sum(W)=1

FIGURE 9. Design of AHP steps for weight preferences for package 3.

are commonly used MCDM approaches in various studies [59]–[63]. The integrated method, named VKIOR–AHP, is suitable to manage and control health-care service provision in hospitals. The integrated method functions by ranking distributed hospitals and chooses the best one for patients with chronic heart disease based on the number of available health-care services.

III. METHODOLOGY

This section presents an overview and explanation of the methodology phase for establishing a health recommender framework for hospital selection, which was presented in detail in our previous study [64]. The two phases are shown in Figure 4.

A. IDENTIFICATION PHASE

This phase comprises six stages, which are discussed in the following subsection.

1) PROPOSE A NEW DESIGN OF TELEMEDICINE ARCHITECTURE (TIERS 1, 2, 3 AND TIER 4)

As mentioned in our previous study [64], the new design for telemedicine architecture includes an intelligent data and service management center (Tier 4), as shown in Figure 5. The new design is connected to telemedicine systems to share medical resources and address the acute shortage of health-care services in cases where the demand increases as result of aging population and disasters. Tier 4 possesses the capability for identifying a suitable hospital to deal with, in addition to providing high-quality and accurate health-care services for patients. In this research, Tier 4 is the part where all processes and decisions arise.

2) IDENTIFICATION OF PATIENTS WITH CHRONIC HEART DISEASE AND HEALTH DATA SET

This step includes the identification of the number and kind of patient. Given the significance of this research, the identified

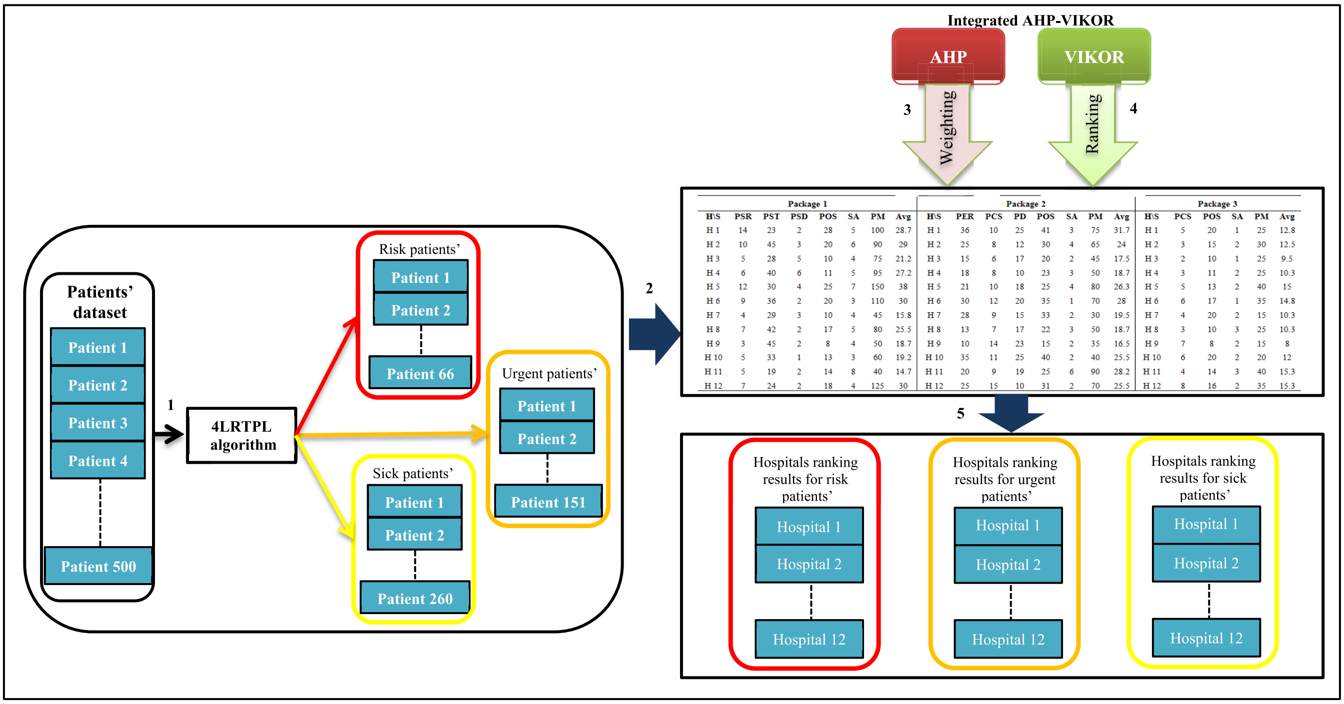


FIGURE 10. Overview of the results of the hospital selection process.

TABLE 6. Values of health-care services criteria (parameters) for each package within 12 hospitals.

Package 1								Package 2								Package 3					
H\S	PSR	PST	PSD	POS	SA	PM	Avg	H\S	PER	PCS	PD	POS	SA	PM	Avg	H\S	PCS	POS	SA	PM	Avg
H 1	14	23	2	28	5	100	28.7	H 1	36	10	25	41	3	75	31.7	H 1	5	20	1	25	12.8
H 2	10	45	3	20	6	90	29	H 2	25	8	12	30	4	65	24	H 2	3	15	2	30	12.5
H 3	5	28	5	10	4	75	21.2	H 3	15	6	17	20	2	45	17.5	H 3	2	10	1	25	9.5
H 4	6	40	6	11	5	95	27.2	H 4	18	8	10	23	3	50	18.7	H 4	3	11	2	25	10.3
H 5	12	30	4	25	7	150	38	H 5	21	10	18	25	4	80	26.3	H 5	5	13	2	40	15
H 6	9	36	2	20	3	110	30	H 6	30	12	20	35	1	70	28	H 6	6	17	1	35	14.8
H 7	4	29	3	10	4	45	15.8	H 7	28	9	15	33	2	30	19.5	H 7	4	20	2	15	10.3
H 8	7	42	2	17	5	80	25.5	H 8	13	7	17	22	3	50	18.7	H 8	3	10	3	25	10.3
H 9	3	45	2	8	4	50	18.7	H 9	10	14	23	15	2	35	16.5	H 9	7	8	2	15	8
H 10	5	33	1	13	3	60	19.2	H 10	35	11	25	40	2	40	25.5	H 10	6	20	2	20	12
H 11	5	19	2	14	8	40	14.7	H 11	20	9	19	25	6	90	28.2	H 11	4	14	3	40	15.3
H 12	7	24	2	18	4	125	30	H 12	25	15	10	31	2	70	25.5	H 12	8	16	2	35	15.3

patients are only those who are remote and suffering from chronic heart diseases. Both texts and sensors were utilized to send the vital signs and complaints of the patient to Tier 4 for assessment and monitoring of their states. Considering the issue of scalability, a large scale of patients, total of 500, will be included in this study. This number was adopted by previous studies in telemedicine [8]–[13].

3) PROPOSE FOUR-LEVEL REMOTE TRIAGE AND PACKAGE LOCALIZATION (4LRTPL) WITHIN TIER 4

As mentioned in our previous study [64], 4LRTPL was proposed to categorize patient conditions and identify the suitable health-care services within Tier 4. The three types of decisions resulting from 4LRTPL are 'triage level', 'triage code (TC) value' and 'health-care service packages'. Table 2 shows four levels of triaging patients, which are linked with three packages of health-care services. For additional details, the entire process of 4LRTPL can be found in our previous study [64].

4) IDENTIFICATION OF DISTRIBUTED HOSPITALS

This research adopted 12 hospitals located in Baghdad city as a 'proof of concept', which represents alternatives in the DM. Each hospital comprises three health-care services packages (Table 2). These hospitals are controlled and managed through Tier 4.

TABLE 7. AHP measurement process for weight preferences of the criteria (health-care services) for three packages (first expert).

Criteria of healthcare services for package 1 (Risk Level)

Criteria	Original DM PSR	PST	PSD	POS	SA	PM	Normalized DM PSR	PST	PSD	POS	SA	PM	Aggregation	Weight
PSR	1.00	0.33	0.20	5.00	3.00	1.00	0.09	0.11	0.07	0.21	0.19	0.12	0.78	0.131
PST	3.00	1.00	1.00	5.00	5.00	3.00	0.28	0.33	0.33	0.21	0.31	0.35	1.82	0.303
PSD	5.00	1.00	1.00	7.00	3.00	3.00	0.47	0.33	0.33	0.29	0.19	0.35	1.96	0.327
POS	0.20	0.20	0.14	1.00	1.00	0.20	0.02	0.07	0.05	0.04	0.06	0.02	0.26	0.043
SA	0.33	0.20	0.33	1.00	1.00	0.33	0.03	0.07	0.11	0.04	0.06	0.04	0.35	0.058
PM	1.00	0.33	0.33	5.00	3.00	1.00	0.09	0.11	0.11	0.21	0.19	0.12	0.83	0.138
Sum	10.53	3.07	3.01	24.00	16.00	8.53								1.00

Criteria of healthcare services for package 2 (Urgent Level)

Criteria	Original DM PER	PSC	PD	POS	SA	PM	Normalized DM PER	PSC	PD	POS	SA	PM	Aggregation	Weight
PSR	1.00	0.20	0.20	1.00	3.00	0.33	0.07	0.05	0.05	0.06	0.23	0.08	0.54	0.090
PST	5.00	1.00	1.00	5.00	3.00	1.00	0.33	0.27	0.26	0.31	0.23	0.25	1.64	0.273
PSD	5.00	1.00	1.00	3.00	3.00	1.00	0.33	0.27	0.26	0.19	0.23	0.25	1.52	0.253
POS	1.00	0.20	0.33	1.00	0.33	0.33	0.07	0.05	0.09	0.06	0.03	0.08	0.38	0.063
SA	0.33	0.33	0.33	3.00	1.00	0.33	0.02	0.09	0.09	0.19	0.08	0.08	0.54	0.091
PM	3.00	1.00	1.00	3.00	3.00	1.00	0.20	0.27	0.26	0.19	0.23	0.25	1.38	0.231
Sum	15.33	3.73	3.87	16.00	13.33	4.00								1.000

Criteria of healthcare services for package 3 (Sick Level)

Criteria	Original DM PCS	POS	PD	PM	Normalized DM PCS	POS	PD	PM	Aggregation	Weight
PCS	1.00	3.00	0.33	1.00	0.19	0.21	0.18	0.19	0.77	0.193
POS	0.33	1.00	0.20	0.20	0.06	0.07	0.11	0.04	0.28	0.070
PD	3.00	5.00	1.00	3.00	0.56	0.36	0.54	0.58	2.03	0.508
PM	1.00	5.00	0.33	1.00	0.19	0.36	0.18	0.19	0.92	0.229
Sum	5.33	14.00	1.87	5.20						1.000

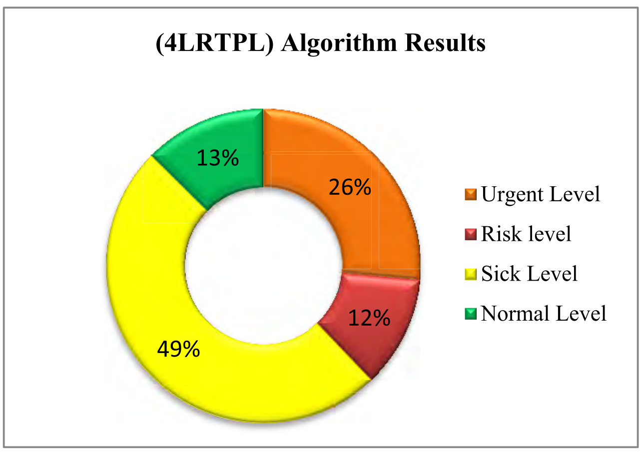


FIGURE 11. Statistical result of triage level for 500 patients.

5) IDENTIFICATION OF HOSPITAL DATASETS FOR HEALTH-CARE SERVICES

The numbers of health-care services in distributed hospitals were obtained from 12 hospitals located in Baghdad. The services are shown as a criterion and parameters set in the DM of this research. Three packages are provided for patients with chronic disease. The six services (parameters) within package 1 are 'prepare surgery room' (PSR), 'prepare surgery team' (PST), 'prepare surgery doctor' (PSD), 'prepare o_2 supplier' (POS), 'send ambulance' (SA) and 'provide medications' (PM). The six services (parameters) within package 2 are 'prepare emergency room' (PER), 'prepare consultant section (PCS)', 'prepare doctor' (PD), POS, SA and (PM). The four services (parameters) within package 3 are PCS, PD, POS and PM. The process of hospital selection is based on the number of services within hospitals, which considered as multi-attribute DM.

6) PROPOSE A DM WITHIN TIER 4

Three DMs are identified within Tier 4 for packages including 1, 2 and 3 based on the triage level of patients. The proposed DMs were based on a crossover of 'multi-services' and 'hospital lists', as shown in Tables 3, 4 and 5.

In these DMs, the alternatives are represented by hospitals, whereas the multi-criteria are represented by health-care services used to evaluate the hospitals. Hospital ranking is the problem for multi-criteria. The reason behind this process is its ability to simultaneously consider diverse procedures for the assigned weight to each service. This process also

TABLE 8. AHP weights for six experts for package 1.

1st Expert			2nd Expert			3rd Expert		
Criteria	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**
PSR	0.131	0.07	PSR	0.055	0.077	PSR	0.151	0.096
PST	0.303		PST	0.153		PST	0.289	
PSD	0.327		PSD	0.062		PSD	0.289	
POS	0.043		POS	0.214		POS	0.095	
SA	0.058		SA	0.154		SA	0.040	
PM	0.138		PM	0.362		PM	0.136	
4st Expert			**5st Expert**			**6st Expert**		
Criteria	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**
PSR	0.107	0.091	PSR	0.354	0.094	PSR	0.071	0.096
PST	0.330		PST	0.236		PST	0.213	
PSD	0.062		PSD	0.137		PSD	0.213	
POS	0.372		POS	0.028		POS	0.159	
SA	0.073		SA	0.209		SA	0.148	
PM	0.057		PM	0.036		PM	0.196	

TABLE 9. AHP weights for six experts for package 2.

1st Expert			2nd Expert			3rd Expert		
Criteria	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**
PER	0.090	0.082	PER	0.060	0.09	PER	0.204	0.078
PSC	0.273		PSC	0.025		PSC	0.054	
PD	0.253		PD	0.340		PD	0.328	
POS	0.063		POS	0.340		POS	0.093	
SA	0.091		SA	0.180		SA	0.047	
PM	0.231		PM	0.054		PM	0.275	
4st Expert			**5st Expert**			**6st Expert**		
Criteria	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**
PER	0.223	0.096	PER	0.323	0.051	PER	0.096	0.087
PSC	0.064		PSC	0.058		PSC	0.194	
PD	0.275		PD	0.137		PD	0.369	
POS	0.065		POS	0.092		POS	0.068	
SA	0.042		SA	0.298		SA	0.091	
PM	0.332		PM	0.093		PM	0.181	

scores the hospitals based on the number of the services. Determining hospital selection under normal cases is difficult and cannot be achieved, especially when the final decision represents hospital selection. A decision-making algorithm and a computer-based approach can be used to address such complexity in selecting a hospital.

B. DEVELOPMENT PHASE

The method includes the integrated MCDM techniques for hospital ranking in Tier 4. Based on Section 2, the integrated MCDM methods require AHP to calculate attributes. In this case, attributes were set as the weights for health-care services to identify each of them and contribute to making a decision. Afterwards, VIKOR was utilized to rank the hospitals based on quantitative information by which criteria were measured and considered for practical justification. Finally, the number of services was designed as the key factor in ranking hospitals in a descending order. Figure 6 illustrates the structure of the integrated AHP-VIKOR method.

TABLE 10. AHP weights for six experts for package 3.

1st Expert			2nd Expert			3rd Expert		
Criteria	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**
PCS	0.193	0.055	PCS	0.150	0.099	PCS	0.058	0.075
POS	0.070		POS	0.434		POS	0.145	
PD	0.508		PD	0.379		PD	0.282	
PM	0.229		PM	0.037		PM	0.515	
4st Expert			**5st Expert**			**6st Expert**		
Criteria	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**	**Criteria**	**Weights**	**Consistency Ratio**
PCS	0.407	0.088	PCS	0.067	0.072	PCS	0.523	0.073
POS	0.275		POS	0.152		POS	0.292	
PD	0.245		PD	0.526		PD	0.047	
PM	0.072		PM	0.255		PM	0.137	

TABLE 11. Final AHP weights for the arithmetic mean of six experts for three packages.

Package 1		Package 2		Package 3	
Criteria	**Weights**	**Criteria**	**Weights**	**Criteria**	**Weights**
PSR	0.145	PER	0.166	PCS	0.233
PST	0.254	PCS	0.111	POS	0.228
PSD	0.182	PD	0.284	PD	0.331
POS	0.152	POS	0.120	PM	0.208
SA	0.114	SA	0.125		
PM	0.154	PM	0.194		

Weights will be assigned to multi-service criteria through AHP technique. AHP is used to derive ratio scales from pairwise comparisons, allowing small inconsistencies in judgment because humans are typically consistent. On another hand, hospitals will be scored accordingly. Hospitals scores' will be ranked in ascending order and the most suitable hospital will be selected according to VIKOR technique. The steps of the integrated AHP-VIKOR method are described in the following subsections.

1) AHP

This section presents the steps for assigning proper weights to the multi-service criteria by using AHP. This procedure comprises six steps [65], [66].

Step 1: The problem is modeled as a hierarchy to start AHP. The hierarchy contains the decision goal and the criteria that must be designed [90]. The hierarchy of the criteria used in AHP pairwise for three packages is demonstrated in Figure 7.

Pairwise comparison among the criteria (of each package) is conducted to obtain the weights.

Step 2: AHP builds pairwise matrix comparison in the following Equation (1) to determine a decision [83], [84]:

$$A = \begin{pmatrix} x_{11} & x_{12} & \cdots & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & \cdots & x_{nn} \end{pmatrix} \quad (1)$$

where $x_{ii} = 1, x_{ji} = \frac{1}{x_{ij}}$

Step 3: This stage involves designing a pairwise comparison questionnaire and distributes it to the experts. In this study, six cardiologists with more than 10 years of experience in cardiovascular diseases were selected. Their preferences and judgments on services used in AHP were evaluated. A sample of attribute pairwise comparisons is illustrated in Figure 8.

NPC = n × (n − 1) /2, where NPC is the number of required pairwise comparisons, and n is the number of criteria. In this stage, the decision-making team will be set up. The AHP extracts the weight of importance of each service from the pairwise comparison using a preference and judgments from the decision-making team. In this research, six experts are selected to show their preferences and judgments on the services used in the AHP. The selection was made based on the idea that having the hospital selection depend exclusively on the number of services is not reasonable without giving more importance to one service over another. Six copies of evaluation forms for each package are revised by the experts, with 15 comparisons for the services of package 1, 15 comparisons for the services of package 2 and 6 comparisons for the services of package 3. These pairwise comparisons are presented to the experts, and their responses are obtained. At this point, all the comparisons for services of each package are performed.

Step 4: In this step, each element in matrix A (1) is normalized to construct the normalized matrix A_{norm} , A_{norm} (aij) is

TABLE 12. Hospital ranking result for four patients with risk level (package 1).

1st Patient			2nd Patient		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 2	0.062448	1	Hospital 5	0.06981	1
Hospital 5	0.129205	2	Hospital 4	0.140892	2
Hospital 4	0.209926	3	Hospital 2	0.221329	3
Hospital 8	0.356905	4	Hospital 8	0.296912	4
Hospital 6	0.370189	5	Hospital 6	0.310196	5
Hospital 9	0.539584	6	Hospital 9	0.483142	6
Hospital 3	0.568526	7	Hospital 3	0.51993	7
Hospital 1	0.578121	8	Hospital 1	0.556522	8
Hospital 7	0.656064	9	Hospital 7	0.602068	9
Hospital 12	0.694216	10	Hospital 12	0.667218	10
Hospital 10	0.743508	11	Hospital 10	0.703614	11
Hospital 11	1.000000	12	Hospital 11	1	12
3rd Patient			**4th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 4	0.059069	1	Hospital 5	0.084761	1
Hospital 5	0.108918	2	Hospital 2	0.086601	2
Hospital 2	0.142974	3	Hospital 4	0.148119	3
Hospital 8	0.235736	4	Hospital 8	0.176937	4
Hospital 6	0.25153	5	Hospital 6	0.192318	5
Hospital 9	0.458626	6	Hospital 9	0.434901	6
Hospital 3	0.490495	7	Hospital 3	0.437526	7
Hospital 1	0.490859	8	Hospital 1	0.48848	8
Hospital 7	0.600443	9	Hospital 7	0.563432	9
Hospital 12	0.634914	10	Hospital 12	0.625329	10
Hospital 10	0.701614	11	Hospital 10	0.693207	11
Hospital 11	1	12	Hospital 11	0.998059	12

created as follows:

$$a_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} xij} \tag{2}$$

$$A_{norm} = \begin{pmatrix} a_{11} & a_{12} & \cdots & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & \cdots & a_{nn} \end{pmatrix} \tag{3}$$

where A(x_{ij}) is given by Equation (2).

Step 5: This step includes AHP pairwise to utilize mathematical calculations, convert judgments and assign weights for each service (in each package). The weights of the decision factor i can be calculated using Equation (4):

$$W_i = \sum_{j=1}^{n} a_{ij}/n \quad \text{and} \quad \sum_{j=1}^{n} W_i = 1 \tag{4}$$

where n is the number of compared elements.

Figure 9 presents the AHP steps for weight preferences used for six doctors for package 3. Figures 18 and 19 in the appendix show the steps of AHP for weight preferences for packages 1 and 2.

Step 6: In this step, Equation (5) is utilized to check the consistency ratio (CR) to the pairwise comparison matrix as follows [67]:

$$CR = CI/RI \tag{5}$$

Consistency index (CI) is calculated by Equation (6) as follows:

$$CI = (\lambda max - n)/(n-1) \tag{6}$$

where λmax is the maximum eigenvalue of the judgement matrix. Random consistency index (RI) is calculated by Equation (7) as follows:

$$RI = \frac{1.98(n-1)}{n}.CI \tag{7}$$

TABLE 13. Hospital ranking result for four patients with urgent level (package 2).

1st Patient			2nd Patient		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 1	0.000000	1	Hospital 1	0.000000	1
Hospital 11	0.244082	2	Hospital 11	0.146006	2
Hospital 6	0.291554	3	Hospital 6	0.195416	3
Hospital 10	0.325616	4	Hospital 10	0.232879	4
Hospital 5	0.359621	5	Hospital 5	0.275896	5
Hospital 8	0.611887	6	Hospital 8	0.561657	6
Hospital 9	0.612984	7	Hospital 9	0.565871	7
Hospital 3	0.654453	8	Hospital 3	0.609201	8
Hospital 7	0.678420	9	Hospital 7	0.632228	9
Hospital 2	0.749018	10	Hospital 2	0.714502	10
Hospital 12	0.822927	11	Hospital 12	0.798541	11
Hospital 4	1.000000	12	Hospital 4	1.000000	12
3rd Patient			**4th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 1	0.038208	1	Hospital 6	0.068102	1
Hospital 11	0.052205	2	Hospital 11	0.095944	2
Hospital 6	0.106764	3	Hospital 1	0.130355	3
Hospital 10	0.143008	4	Hospital 10	0.161709	4
Hospital 5	0.197610	5	Hospital 5	0.228621	5
Hospital 9	0.521548	6	Hospital 9	0.534773	6
Hospital 8	0.521565	7	Hospital 8	0.542744	7
Hospital 3	0.576026	8	Hospital 3	0.592210	8
Hospital 7	0.594659	9	Hospital 7	0.605159	9
Hospital 2	0.679730	10	Hospital 2	0.691939	10
Hospital 12	0.769230	11	Hospital 12	0.766805	11
Hospital 4	1.000000	12	Hospital 4	1.000000	12

A pairwise comparison matrix with a corresponding CR of no more than 10% or 0.1 is acceptable [55], [67], [68]; otherwise it will be ignored.

2) ADAPTIVE VIKOR METHOD FOR HOSPITAL RANKING

In this stage, VIKOR method was utilized to rank hospitals because it can identify the most appropriate decision. The five steps of VIKOR technique are as follows [27], [48]:

Step 1: Determine the best f_i^* and worst f_i^- values of all criterion functions, $i = 1; 2; \ldots ;$ n. If the ith function represents a benefit, then

$$f_i^* = \max_j f_{ij}, \quad f_i^- = \min_j f_{ij} \tag{8}$$

where f_i^* *is best* values of all criterion, and f_i^- is worst *v*alues of all criterion.

Step 2: In this step, a set of calculated weights is provided to the DM. The resulting matrix is calculated using Equation (9).

$$WM = wi * (f_i^* - fij)/(f_i^* - f_i^-) \tag{9}$$

This step creates a weighted matrix, as shown in Equation (10).

$$\begin{bmatrix} \frac{w_1\left(f_i^* - f11\right)}{f_i^* - f_i^-} & \cdots & \frac{w_i\left(f_i^* - fij\right)}{f_i^* - f_i^-} \\ \frac{w_1\left(f_i^* - f21\right)}{f_i^* - f_i^-} & \cdots & \frac{w_i\left(f_i^* - fij\right)}{f_i^* - f_i^-} \\ \vdots & \vdots & \vdots \\ \frac{w_1\left(f_i^* - f31\right)}{f_i^* - f_i^-} & \cdots & \frac{w_i\left(f_i^* - fij\right)}{f_i^* - f_i^-} \end{bmatrix} \tag{10}$$

TABLE 14. Hospital ranking result for four patients with sick level (package 3).

1st Patient			2nd Patient		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 11	0.000000	1	Hospital 12	0.000000	1
Hospital 12	0.040489	2	Hospital 10	0.107386	2
Hospital 10	0.145396	3	Hospital 5	0.110793	3
Hospital 5	0.148777	4	Hospital 11	0.269218	4
Hospital 8	0.306819	5	Hospital 8	0.275647	5
Hospital 2	0.330670	6	Hospital 2	0.300049	6
Hospital 7	0.361223	7	Hospital 7	0.332792	7
Hospital 4	0.427093	8	Hospital 4	0.398704	8
Hospital 9	0.510803	9	Hospital 9	0.488089	9
Hospital 6	0.695301	10	Hospital 6	0.688252	10
Hospital 1	0.748519	11	Hospital 1	0.742701	11
Hospital 3	1.000000	12	Hospital 3	1.000000	12
3rd Patient			**4th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 10	0.001438	1	Hospital 5	0.000000	1
Hospital 5	0.013525	2	Hospital 11	0.167031	2
Hospital 11	0.177736	3	Hospital 8	0.185820	3
Hospital 8	0.196313	4	Hospital 2	0.204744	4
Hospital 2	0.214430	5	Hospital 7	0.251222	5
Hospital 7	0.261382	6	Hospital 4	0.325417	6
Hospital 4	0.331839	7	Hospital 9	0.403490	7
Hospital 9	0.411199	8	Hospital 12	0.586472	8
Hospital 12	0.597658	9	Hospital 6	0.586772	9
Hospital 6	0.597950	10	Hospital 1	0.661349	10
Hospital 1	0.670510	11	Hospital 10	0.732016	11
Hospital 3	1.000000	12	Hospital 3	1.000000	12

Step 3: Compute Sj and Rj by using Equations (11) and (12):

$$Sj = \sum_{i=1}^{n} wi * (f_i^* - fij)/(f_i^* - f_i^-) \quad (11)$$

$$Rj = \max_i wi * (f_i^* - fij)/(f_i^* - f_i^-) \quad (12)$$

where $j = 1, 2, 3, \ldots, J$, $i = 1, 2, 3, \ldots, n$.

Step 4: The values $Q_j, j = (1, 2, \cdots, J)$ were computed by using Equation (13): $S^* S_j$

$$Qj = \frac{v(S_j - S^*)}{S^- - S^*} + \frac{(1-v)(R_j - R^*)}{(R^- - R^*)} \quad (13)$$

where

$$S^* = min_j S_j, \quad S^- = max_j S_j$$
$$R^* = min_j R_j, \quad R^- = max_j R_j$$

v is the weight of the strategy of 'the majority of criteria' (or 'the maximum group utility'); here, v = 0.5

Step 5: The set of hospitals can be ordered by sorting the value Q in ascending order.

IV. RESULTS AND DISCUSSION

This section presents the ranking and selection of hospitals and their three corresponding health-care service packages for case study of heart chronic disease based on the different preferences of evaluators. A pairwise comparison method is applied to extract the relevant importance for the criteria for each evaluator as part of AHP. The calculated weights are utilized on the basis of multiple decision makers (six experts) and applied to VIKOR configurations to obtain the final ranking of the 12 hospitals with respect to multi-services.

TABLE 15. Final statistical results of hospital selection for patients within the three packages (Risk, Urgent and Sick).

	P/H	H 1	H 2	H 3	H 4	H 5	H 6	H 7	H 8	H 9	H 10	H 11	H 12
Package 1	1st P		√										
	2nd P					√							
	3rd P				√								
	4th P					√							
	5th P		√										
	6th P				√								
	7th P								√				
	8th P						√						
	9th P					√							
	10th P				√								
	11th P		√										
	12th P								√				
	13th P						√						
	14th P					√							
	15th P									√			
	16th P				√								
	17th P			√									
	18th P	√											
	19th P		√										
	20th P					√							
	Total	1	4	1	4	5	2	0	2	1	0	0	0
	%	5%	20%	5%	20%	25%	10%	0%	10%	5%	0%	0%	0%
	--End of package 1--												
	P/H	**H 1**	**H 2**	**H 3**	**H 4**	**H 5**	**H 6**	**H 7**	**H 8**	**H 9**	**H 10**	**H 11**	**H 12**
Package 2	1st P	√											
	2nd P	√											
	3rd P	√											
	4th P						√						
	5th P											√	
	6th Pa	√											
	7th P						√						
	8th P										√		
	9th P											√	
	10th P					√							
	11th P	√											
	12th P										√		
	13th P	√											
	14th P											√	
	15th P						√						
	16th P	√											

TABLE 15. ***(Continued.)*** **Final statistical results of hospital selection for patients within the three packages (Risk, Urgent and Sick).**

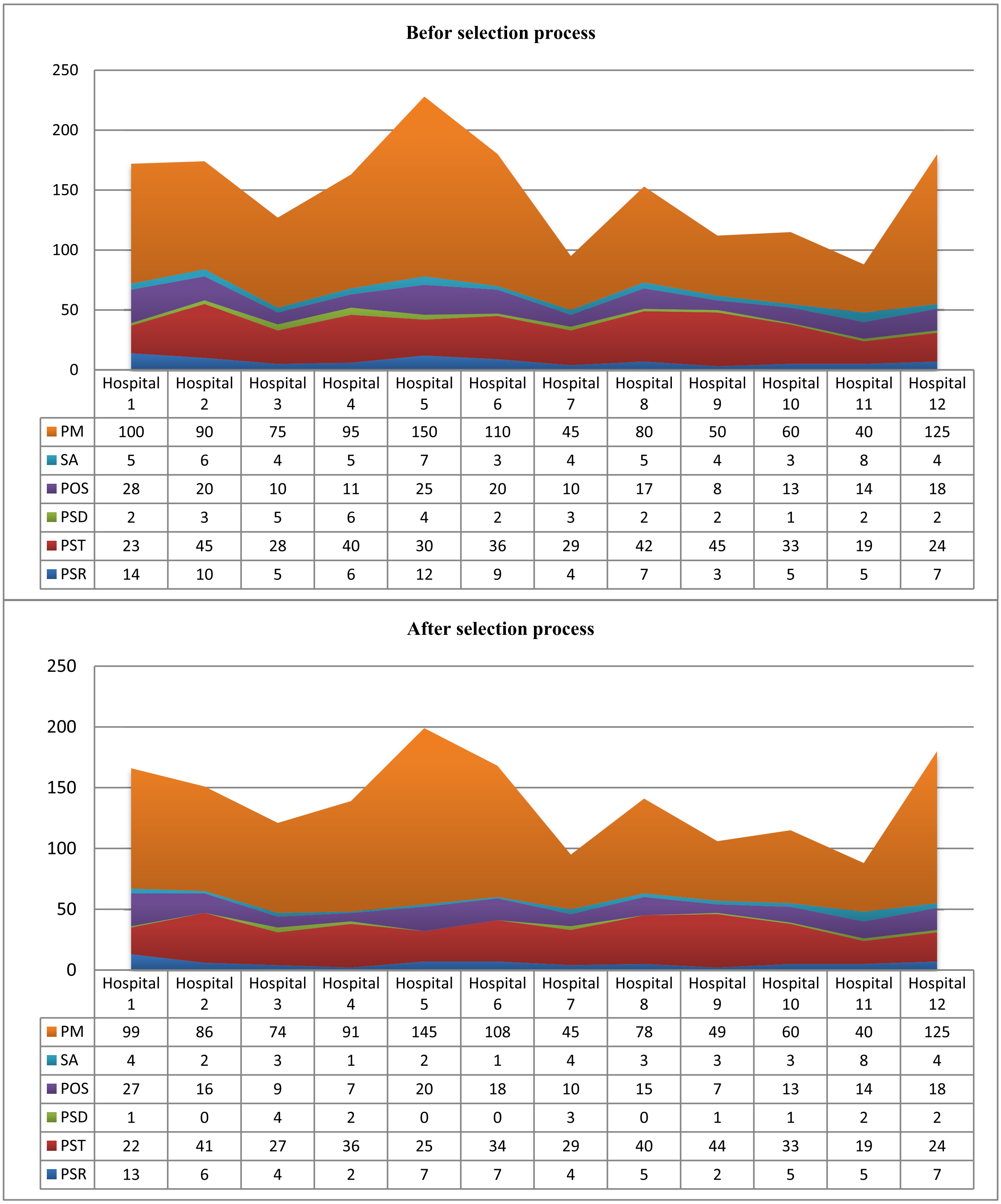
	17th P					√							
	18th P										√		
	19th P	√											
	20th P						√						
	Total	8	0	0	0	2	4	0	0	0	3	3	0
	%	40%	0%	0%	0%	10%	20%	0%	0%	0%	15%	15%	0%
	--End of package 2--												
	P/H	**H 1**	**H 2**	**H 3**	**H 4**	**H 5**	**H 6**	**H 7**	**H 8**	**H 9**	**H 10**	**H 11**	**H 12**
Package 3	1st P											√	
	2nd P												√
	3rd P										√		
	4th P					√							
	5th P											√	
	6th P								√				
	7th P		√										
	8th P							√					
	9th P				√								
	10th P									√			
	11th P								√				
	12th P						√						
	13th P												√
	14th P	√											
	15th P					√							
	16th P										√		
	17th P											√	
	18th P		√										
	19th P							√					
	20th P			√									
	Total	1	2	1	1	2	1	2	2	1	2	3	2
	%	5%	10%	5%	5%	10%	5%	10%	10%	5%	10%	15%	10%
	--End of package 3--												

P= Patient
H= Hospital

Section 4.1 presents the data and 4LRTPL algorithm results of the patients. Section 4.2 discusses the hospitals' dataset statuses and results for DMs. The result of AHP method in Section 4.3 illustrates the weights for the overall criteria of the three packages. The judgement of each expert is converted using mathematical calculations to show the overall weights. Section 4.4 presents the ranking results for VIKOR method and the ranking and selection results. Figure 10 presents the overview of the results of hospital selection.

A. PRESENTATION OF PATIENTS' DATA AND (4LRTPL) ALGORITHM RESULT

Four significant sources were utilized to present the data of patients with chronic heart diseases. Three of these sources are wearable, namely, ECG, SpO2 and BP, and the fourth is text. These sources were utilized to transfer the vital signs of the patients to Tier 4 for monitoring and evaluating of their situation. The result of the triage level for 500 patients are 13.2% (n = 66/500), 30.2% (n = 151/500),



	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10	Hospital 11	Hospital 12
PM	100	90	75	95	150	110	45	80	50	60	40	125
SA	5	6	4	5	7	3	4	5	4	3	8	4
POS	28	20	10	11	25	20	10	17	8	13	14	18
PSD	2	3	5	6	4	2	3	2	2	1	2	2
PST	23	45	28	40	30	36	29	42	45	33	19	24
PSR	14	10	5	6	12	9	4	7	3	5	5	7

	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10	Hospital 11	Hospital 12
PM	99	86	74	91	145	108	45	78	49	60	40	125
SA	4	2	3	1	2	1	4	3	3	3	8	4
POS	27	16	9	7	20	18	10	15	7	13	14	18
PSD	1	0	4	2	0	0	3	0	1	1	2	2
PST	22	41	27	36	25	34	29	40	44	33	19	24
PSR	13	6	4	2	7	7	4	5	2	5	5	7

FIGURE 12. **Hospital status before and after hospital selection for patients with risk level.**

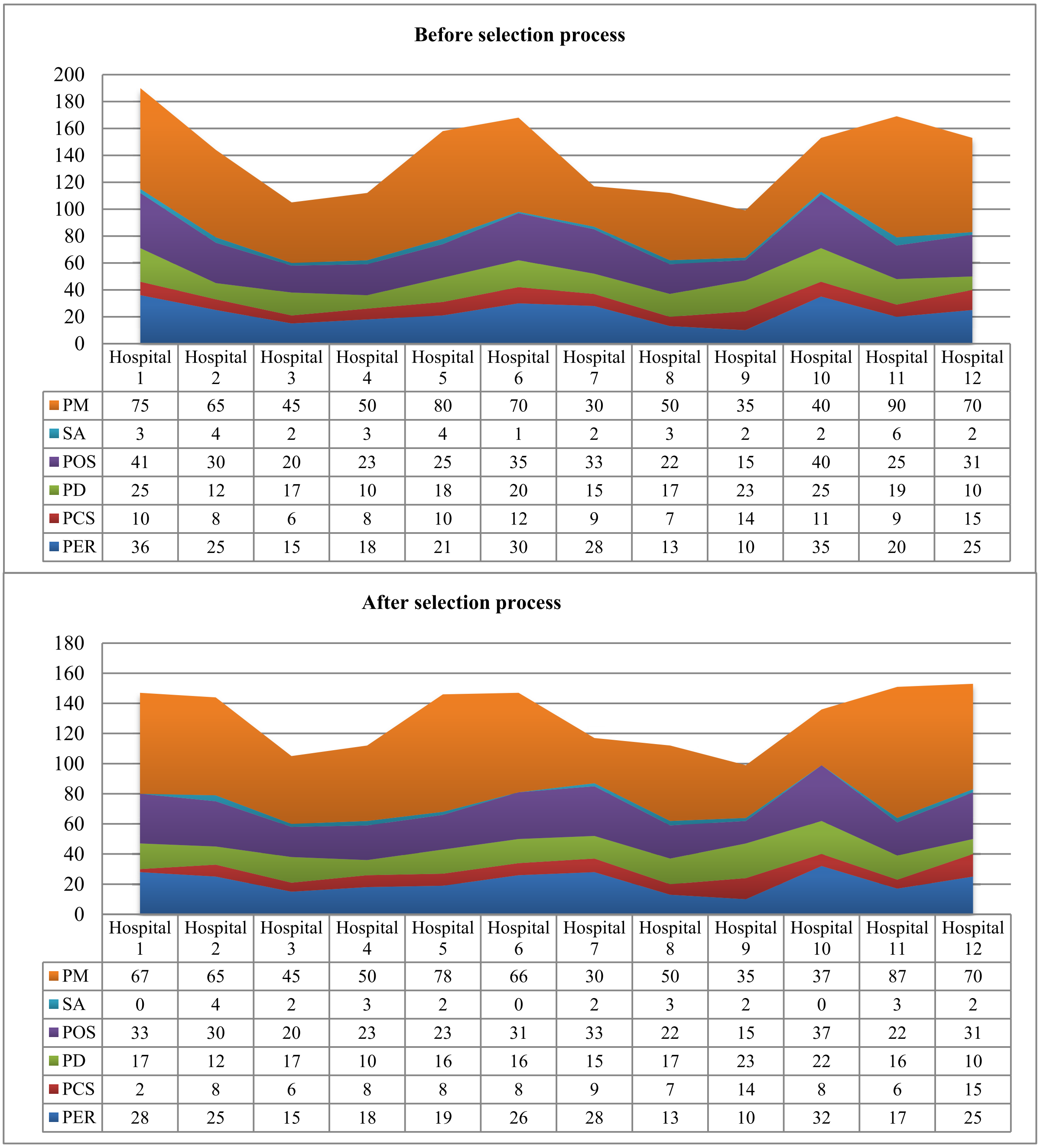
52% (n = 260/500) and 4.6% (n = 23/500) for patients in the risk, urgent and sick levels and for those who do not need services from hospitals based on TC values calculated by (4LRTPL) algorithm (Figure 11), respectively. Table 21 in Appendix illustrates the dataset and 4LRTPL algorithm results of the patients.

The results showed that (66), (151) and (260) patients required health-care services of packages 1, 2 and 3, respectively.

B. STATUS OF HOSPITALS' DATASET AND RESULT FOR DMs

In this study, the number of health-care services collected from 12 hospitals located in Baghdad city provided a proof of concept.

The types of health-care service criteria/attributes (which represents as parameters setting in this research) for each package are identified in Section 3.1.5. The values of these parameters in each package within 12 hospitals are shown in Table 6.



Before selection process

	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10	Hospital 11	Hospital 12
PM	75	65	45	50	80	70	30	50	35	40	90	70
SA	3	4	2	3	4	1	2	3	2	2	6	2
POS	41	30	20	23	25	35	33	22	15	40	25	31
PD	25	12	17	10	18	20	15	17	23	25	19	10
PCS	10	8	6	8	10	12	9	7	14	11	9	15
PER	36	25	15	18	21	30	28	13	10	35	20	25

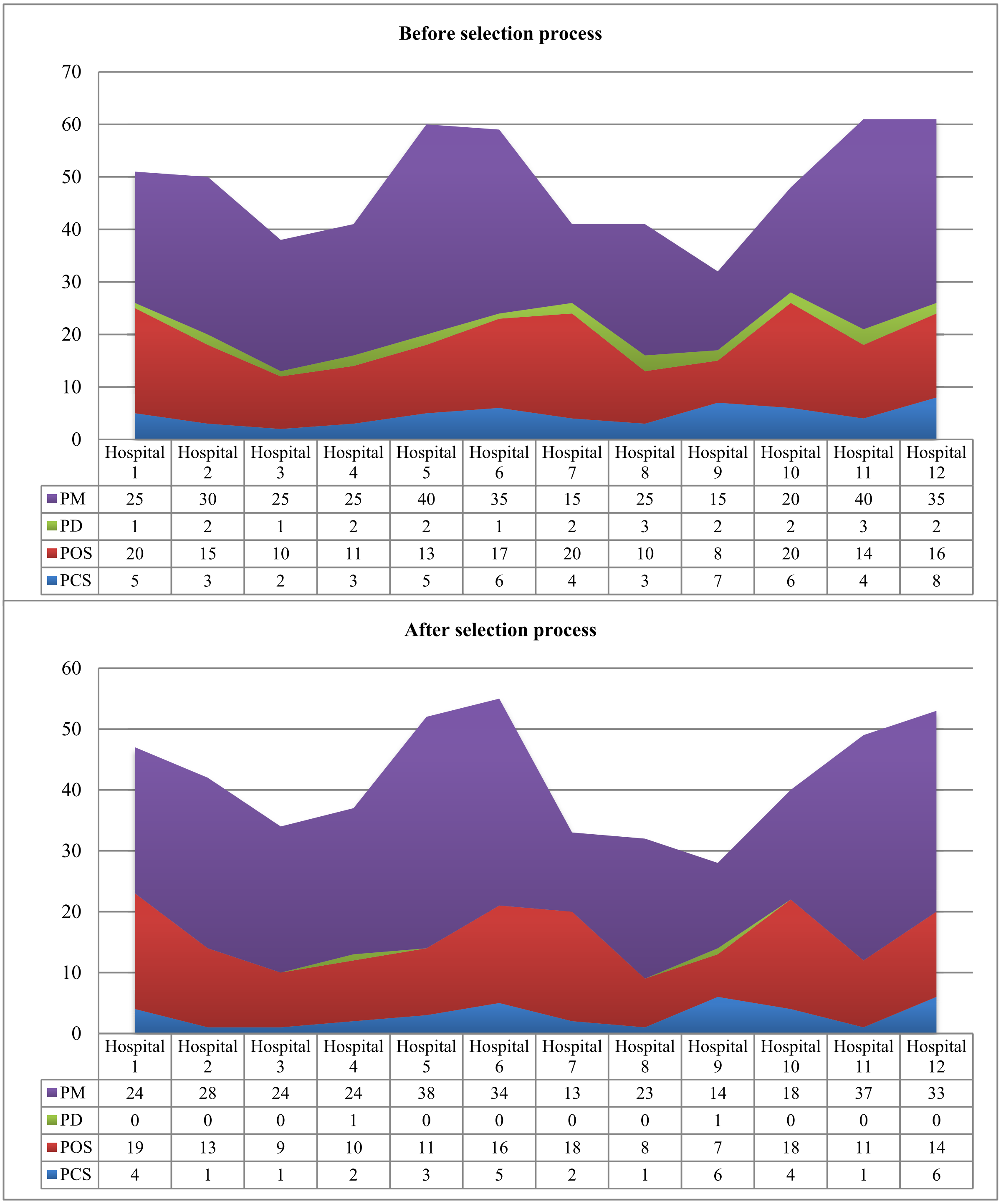
After selection process

	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10	Hospital 11	Hospital 12
PM	67	65	45	50	78	66	30	50	35	37	87	70
SA	0	4	2	3	2	0	2	3	2	0	3	2
POS	33	30	20	23	23	31	33	22	15	37	22	31
PD	17	12	17	10	16	16	15	17	23	22	16	10
PCS	2	8	6	8	8	8	9	7	14	8	6	15
PER	28	25	15	18	19	26	28	13	10	32	17	25

FIGURE 13. **Hospital status before and after hospital selection for patients with urgent level.**

Table 6 presents the states of disparity in the number of the services in hospitals based on the capacity and crowding of each hospital. In package 1, hospitals 5 and 11 showed the highest and lowest average of services, respectively. In package 2, hospitals 1 and 9 showed the highest and lowest average of services, respectively. Finally, in package 3, hospitals 11 and 12 showed the highest average of services, and hospital 9 showed the lowest average.

In the proposed DMs, 12 hospitals represented the alternatives, as mentioned in Section 3.1.4. In section 3.1.5, the available health-care services in these hospitals are represented as criteria and parameter settings in DM. Three packages were provided for patients with chronic disease, as mentioned in Section 3.1.3. Thus, multiple health-care services with hospitals constructed three DMs structures, namely, DMs for packages 1, 2 and 3. The next section reports the process of measuring the weight by using AHP method with different experts. The section describes multi-criteria analysis with the resulting weights from AHP method.



Before selection process

	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10	Hospital 11	Hospital 12
PM	25	30	25	25	40	35	15	25	15	20	40	35
PD	1	2	1	2	2	1	2	3	2	2	3	2
POS	20	15	10	11	13	17	20	10	8	20	14	16
PCS	5	3	2	3	5	6	4	3	7	6	4	8

After selection process

	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10	Hospital 11	Hospital 12
PM	24	28	24	24	38	34	13	23	14	18	37	33
PD	0	0	0	1	0	0	0	0	1	0	0	0
POS	19	13	9	10	11	16	18	8	7	18	11	14
PCS	4	1	1	2	3	5	2	1	6	4	1	6

FIGURE 14. Hospital status before and after hospital selection for patients with sick level.

C. WEIGHT MEASUREMENT USING AHP

In this section, the AHP results are presented and explained. The results of the weights for the multi-services in each package presented the importance of each service. The results for the CR that expressed the internal consistency of the conducted judgments were calculated. Table 7 presents an AHP sample measurement process for weight preferences of the first expert for three packages, whereas the results of the other five experts are shown in detail in Tables 22, 23, 24, 25 and 26 in the Appendix.

Table 7 shows the health-care services criteria, namely, original matrix, normalized matrix and aggregation, which were calculated to obtain weights. Tables 8, 9 and 10 illustrate the weights of multi-services within three packages for

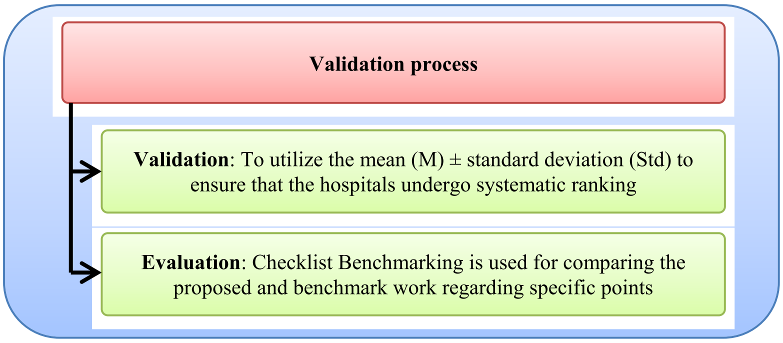


FIGURE 15. Structure of validation and evaluation processes.

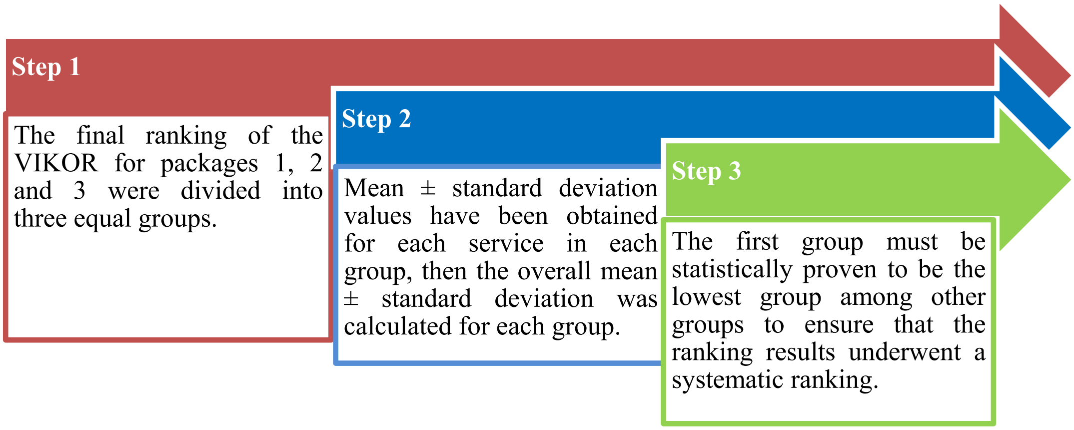


FIGURE 16. Structure of the validation process.

six experts. The overall CR for the six experts scored an acceptable ratio of less than 0.1, as mentioned in Section 3.2.1.

For package 1 (risk level), Table 8 illustrates that the comprehensive weights of six experts have been computed to obtain one set of weights for each expert. The first expert assigned the maximum weight for PSD service with a value of 0.33 and obtained the minimum weight by POS with a value of 0.04. The second expert assigned the maximum weight for PM service with a value of 0.36 and obtained the minimum weight by PSR with a value of 0.05. The third expert assigned the maximum weight for PST and PSD services with a value of 0.29 and obtained the minimum weight by PSR with a value of 0.04. The fourth expert assigned the maximum weight for POS service with a value of 0.37 and obtained the minimum weight obtained by PM and PSD services with a value of 0.06. The fifth expert assigned the maximum weight for PSR service with a value of 0.35 and obtained the minimum weight by POS service with a value of 0.03. The last expert assigned the maximum weight for PST and PSD services with a value of 0.21 and obtained the minimum weight obtained by PSR service with a value of 0.03.

For package 2 (urgent level), Table 9 illustrates the comprehensive weights of the six experts to obtain one set of weight for each of them. The first expert assigned the maximum weight for PCS service with a value of 0.27 and obtained the minimum weight by POS with a value of 0.06. The second expert assigned the maximum weight for PD and POS services with a value of 0.34 and obtained the minimum weight by PCS with a value of 0.02. The third expert assigned the maximum weight for PD service with a value of 0.33 and obtained the minimum weight by PCS and SA services with a value of 0.05. The fourth expert assigned the maximum weight for PM service with a value of 0.33 and obtained the minimum weight by SA service with a value of 0.04. The fifth expert assigned the maximum weight for PER service with a value of 0.32 and obtained the minimum weight by PCS service with a value of 0.06. The last expert assigned the maximum weight for PD service with a value of 0.37 and obtained the minimum weight by POS service with a value of 0.07.

For package 3 (sick level), Table 10 illustrates that the comprehensive weights of six experts have been computed to obtain one set of weights for each expert. The first expert assigned the maximum weight for PD service with a value

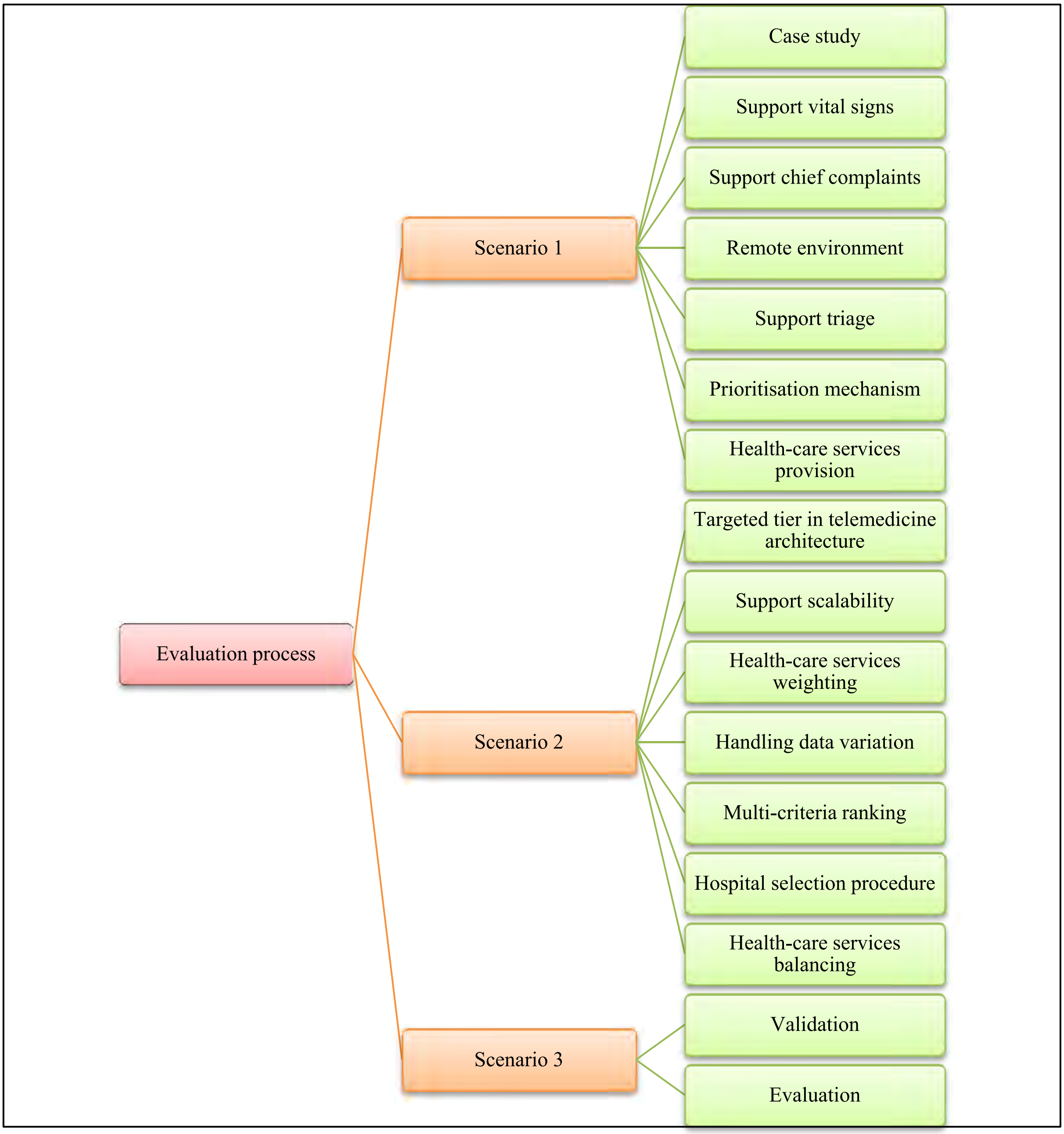


FIGURE 17. Relations between the comparison points and scenarios.

of 0.51and obtained the minimum weight by POS with a value of 0.07. The second expert assigned the maximum weight for POS service with a value of 0.43 and obtained the minimum weight by PM with a value of 0.04. The third expert assigned the maximum weight for PM service with a value of 0.52 and obtained the minimum weight by PCS service with a value of 0.06. The fourth expert assigned the maximum weight for PCS service with a value of 0.41 and obtained the minimum weight by PM service with a value of 0.07. The fifth expert assigned the maximum weight for PD service with a value of 0.53 and obtained the minimum weight by PCS service with a value of 0.07. The last expert assigned the maximum weight for PCS service with a value of 0.52 and obtained the minimum weight by PD service with a value of 0.05.

Based on the previous discussion, the results illustrated that a variation in the weight preferences of the six experts exists. Therefore, adopting an arithmetic mean for the final weighs of the six expert preferences was required to eliminate the variation between them and properly ranking the hospitals [69]. The calculation of the arithmetic means for six experts is shown in Table 11.

TABLE 16. Statistical analysis results for the three groups of the hospital ranking results for 20 patients with risk level.

Hospitals Ranking Results	1st Group	2nd Group	3rd Group
1st Patient	0.066 ± 0.045	0.098 ± 0.057	0.124 ± 0.039
2nd Patient	0.070 ± 0.046	0.098 ± 0.057	0.124 ± 0.039
3th Patient	0.074 ± 0.043	0.098 ± 0.057	0.123 ± 0.039
4th Patient	0.074 ± 0.045	0.095 ± 0.059	0.122 ± 0.041
5th Patient	0.081 ± 0.034	0.093 ± 0.062	0.122 ± 0.041
6th Patient	0.082 ± 0.044	0.096 ± 0.060	0.122 ± 0.041
7th Patient	0.086 ± 0.042	0.096 ± 0.060	0.122 ± 0.041
8th Patient	0.087 ± 0.043	0.122 ± 0.041	0.099 ± 0.059
9th Patient	0.089 ± 0.051	0.096 ± 0.051	0.120 ± 0.039
10th Patient	0.093 ± 0.051	0.096 ± 0.051	0.120 ± 0.039
11th Patient	0.096 ± 0.054	0.097 ± 0.048	0.120 ± 0.039
12th Patient	0.086 ± 0.041	0.101 ± 0.042	0.115 ± 0.038
13th Patient	0.089 ± 0.053	0.105 ± 0.038	0.112 ± 0.046
14th Patient	0.091 ± 0.059	0.103 ± 0.039	0.111 ± 0.045
15th Patient	0.094 ± 0.057	0.103 ± 0.032	0.111 ± 0.045
16th Patient	0.089 ± 0.054	0.105 ± 0.039	0.108 ± 0.044
17th Patient	0.088 ± 0.056	0.110 ± 0.029	0.108 ± 0.044
18th Patient	0.091 ± 0.048	0.108 ± 0.036	0.103 ± 0.047
19th Patient	0.088 ± 0.043	0.103 ± 0.038	0.112 ± 0.045
20th Patient	0.090 ± 0.044	0.103 ± 0.038	0.112 ± 0.045

TABLE 17. Statistical analysis results for the three groups of the hospital ranking results for 20 patients with urgent level.

Hospitals Ranking Results	1st Group	2nd Group	3rd Group
1st Patient	0.052 ± 0.046	0.104 ± 0.039	0.107 ± 0.036
2nd Patient	0.054 ± 0.046	0.103 ± 0.039	0.106 ± 0.036
3th Patient	0.057 ± 0.047	0.103 ± 0.039	0.106 ± 0.036
4th Patient	0.057 ± 0.046	0.101 ± 0.039	0.104 ± 0.036
5th Patient	0.060 ± 0.047	0.103 ± 0.038	0.105 ± 0.035
6th Patient	0.061 ± 0.049	0.099 ± 0.040	0.102 ± 0.036
7th Patient	0.062 ± 0.048	0.097 ± 0.039	0.100 ± 0.036
8th Patient	0.062 ± 0.051	0.100 ± 0.045	0.100 ± 0.036
9th Patient	0.061 ± 0.050	0.097 ± 0.046	0.098 ± 0.037
10th Patient	0.063 ± 0.045	0.096 ± 0.043	0.097 ± 0.038
11th Patient	0.066 ± 0.050	0.097 ± 0.039	0.097 ± 0.038
12th Patient	0.066 ± 0.050	0.096 ± 0.038	0.096 ± 0.038
13th Patient	0.068 ± 0.038	0.090 ± 0.051	0.094 ± 0.039
14th Patient	0.069 ± 0.036	0.089 ± 0.050	0.093 ± 0.038
15th Patient	0.067 ± 0.040	0.094 ± 0.041	0.093 ± 0.038
16th Patient	0.069 ± 0.044	0.094 ± 0.041	0.093 ± 0.038
17th Patient	0.070 ± 0.045	0.093 ± 0.040	0.092 ± 0.038
18th Patient	0.072 ± 0.049	0.094 ± 0.038	0.092 ± 0.038
19th Patient	0.072 ± 0.047	0.089 ± 0.049	0.095 ± 0.041
20th Patient	0.073 ± 0.048	0.093 ± 0.03	0.091 ± 0.038

D. RESULTS OF VIKOR DECISION MAKING

As mentioned in section 3.2.2, the set of hospitals were ranked by the value Q in ascending order. A total of 20 patients out of 66 with the risk level, 20 patients out of 151 with urgent level and 20 patients out of 260 with sick level have been followed from the results of 4LRTPL algorithm in Section 4.1 to discuss the ranking results and managing the loading of health-care services amongst hospitals. The reason was to produce the scenario of comparisons for the managing and controlling process of health-care services amongst hospitals as a 'proof of concept'. In this section, the results of the VIKOR decision-making context for three packages (Risk, Urgent and Sick) are presented in the following subsections.

TABLE 18. Statistical analysis results for the three groups of the hospital ranking results for 20 patients with sick level.

Hospitals Ranking Results	1st Group	2nd Group	3rd Group
1st Patient	0.092 ± 0.071	0.139 ± 0.060	0.162 ± 0.086
2nd Patient	0.101 ± 0.055	0.139 ± 0.060	0.162 ± 0.086
3th Patient	0.110 ± 0.079	0.143 ± 0.062	0.149 ± 0.057
4th Patient	0.120 ± 0.057	0.140 ± 0.088	0.158 ± 0.055
5th Patient	0.126 ± 0.068	0.137 ± 0.085	0.166 ± 0.059
6th Patient	0.136 ± 0.062	0.130 ± 0.076	0.178 ± 0.058
7th Patient	0.101 ± 0.063	0.129 ± 0.101	0.178 ± 0.058
8th Patient	0.115 ± 0.063	0.131 ± 0.038	0.187 ± 0.034
9th Patient	0.121 ± 0.103	0.140 ± 0.045	0.194 ± 0.045
10th Patient	0.121 ± 0.116	0.156 ± 0.058	0.203 ± 0.039
11th Patient	0.126 ± 0.099	0.167 ± 0.059	0.205 ± 0.049
12th Patient	0.044 ± 0.040	0.085 ± 0.052	0.148 ± 0.080
13th Patient	0.053 ± 0.047	0.099 ± 0.042	0.150 ± 0.106
14th Patient	0.060 ± 0.056	0.107 ± 0.038	0.145 ± 0.108
15th Patient	0.071 ± 0.053	0.109 ± 0.059	0.150 ± 0.059
16th Patient	0.077 ± 0.056	0.116 ± 0.101	0.159 ± 0.062
17th Patient	0.094 ± 0.046	0.116 ± 0.109	0.168 ± 0.060
18th Patient	0.103 ± 0.040	0.120 ± 0.097	0.179 ± 0.059
19th Patient	0.108 ± 0.060	0.131 ± 0.038	0.189 ± 0.037
20th Patient	0.115 ± 0.098	0.140 ± 0.045	0.196 ± 0.047

1) HOSPITALS RANKING RESULTS FOR RISK PATIENTS'

The weights of the health-care services for package 1 were 25.4%, 18.2%, 15.2%, 15.4%, 14.5% and 11.4% for PST, PSD, POS, PM, PSR and SA, as shown in Table 11, respectively. Each hospital was ranked according to these weights. Table 12 shows the hospitals ranking result for four patients with risk level (package 1), whereas Table 27 in Appendix E shows the hospitals ranking result for other 16 patients with this level.

2) HOSPITALS RANKING RESULTS FOR URGENT PATIENTS'

The weights of the health-care services for package 2 were 28.4%, 19.4%, 16.6%, 12.5%, 12% and 11.1% for PD, PM, PER, SA, POS and PCS, as shown in Table 11, respectively. Each hospital in this package was evaluated according to these weights. Table 13 shows the hospitals ranking result for four patients with urgent level (package 2) after applying the weights, which was calculated by the average of the preferences of the six experts, whereas Table 28 in Appendix shows the hospitals ranking result for other 16 patients with this level.

TABLE 19. Checklist benchmarking.

Checklist issues	Benchmark	Proposed
Case study	Supported	Supported
Remote Environment	Not supported (real-time monitoring only)	Supported remote health monitoring
Support vital signs	Supported	Supported
Support chief complaints	Not supported	Supported
Triage	Data and information gathered from the patients are classified into two: the first is patient therapy at home, and the second is the transportation of the patient to a hospital or leave recommendations for a patient to visit hospital by taxi.	The patients are classified into four levels, namely, risk, urgent, sick and normal
Prioritisation mechanism	The selected hospital receives an early notification that the patients are being transported by ambulance to prepare facilities and doctors. Urgent and regular patients being served by the hospital with different of priority can change dynamically.	Not supported
Health-care services provision	The facilities and doctors are prepared for the patients who are being transported to the hospital.	Several health-care services are grouped into the following four packages: 1. Package 1 for risk level patients 2. Package 2 for urgent level patients 3. Package 3 for sick level patients 4. Package 4 for normal situation patients
Targeted tier in telemedicine architecture	Tier 3	Produce Tier 4 in the current telemedicine architecture
Support Scalability	Not supported	Yes
Health-care services weighting	Not supported	In the proposed framework, six doctors assigned the proper weights to the multi-service criteria
Handling data variation	Not supported	Selection process involves simultaneous consideration of the health-care services numbers from multiple attributes that generated data variation, which is addressed in the proposed framework.
Multi-criteria ranking	DSS to select proper hospital	Multi-criteria decision making has been applied to deal with multiple health-care services criteria within the hospitals. The hospital selection process must consider the availability of these services that affects the selection process.
Hospital selection	Real-time monitoring for medical centres to support the decision.	Hospitals are ranked according to their capacity and

3) HOSPITALS RANKING RESULTS FOR SICK PATIENTS'

The weights of the health-care services for package 3 were 33.1%, 23.3%, 22.8% and 20.8% for PD, PCS, POS and PM, as shown in Table 11 in Section 4.4, respectively. Each hospital in this package was evaluated according to these weights. Table 14 shows the hospital ranking result for four patients with sick level (package 3) after applying the weights, which was calculated by the average of the

TABLE 19. ***(Continued.)*** **Checklist benchmarking.**

procedure	Proper hospital selection based on few number or no patients in the queue for therapy within hospitals and traffic model.	available health-care services from the highest to the lowest levels.
Health-care services balancing amongst hospitals	Set of ambulance controlled by different medical centres are managed. Permanent monitoring of ambulance and specific traffic model for routing and continuous traffic monitoring are done.	Proposed a new design of telemedicine architecture for providing health-care services, and such design managed and controlled the health-care services load amongst hospitals.
Validation	No validation provided	Objectively validation
Evaluation	No evaluation provided	Checklist benchmarking

TABLE 20. **Comparison of scenarios and their related comparison points in the benchmark and proposed framework.**

Scenarios	Comparison points	Benchmark	Proposed
First scenario	Case study	√	√
	Remote Environment	x	√
	Support vital signs	√	√
	Support chief complaints	x	√
	Triage	√	√
	Prioritisation mechanism	√	x
	Health-care services provision	√	√
Second scenario	Targeted tier in telemedicine architecture	√	√
	Support Scalability	x	√
	Health-care services weighting	x	√
	Handling data variation	x	√
	Multi-criteria ranking	x	√
	Hospital selection procedure	x	√
	Health-care services balancing amongst hospitals	x	√
Third scenario	Validation	x	√
	Evaluation	x	√
Total score		37.5%	93.75%
Finding difference		56.25%	

preferences of the six experts, whereas Table 29 Appendix shows the hospital ranking result for other 16 patients with this level.

4) DISCUSSION FOR VIKOR RESULTS

Based on the results of the VIKOR decision making, the ranking results for all 20 patients within each package must be discussed to show the differences in hospital ranking and the management process for health-care service provision amongst hospitals.

The number of health-care services in hospitals was the key factor in the selection process for all patients with risk, urgent and sick levels (all packages).After the selection process, Figures 12, 13 and 14 show the status of the hospital before and after selection of appropriate hospital for all patients with risk, urgent and sick levels.

In package 1, each service has been booked 20 times from different hospitals based on its capacity and availability. All health-care services within this package decreased and were provided five times from hospital 5; four times from hospitals 2 and 4; twice from hospitals 6 and 8; and only once from hospitals 1, 3 and 9. In package 2, all health-care services decreased and were provided eight times from hospital 1; four times from hospital 6; thrice from

Each Evaluator	Criteria	Original matrix						Normalised matrix						Aggregation	Weight
		PSR	PST	PSD	POS	SA	PM	PSR	PST	PSD	POS	SA	PM		
	PSR	PSR(1)	PSR/ PST	PSR/ PSD	PSR/ POS	PSR/ SA	PSR/ PM	PSR(1)/ Sum 1	(PSR/PST)/Sum 2	(PSR/PSD) /Sum 3	(PSR/POS)/Sum 4	(PSR/SA)/Sum 5	(PSR/PM)/ Sum 6	Sum-PSR	W1=Sum-PSR/n
	PST	PST/ PSR	PST (1)	PST/ PSD	PST/ POS	PST/ SA	PST/ PM	(PST/PSR)/Sum 1	PST1 /Sum 2	(PST/PSD)/Sum 3	(PST/POS)/Sum 4	(PST/SA)/Sum 5	(PST/PM)/ Sum 6	Sum-PST	W2=Sum-PST/n
	PSD	PSD/ PSR	PSD/ PST	PSD (1)	PSD/ POS	PSD/ SA	PSD/ PM	(PSD/PSR) /Sum 1	(PSD/PST)/Sum 2	PSD1/ Sum 3	(PSD/POS)/Sum 4	(PSD/SA)/Sum 5	(PSD/PM)/ Sum 6	Sum-PSD	W3=Sum-PSD/n
	POS	POS/ PSR	POS/ PST	POS/ PSD	POS(1)	POS/ SA	POS/ PM	(POS/PSR) /Sum 1	(POS/PST)/Sum 2	(POS/PSD)/Sum 3	POS1/Sum 4	(POS/SA)/Sum 5	(POS/PM)/ Sum 6	Sum-POS	W4=Sum-POS/n
	SA	SA/ PSR	SA/ PST	SA/ PSD	SA/ POS	SA(1)	SA/ PM	(SA/PSR)/Sum 1	(SA/PST) /Sum 2	(SA/PSD)/ Sum 3	(SA/POS)/Sum 4	SA1/ Sum 5	(SA/PM)/ Sum 6	Sum-SA	W5=Sum-SA/n
	PM	PM/ PSR	PM/ PST	PM/ PSD	SM/ POS	PM/ SA	PM(1)	(PM/PSR)/Sum 1	(PM/PST)/Sum 2	(PM/PSD)/Sum 3	(PM/POS)/Sum 4	(PM/SA)/Sum 5	PM1/ Sum 6	Sum-PM	W6=Sum-PM/n
	Sum	Sum1	Sum2	Sum3	Sum 4	Sum5	Sum 6								Sum(W)=1

FIGURE 18. Design of AHP steps for weight preferences for package 1.

Each Evaluator	Criteria	Original matrix						Normalised matrix						Aggregation	Weight
		PER	PCS	PD	POS	SA	PM	PER	PCS	PD	POS	SA	PM		
	PER	PER(1)	PER /PCR	PER /PD	PER /POS	PER /SA	PER /PM	PER(1)/ Sum1	(PER /PCS) /Sum2	(PER /PD)/ Sum3	(PER /POS) /Sum4	(PER /SA) /Sum5	(PER /PM) /Sum6	Sum-PER	W1=Sum-PER/n
	PCS	PCS /PER	PCS (1)	PCS /PD	PCS /POS	PCS /SA	PCS /PM	(PCS /PER) /Sum1	PCS1/ Sum2	(PCS /PD)/ Sum3	(PCS /POS) /Sum4	(PCS /SA) /Sum5	(PCS /PM) /Sum6	Sum-PCS	W2=Sum-PCS/n
	PD	PD/PER	PD/PCS	PD(1)	PD/POS	PD/SA	PD/PM	(PD/PER) /Sum1	(PD/PCS) /Sum2	PD1/ Sum3	(PD/POS) /Sum4	(PD/SA) /Sum5	(PD/PM) /Sum6	Sum-PD	W3=Sum-PD/n
	POS	POS/PER	POS/PCS	POS/PD	POS(1)	POS/SA	POS/PM	(POS/PER) /Sum1	(POS/PCS) /Sum2	(POS/PD) /Sum3	POS1 / Sum4	(POS/SA) /Sum5	(POS/PM) /Sum6	Sum-POS	W4=Sum-POS/n
	SA	SA/PER	SA/PCS	SA/PD	SA/POS	SA(1)	SA/PM	(SA/PER) /Sum1	(SA/PCS) /Sum2	(SA/PD) /Sum3	(SA/POS) /Sum4	SA1/ Sum5	(SA/PM) /Sum6	Sum-SA	W5=Sum-SA/n
	PM	PM/PER	PM/PCS	PM/PD	PM/POS	PM/SA	PM(1)	(PM/PER) /Sum1	(PM/PCS) /Sum2	(PM/PD) /Sum3	(PM/POS) /Sum4	(PM/SA) /Sum5	PM1/ Sum6	Sum-PM	W6=Sum-PM/n
	Sum	Sum1	Sum2	Sum3	Sum 4	Sum 5	Sum 6								Sum(W)=1

FIGURE 19. Design of AHP steps for weight preferences for package 2.

hospitals 10 and 11; and twice from hospital 5. In package 3, all health-care services were provided and decreased thrice from hospital 11; twice from hospitals 2, 5, 7, 8, 10 and 12; and once from hospitals 1, 3, 4, 6 and 9.

Table 15 shows the final statistical results of the hospital selection for selected patients within three packages (Risk, Urgent and Sick).

The first part of Table 15 shows the hospitals ranking result for 20 patients with risk level (package 1), in this part, hospital 5 was suitable and selected with a percentage of 25% (n = 5/20) for the second, fourth, ninth, fourteenth and twentieth patient. Hospital 2 was suitable and selected with a percentage of 20% (n = 4/20) for the first, fifth, eleventh and nineteenth patient. Hospital 4 was suitable and selected with a percentage of 20% (n = 4/20) for the third, sixth, tenth and sixteenth patient. Hospital 6 was suitable and selected with a percentage of 10% (n = 2/20) for the eighth and thirteenth patient, hospital 8 was suitable and selected with a percentage of 10% (n = 2/20) for the seventh and twelfth patient. Hospitals 1, 3 and 9 were suitable and selected with a percentage of 5% (n = 1/20) each for the eighteenth, seventeenth and fifteenth patient, respectively. The second part of Table 15 shows hospitals ranking result for 20 patients with urgent level (package 2), hospital 1 was suitable and selected with a percentage of 40% (n = 8/20) for the first, second, third, sixth, eleventh, thirteenth, sixteenth and nineteenth patient. Hospital 6 was suitable and selected with a percentage of 20% (n = 4/20) for the fourth, seventh, fifteenth

TABLE 21. Dataset samples of 500 patients and 4LRTPL algorithm results.

Patient. no	SL	HBP	LBP	CP	SOB	PAL	PIR	P	QRSW	PP	STE	TC
1	97	23	12	false	false	false	False	67	0.06	0.06576267	true	32
2	97	23	12	false	false	false	True	67	0.06	0.06576267	true	34
3	97	23	12	false	false	true	False	67	0.06	0.06576267	true	44
4	97	23	12	false	false	true	True	67	0.06	0.06576267	true	46
5	97	23	12	false	true	false	False	67	0.06	0.06576267	true	38
6	97	23	12	false	true	false	True	67	0.06	0.06576267	true	40
7	97	23	12	false	true	true	False	67	0.06	0.06576267	true	50
8	97	23	12	false	true	true	True	67	0.06	0.06576267	true	52
9	97	23	12	true	false	false	False	67	0.06	0.06576267	true	50
10	97	23	12	true	false	false	True	67	0.06	0.06576267	true	52
11	97	23	12	true	false	true	False	67	0.06	0.06576267	true	62
12	97	23	12	true	false	true	True	67	0.06	0.06576267	true	64
13	97	23	12	true	true	false	False	67	0.06	0.06576267	true	56
14	97	23	12	true	true	false	True	67	0.06	0.06576267	true	58
15	97	23	12	true	true	true	False	67	0.06	0.06576267	true	68
16	97	23	12	true	true	true	True	67	0.06	0.06576267	true	70
17	92	23	12	false	false	false	False	67	0.06	0.06576267	true	38
18	92	23	12	false	false	false	True	67	0.06	0.06576267	true	40
19	92	23	12	false	false	true	False	67	0.06	0.06576267	true	50
20	92	23	12	false	false	true	True	67	0.06	0.06576267	true	52
21	92	23	12	false	true	false	False	67	0.06	0.06576267	true	44
22	92	23	12	false	true	false	True	67	0.06	0.06576267	true	46
23	92	23	12	false	true	true	False	67	0.06	0.06576267	true	56
24	92	23	12	false	true	true	True	67	0.06	0.06576267	true	58
25	92	23	12	true	false	false	False	67	0.06	0.06576267	true	56
26	92	23	12	true	false	false	True	67	0.06	0.06576267	true	58
27	92	23	12	true	false	true	False	67	0.06	0.06576267	true	68
28	92	23	12	true	false	true	True	67	0.06	0.06576267	true	70
29	92	23	12	true	true	false	False	67	0.06	0.06576267	true	62
30	92	23	12	true	true	false	True	67	0.06	0.06576267	true	64
31	92	23	12	true	true	true	False	67	0.06	0.06576267	true	74
32	92	23	12	true	true	true	True	67	0.06	0.06576267	true	76
33	97	15	10	false	false	false	False	67	0.06	0.06576267	true	26
34	97	15	10	false	false	false	True	67	0.06	0.06576267	true	28
35	97	15	10	false	false	true	False	67	0.06	0.06576267	true	38
36	97	15	10	false	false	true	True	67	0.06	0.06576267	true	40
37	97	15	10	false	true	false	False	67	0.06	0.06576267	true	32
38	97	15	10	false	true	false	True	67	0.06	0.06576267	true	34
39	97	15	10	false	true	true	False	67	0.06	0.06576267	true	44
40	97	15	10	false	true	true	True	67	0.06	0.06576267	true	46
41	97	15	10	true	false	false	False	67	0.06	0.06576267	true	44
42	97	15	10	true	false	false	True	67	0.06	0.06576267	true	46
43	97	15	10	true	false	true	False	67	0.06	0.06576267	true	56
44	97	15	10	true	false	true	True	67	0.06	0.06576267	true	58
45	97	15	10	true	true	false	False	67	0.06	0.06576267	true	50
46	97	15	10	true	true	false	True	67	0.06	0.06576267	true	52
47	97	15	10	true	true	true	False	67	0.06	0.06576267	true	62
48	97	15	10	true	true	true	True	67	0.06	0.06576267	true	64
49	92	15	10	false	false	false	False	67	0.06	0.06576267	true	32
50	92	15	10	false	false	false	True	67	0.06	0.06576267	true	34
51	92	15	10	false	false	true	False	67	0.06	0.06576267	true	44
52	92	15	10	false	false	true	True	67	0.06	0.06576267	true	46
53	92	15	10	false	true	false	False	67	0.06	0.06576267	true	38
54	92	15	10	false	true	false	True	67	0.06	0.06576267	true	40
55	92	15	10	false	true	true	False	67	0.06	0.06576267	true	50
56	92	15	10	false	true	true	True	67	0.06	0.06576267	true	52
57	92	15	10	true	false	false	False	67	0.06	0.06576267	true	50
58	92	15	10	true	false	false	True	67	0.06	0.06576267	true	52
59	92	15	10	true	false	true	False	67	0.06	0.06576267	true	62
60	92	15	10	true	false	true	True	67	0.06	0.06576267	true	64
61	92	15	10	true	true	false	False	67	0.06	0.06576267	true	56
62	92	15	10	true	true	false	True	67	0.06	0.06576267	true	58
63	92	15	10	true	true	true	False	67	0.06	0.06576267	true	68
64	92	15	10	true	true	true	True	67	0.06	0.06576267	true	70

TABLE 21. ***(Continued.)*** **Dataset samples of 500 patients and 4LRTPL algorithm results.**

65	97	12	8	false	false	false	False	67	0.06	0.06576267	true	20
66	97	12	8	false	false	false	True	67	0.06	0.06576267	true	22
67	97	12	8	false	false	true	False	67	0.06	0.06576267	true	32
68	97	12	8	false	false	true	True	67	0.06	0.06576267	true	34
69	97	12	8	false	true	false	False	67	0.06	0.06576267	true	26
70	97	12	8	false	true	false	True	67	0.06	0.06576267	true	28
71	97	12	8	false	true	true	False	67	0.06	0.06576267	true	38
72	97	12	8	false	true	true	True	67	0.06	0.06576267	true	40
73	97	12	8	true	false	false	False	67	0.06	0.06576267	true	38
74	97	12	8	true	false	false	True	67	0.06	0.06576267	true	40
75	97	12	8	true	false	true	False	67	0.06	0.06576267	true	50
76	97	12	8	true	false	true	True	67	0.06	0.06576267	true	52
77	97	12	8	true	true	false	False	67	0.06	0.06576267	true	44
78	97	12	8	true	true	false	True	67	0.06	0.06576267	true	46
79	97	12	8	true	true	true	False	67	0.06	0.06576267	true	56
80	97	12	8	true	true	true	True	67	0.06	0.06576267	true	58
81	92	12	8	false	false	false	False	67	0.06	0.06576267	true	26
82	92	12	8	false	false	false	True	67	0.06	0.06576267	true	28
83	92	12	8	false	false	true	False	67	0.06	0.06576267	true	38
84	92	12	8	false	false	true	True	67	0.06	0.06576267	true	40
85	92	12	8	false	true	false	False	67	0.06	0.06576267	true	32
86	92	12	8	false	true	false	True	67	0.06	0.06576267	true	34
87	92	12	8	false	true	true	False	67	0.06	0.06576267	true	44
88	92	12	8	false	true	true	True	67	0.06	0.06576267	true	46
89	92	12	8	true	false	false	False	67	0.06	0.06576267	true	44
90	92	12	8	true	false	false	True	67	0.06	0.06576267	true	46
91	92	12	8	true	false	true	False	67	0.06	0.06576267	true	56
92	92	12	8	true	false	true	True	67	0.06	0.06576267	true	58
93	92	12	8	true	true	false	False	67	0.06	0.06576267	true	50
94	92	12	8	true	true	false	True	67	0.06	0.06576267	true	52
95	92	12	8	true	true	true	False	67	0.06	0.06576267	true	62
96	92	12	8	true	true	true	True	67	0.06	0.06576267	true	64
97	80	12	8	false	false	false	False	67	0.06	0.06576267	true	32
98	80	12	8	false	false	false	True	67	0.06	0.06576267	true	34
99	80	12	8	false	false	true	False	67	0.06	0.06576267	true	44
100	80	12	8	false	false	true	True	67	0.06	0.06576267	true	46
101	80	12	8	false	true	false	False	67	0.06	0.06576267	true	38
102	80	12	8	false	true	false	True	67	0.06	0.06576267	true	40
103	80	12	8	false	true	true	False	67	0.06	0.06576267	true	50
104	80	12	8	false	true	true	True	67	0.06	0.06576267	true	52
105	80	12	8	true	false	false	False	67	0.06	0.06576267	true	50
106	80	12	8	true	false	false	True	67	0.06	0.06576267	true	52
107	80	12	8	true	false	true	False	67	0.06	0.06576267	true	62
108	80	12	8	true	false	true	True	67	0.06	0.06576267	true	64
109	80	12	8	true	true	false	False	67	0.06	0.06576267	true	56
110	80	12	8	true	true	false	True	67	0.06	0.06576267	true	58
111	80	12	8	true	true	true	False	67	0.06	0.06576267	true	68
112	80	12	8	true	true	true	True	67	0.06	0.06576267	true	70
113	80	15	10	false	false	false	False	67	0.06	0.06576267	true	38
114	80	15	10	false	false	false	True	67	0.06	0.06576267	true	40
115	80	15	10	false	false	true	False	67	0.06	0.06576267	true	50
116	80	15	10	false	false	true	True	67	0.06	0.06576267	true	52
117	80	15	10	false	true	false	False	67	0.06	0.06576267	true	44
118	80	15	10	false	true	false	True	67	0.06	0.06576267	true	46
119	80	15	10	false	true	true	False	67	0.06	0.06576267	true	56
120	80	15	10	false	true	true	True	67	0.06	0.06576267	true	58
121	80	15	10	true	false	false	False	67	0.06	0.06576267	true	56
122	80	15	10	true	false	false	True	67	0.06	0.06576267	true	58
123	80	15	10	true	false	true	False	67	0.06	0.06576267	true	68
124	80	15	10	true	false	true	True	67	0.06	0.06576267	true	70
125	80	15	10	true	true	false	False	67	0.06	0.06576267	true	62
126	80	15	10	true	true	false	True	67	0.06	0.06576267	true	64
127	80	15	10	true	true	true	False	67	0.06	0.06576267	true	74
128	80	15	10	true	true	true	True	67	0.06	0.06576267	true	76
129	80	23	12	false	false	false	False	67	0.06	0.06576267	true	44
130	80	23	12	false	false	false	True	67	0.06	0.06576267	true	46
131	80	23	12	false	false	true	False	67	0.06	0.06576267	true	56

TABLE 21. *(Continued.)* Dataset samples of 500 patients and 4LRTPL algorithm results.

132	80	23	12	false	false	true	True	67	0.06	0.06576267	true	58
133	80	23	12	false	true	false	False	67	0.06	0.06576267	true	50
134	80	23	12	false	true	false	True	67	0.06	0.06576267	true	52
135	80	23	12	false	true	true	False	67	0.06	0.06576267	true	62
136	80	23	12	false	true	true	True	67	0.06	0.06576267	true	64
137	80	23	12	true	false	false	False	67	0.06	0.06576267	true	62
138	80	23	12	true	false	false	True	67	0.06	0.06576267	true	64
139	80	23	12	true	false	true	False	67	0.06	0.06576267	true	74
140	80	23	12	true	false	true	True	67	0.06	0.06576267	true	76
141	80	23	12	true	true	false	False	67	0.06	0.06576267	true	68
142	80	23	12	true	true	false	True	67	0.06	0.06576267	true	70
143	80	23	12	true	true	true	False	67	0.06	0.06576267	true	80
144	80	23	12	true	true	true	True	67	0.06	0.06576267	true	82
145	97	23	12	false	false	false	False	54	0.5	0.03737244	false	26
146	97	23	12	false	false	false	True	54	0.5	0.03737244	false	28
147	97	23	12	false	false	true	False	54	0.5	0.03737244	false	38
148	97	23	12	false	false	true	True	54	0.5	0.03737244	false	40
149	97	23	12	false	true	false	False	54	0.5	0.03737244	false	32
150	97	23	12	false	true	false	True	54	0.5	0.03737244	false	34
151	97	23	12	false	true	true	False	54	0.5	0.03737244	false	44
152	97	23	12	false	true	true	True	54	0.5	0.03737244	false	46
153	97	23	12	true	false	false	False	54	0.5	0.03737244	false	44
154	97	23	12	true	false	false	True	54	0.5	0.03737244	false	46
155	97	23	12	true	false	true	False	54	0.5	0.03737244	false	56
156	97	23	12	true	false	true	True	54	0.5	0.03737244	false	58
157	97	23	12	true	true	false	False	54	0.5	0.03737244	false	50
158	97	23	12	true	true	false	True	54	0.5	0.03737244	false	52
159	97	23	12	true	true	true	False	54	0.5	0.03737244	false	62
160	97	23	12	true	true	true	True	54	0.5	0.03737244	false	64
161	92	23	12	false	false	false	False	54	0.5	0.03737244	false	32
162	92	23	12	false	false	false	True	54	0.5	0.03737244	false	34
163	92	23	12	false	false	true	False	54	0.5	0.03737244	false	44
164	92	23	12	false	false	true	True	54	0.5	0.03737244	false	46
165	92	23	12	false	true	false	False	54	0.5	0.03737244	false	38
166	92	23	12	false	true	false	True	54	0.5	0.03737244	false	40
167	92	23	12	false	true	true	False	54	0.5	0.03737244	false	50
168	92	23	12	false	true	true	True	54	0.5	0.03737244	false	52
169	92	23	12	true	false	false	False	54	0.5	0.03737244	false	50
170	92	23	12	true	false	false	True	54	0.5	0.03737244	false	52
171	92	23	12	true	false	true	False	54	0.5	0.03737244	false	62
172	92	23	12	true	false	true	True	54	0.5	0.03737244	false	64
173	92	23	12	true	true	false	False	54	0.5	0.03737244	false	56
174	92	23	12	true	true	false	True	54	0.5	0.03737244	false	58
175	92	23	12	true	true	true	False	54	0.5	0.03737244	false	68
176	92	23	12	true	true	true	True	54	0.5	0.03737244	false	70
177	97	15	10	false	false	false	False	54	0.5	0.03737244	false	20
178	97	15	10	false	false	false	True	54	0.5	0.03737244	false	22
179	97	15	10	false	false	true	False	54	0.5	0.03737244	false	32
180	97	15	10	false	false	true	True	54	0.5	0.03737244	false	34
181	97	15	10	false	true	false	False	54	0.5	0.03737244	false	26
182	97	15	10	false	true	false	True	54	0.5	0.03737244	false	28
183	97	15	10	false	true	true	False	54	0.5	0.03737244	false	38
184	97	15	10	false	true	true	True	54	0.5	0.03737244	false	40
185	97	15	10	true	false	false	False	54	0.5	0.03737244	false	38
186	97	15	10	true	false	false	True	54	0.5	0.03737244	false	40
187	97	15	10	true	false	true	False	54	0.5	0.03737244	false	50
188	97	15	10	true	false	true	True	54	0.5	0.03737244	false	52
189	97	15	10	true	true	false	False	54	0.5	0.03737244	false	44
190	97	15	10	true	true	false	True	54	0.5	0.03737244	false	46
191	97	15	10	true	true	true	False	54	0.5	0.03737244	false	56
192	97	15	10	true	true	true	True	54	0.5	0.03737244	false	58
193	92	15	10	false	false	false	False	54	0.5	0.03737244	false	26
194	92	15	10	false	false	false	True	54	0.5	0.03737244	false	28
195	92	15	10	false	false	true	False	54	0.5	0.03737244	false	38
196	92	15	10	false	false	true	True	54	0.5	0.03737244	false	40
197	92	15	10	false	true	false	False	54	0.5	0.03737244	false	32
198	92	15	10	false	true	false	True	54	0.5	0.03737244	false	34

TABLE 21. *(Continued.)* **Dataset samples of 500 patients and 4LRTPL algorithm results.**

199	92	15	10	false	true	true	False	54	0.5	0.03737244	false	44
200	92	15	10	false	true	true	True	54	0.5	0.03737244	false	46
201	92	15	10	true	false	false	False	54	0.5	0.03737244	false	44
202	92	15	10	true	false	false	True	54	0.5	0.03737244	false	46
203	92	15	10	true	false	true	False	54	0.5	0.03737244	false	56
204	92	15	10	true	false	true	True	54	0.5	0.03737244	false	58
205	92	15	10	true	true	false	False	54	0.5	0.03737244	false	50
206	92	15	10	true	true	false	True	54	0.5	0.03737244	false	52
207	92	15	10	true	true	true	False	54	0.5	0.03737244	false	62
208	92	15	10	true	true	true	True	54	0.5	0.03737244	false	64
209	97	12	8	false	false	false	False	54	0.5	0.03737244	false	14
210	97	12	8	false	false	false	True	54	0.5	0.03737244	false	16
211	97	12	8	false	false	true	False	54	0.5	0.03737244	false	26
212	97	12	8	false	false	true	True	54	0.5	0.03737244	false	28
213	97	12	8	false	true	false	False	54	0.5	0.03737244	false	20
214	97	12	8	false	true	false	True	54	0.5	0.03737244	false	22
215	97	12	8	false	true	true	False	54	0.5	0.03737244	false	32
216	97	12	8	false	true	true	True	54	0.5	0.03737244	false	34
217	97	12	8	true	false	false	False	54	0.5	0.03737244	false	32
218	97	12	8	true	false	false	True	54	0.5	0.03737244	false	34
219	97	12	8	true	false	true	False	54	0.5	0.03737244	false	44
220	97	12	8	true	false	true	True	54	0.5	0.03737244	false	46
221	97	12	8	true	true	false	False	54	0.5	0.03737244	false	38
222	97	12	8	true	true	false	True	54	0.5	0.03737244	false	40
223	97	12	8	true	true	true	False	54	0.5	0.03737244	false	50
224	97	12	8	true	true	true	True	54	0.5	0.03737244	false	52
225	92	12	8	false	false	false	False	54	0.5	0.03737244	false	20
226	92	12	8	false	false	false	True	54	0.5	0.03737244	false	22
227	92	12	8	false	false	true	False	54	0.5	0.03737244	false	32
228	92	12	8	false	false	true	True	54	0.5	0.03737244	false	34
229	92	12	8	false	true	false	False	54	0.5	0.03737244	false	26
230	92	12	8	false	true	false	True	54	0.5	0.03737244	false	28
231	92	12	8	false	true	true	False	54	0.5	0.03737244	false	38
232	92	12	8	false	true	true	True	54	0.5	0.03737244	false	40
233	92	12	8	true	false	false	False	54	0.5	0.03737244	false	38
234	92	12	8	true	false	false	True	54	0.5	0.03737244	false	40
235	92	12	8	true	false	true	False	54	0.5	0.03737244	false	50
236	92	12	8	true	false	true	True	54	0.5	0.03737244	false	52
237	92	12	8	true	true	false	False	54	0.5	0.03737244	false	44
238	92	12	8	true	true	false	True	54	0.5	0.03737244	false	46
239	92	12	8	true	true	true	False	54	0.5	0.03737244	false	56
240	92	12	8	true	true	true	True	54	0.5	0.03737244	false	58
241	80	12	8	false	false	false	False	54	0.5	0.03737244	false	26
242	80	12	8	false	false	false	True	54	0.5	0.03737244	false	28
243	80	12	8	false	false	true	False	54	0.5	0.03737244	false	38
244	80	12	8	false	false	true	True	54	0.5	0.03737244	false	40
245	80	12	8	false	true	false	False	54	0.5	0.03737244	false	32
246	80	12	8	false	true	false	True	54	0.5	0.03737244	false	34
247	80	12	8	false	true	true	False	54	0.5	0.03737244	false	44
248	80	12	8	false	true	true	True	54	0.5	0.03737244	false	46
249	80	12	8	true	false	false	False	54	0.5	0.03737244	false	44
250	80	12	8	true	false	false	True	54	0.5	0.03737244	false	46
251	80	12	8	true	false	true	False	54	0.5	0.03737244	false	56
252	80	12	8	true	false	true	True	54	0.5	0.03737244	false	58
253	80	12	8	true	true	false	False	54	0.5	0.03737244	false	50
254	80	12	8	true	true	false	True	54	0.5	0.03737244	false	52
255	80	12	8	true	true	true	False	54	0.5	0.03737244	false	62
256	80	12	8	true	true	true	True	54	0.5	0.03737244	false	64
257	80	15	10	false	false	false	False	54	0.5	0.03737244	false	32
258	80	15	10	false	false	false	True	54	0.5	0.03737244	false	34
259	80	15	10	false	false	true	False	54	0.5	0.03737244	false	44
260	80	15	10	false	false	true	True	54	0.5	0.03737244	false	46
261	80	15	10	false	true	false	False	54	0.5	0.03737244	false	38
262	80	15	10	false	true	false	True	54	0.5	0.03737244	false	40
263	80	15	10	false	true	true	False	54	0.5	0.03737244	false	50
264	80	15	10	false	true	true	True	54	0.5	0.03737244	false	52
265	80	15	10	true	false	false	False	54	0.5	0.03737244	false	50

TABLE 21. *(Continued.)* **Dataset samples of 500 patients and 4LRTPL algorithm results.**

266	80	15	10	true	false	false	True	54	0.5	0.03737244	false	52
267	80	15	10	true	false	true	False	54	0.5	0.03737244	false	62
268	80	15	10	true	false	true	True	54	0.5	0.03737244	false	64
269	80	15	10	true	true	false	False	54	0.5	0.03737244	false	56
270	80	15	10	true	true	false	True	54	0.5	0.03737244	false	58
271	80	15	10	true	true	true	False	54	0.5	0.03737244	false	68
272	80	15	10	true	true	true	True	54	0.5	0.03737244	false	70
273	80	23	12	false	false	false	False	54	0.5	0.03737244	false	38
274	80	23	12	false	false	false	True	54	0.5	0.03737244	false	40
275	80	23	12	false	false	true	False	54	0.5	0.03737244	false	50
276	80	23	12	false	false	true	True	54	0.5	0.03737244	false	52
277	80	23	12	false	true	false	False	54	0.5	0.03737244	false	44
278	80	23	12	false	true	false	True	54	0.5	0.03737244	false	46
279	80	23	12	false	true	true	False	54	0.5	0.03737244	false	56
280	80	23	12	false	true	true	True	54	0.5	0.03737244	false	58
281	80	23	12	true	false	false	False	54	0.5	0.03737244	false	56
282	80	23	12	true	false	false	True	54	0.5	0.03737244	false	58
283	80	23	12	true	false	true	False	54	0.5	0.03737244	false	68
284	80	23	12	true	false	true	True	54	0.5	0.03737244	false	70
285	80	23	12	true	true	false	False	54	0.5	0.03737244	false	62
286	80	23	12	true	true	false	True	54	0.5	0.03737244	false	64
287	80	23	12	true	true	true	False	54	0.5	0.03737244	false	74
288	80	23	12	true	true	true	True	54	0.5	0.03737244	false	76
289	97	23	12	false	false	false	False	77	0.047	0.266642311	true	36
290	97	23	12	false	false	false	True	77	0.047	0.266642311	true	38
291	97	23	12	false	false	true	False	77	0.047	0.266642311	true	48
292	97	23	12	false	false	true	True	77	0.047	0.266642311	true	50
293	97	23	12	false	true	false	False	77	0.047	0.266642311	true	42
294	97	23	12	false	true	false	True	77	0.047	0.266642311	true	44
295	97	23	12	false	true	true	False	77	0.047	0.266642311	true	54
296	97	23	12	false	true	true	True	77	0.047	0.266642311	true	56
297	97	23	12	true	false	false	False	77	0.047	0.266642311	true	54
298	97	23	12	true	false	false	True	77	0.047	0.266642311	true	56
299	97	23	12	true	false	true	False	77	0.047	0.266642311	true	66
300	97	23	12	true	false	true	True	77	0.047	0.266642311	true	68
301	97	23	12	true	true	false	False	77	0.047	0.266642311	true	60
302	97	23	12	true	true	false	True	77	0.047	0.266642311	true	62
303	97	23	12	true	true	true	False	77	0.047	0.266642311	true	72
304	97	23	12	true	true	true	True	77	0.047	0.266642311	true	74
305	92	23	12	false	false	false	False	77	0.047	0.266642311	true	42
306	92	23	12	false	false	false	True	77	0.047	0.266642311	true	44
307	92	23	12	false	false	true	False	77	0.047	0.266642311	true	54
308	92	23	12	false	false	true	True	77	0.047	0.266642311	true	56
309	92	23	12	false	true	false	False	77	0.047	0.266642311	true	48
310	92	23	12	false	true	false	True	77	0.047	0.266642311	true	50
311	92	23	12	false	true	true	False	77	0.047	0.266642311	true	60
312	92	23	12	false	true	true	True	77	0.047	0.266642311	true	62
313	92	23	12	true	false	false	False	77	0.047	0.266642311	true	60
314	92	23	12	true	false	false	True	77	0.047	0.266642311	true	62
315	92	23	12	true	false	true	False	77	0.047	0.266642311	true	72
316	92	23	12	true	false	true	True	77	0.047	0.266642311	true	74
317	92	23	12	true	true	false	False	77	0.047	0.266642311	true	66
318	92	23	12	true	true	false	True	77	0.047	0.266642311	true	68
319	92	23	12	true	true	true	False	77	0.047	0.266642311	true	78
320	92	23	12	true	true	true	True	77	0.047	0.266642311	true	80
321	97	15	10	false	false	false	False	77	0.047	0.266642311	true	30
322	97	15	10	false	false	false	True	77	0.047	0.266642311	true	32
323	97	15	10	false	false	true	False	77	0.047	0.266642311	true	42
324	97	15	10	false	false	true	True	77	0.047	0.266642311	true	44
325	97	15	10	false	true	false	False	77	0.047	0.266642311	true	36
326	97	15	10	false	true	false	True	77	0.047	0.266642311	true	38
327	97	15	10	false	true	true	False	77	0.047	0.266642311	true	48
328	97	15	10	false	true	true	True	77	0.047	0.266642311	true	50
329	97	15	10	true	false	false	False	77	0.047	0.266642311	true	48
330	97	15	10	true	false	false	True	77	0.047	0.266642311	true	50
331	97	15	10	true	false	true	False	77	0.047	0.266642311	true	60
332	97	15	10	true	false	true	True	77	0.047	0.266642311	true	62

TABLE 21. *(Continued.)* Dataset samples of 500 patients and 4LRTPL algorithm results.

333	97	15	10	true	true	false	False	77	0.047	0.266642311	true	54
334	97	15	10	true	true	false	True	77	0.047	0.266642311	true	56
335	97	15	10	true	true	true	False	77	0.047	0.266642311	true	66
336	97	15	10	true	true	true	True	77	0.047	0.266642311	true	68
337	92	15	10	false	false	false	False	77	0.047	0.266642311	true	36
338	92	15	10	false	false	false	True	77	0.047	0.266642311	true	38
339	92	15	10	false	false	true	False	77	0.047	0.266642311	true	48
340	92	15	10	false	false	true	True	77	0.047	0.266642311	true	50
341	92	15	10	false	true	false	False	77	0.047	0.266642311	true	42
342	92	15	10	false	true	false	True	77	0.047	0.266642311	true	44
343	92	15	10	false	true	true	False	77	0.047	0.266642311	true	54
344	92	15	10	false	true	true	True	77	0.047	0.266642311	true	56
345	92	15	10	true	false	false	False	77	0.047	0.266642311	true	54
346	92	15	10	true	false	false	True	77	0.047	0.266642311	true	56
347	92	15	10	true	false	true	False	77	0.047	0.266642311	true	66
348	92	15	10	true	false	true	True	77	0.047	0.266642311	true	68
349	92	15	10	true	true	false	False	77	0.047	0.266642311	true	60
350	92	15	10	true	true	false	True	77	0.047	0.266642311	true	62
351	92	15	10	true	true	true	False	77	0.047	0.266642311	true	72
352	92	15	10	true	true	true	True	77	0.047	0.266642311	true	74
353	97	12	8	false	false	false	False	77	0.047	0.266642311	true	24
354	97	12	8	false	false	false	True	77	0.047	0.266642311	true	26
355	97	12	8	false	false	true	False	77	0.047	0.266642311	true	36
356	97	12	8	false	false	true	True	77	0.047	0.266642311	true	38
357	97	12	8	false	true	false	False	77	0.047	0.266642311	true	30
358	97	12	8	false	true	false	True	77	0.047	0.266642311	true	32
359	97	12	8	false	true	true	False	77	0.047	0.266642311	true	42
360	97	12	8	false	true	true	True	77	0.047	0.266642311	true	44
361	97	12	8	true	false	false	False	77	0.047	0.266642311	true	42
362	97	12	8	true	false	false	True	77	0.047	0.266642311	true	44
363	97	12	8	true	false	true	False	77	0.047	0.266642311	true	54
364	97	12	8	true	false	true	True	77	0.047	0.266642311	true	56
365	97	12	8	true	true	false	False	77	0.047	0.266642311	true	48
366	97	12	8	true	true	false	True	77	0.047	0.266642311	true	50
367	97	12	8	true	true	true	False	77	0.047	0.266642311	true	60
368	97	12	8	true	true	true	True	77	0.047	0.266642311	true	62
369	92	12	8	false	false	false	False	77	0.047	0.266642311	true	30
370	92	12	8	false	false	false	True	77	0.047	0.266642311	true	32
371	92	12	8	false	false	true	False	77	0.047	0.266642311	true	42
372	92	12	8	false	false	true	True	77	0.047	0.266642311	true	44
373	92	12	8	false	true	false	False	77	0.047	0.266642311	true	36
374	92	12	8	false	true	false	True	77	0.047	0.266642311	true	38
375	92	12	8	false	true	true	False	77	0.047	0.266642311	true	48
376	92	12	8	false	true	true	True	77	0.047	0.266642311	true	50
377	92	12	8	true	false	false	False	77	0.047	0.266642311	true	48
378	92	12	8	true	false	false	True	77	0.047	0.266642311	true	50
379	92	12	8	true	false	true	False	77	0.047	0.266642311	true	60
380	92	12	8	true	false	true	True	77	0.047	0.266642311	true	62
381	92	12	8	true	true	false	False	77	0.047	0.266642311	true	54
382	92	12	8	true	true	false	True	77	0.047	0.266642311	true	56
383	92	12	8	true	true	true	False	77	0.047	0.266642311	true	66
384	92	12	8	true	true	true	True	77	0.047	0.266642311	true	68
385	80	12	8	false	false	false	False	77	0.047	0.266642311	true	36
386	80	12	8	false	false	false	True	77	0.047	0.266642311	true	38
387	80	12	8	false	false	true	False	77	0.047	0.266642311	true	48
388	80	12	8	false	false	true	True	77	0.047	0.266642311	true	50
389	80	12	8	false	true	false	False	77	0.047	0.266642311	true	42
390	80	12	8	false	true	false	True	77	0.047	0.266642311	true	44
391	80	12	8	false	true	true	False	77	0.047	0.266642311	true	54
392	80	12	8	false	true	true	True	77	0.047	0.266642311	true	56
393	80	12	8	true	false	false	False	77	0.047	0.266642311	true	54
394	80	12	8	true	false	false	True	77	0.047	0.266642311	true	56
395	80	12	8	true	false	true	False	77	0.047	0.266642311	true	66
396	80	12	8	true	false	true	True	77	0.047	0.266642311	true	68
397	80	12	8	true	true	false	False	77	0.047	0.266642311	true	60
398	80	12	8	true	true	false	True	77	0.047	0.266642311	true	62
399	80	12	8	true	true	true	False	77	0.047	0.266642311	true	72

TABLE 21. *(Continued.)* **Dataset samples of 500 patients and 4LRTPL algorithm results.**

400	80	12	8	true	true	true	True	77	0.047	0.266642311	true	74
401	80	15	10	false	false	false	False	77	0.047	0.266642311	true	42
402	80	15	10	false	false	false	True	77	0.047	0.266642311	true	44
403	80	15	10	false	false	true	False	77	0.047	0.266642311	true	54
404	80	15	10	false	false	true	True	77	0.047	0.266642311	true	56
405	80	15	10	false	true	false	False	77	0.047	0.266642311	true	48
406	80	15	10	false	true	false	True	77	0.047	0.266642311	true	50
407	80	15	10	false	true	true	False	77	0.047	0.266642311	true	60
408	80	15	10	false	true	true	True	77	0.047	0.266642311	true	62
409	80	15	10	true	false	false	False	77	0.047	0.266642311	true	60
410	80	15	10	true	false	false	True	77	0.047	0.266642311	true	62
411	80	15	10	true	false	true	False	77	0.047	0.266642311	true	72
412	80	15	10	true	false	true	True	77	0.047	0.266642311	true	74
413	80	15	10	true	true	false	False	77	0.047	0.266642311	true	66
414	80	15	10	true	true	false	True	77	0.047	0.266642311	true	68
415	80	15	10	true	true	true	False	77	0.047	0.266642311	true	78
416	80	15	10	true	true	true	True	77	0.047	0.266642311	true	80
417	80	23	12	false	false	false	False	77	0.047	0.266642311	true	48
418	80	23	12	false	false	false	True	77	0.047	0.266642311	true	50
419	80	23	12	false	false	true	False	77	0.047	0.266642311	true	60
420	80	23	12	false	false	true	True	77	0.047	0.266642311	true	62
421	80	23	12	false	true	false	False	77	0.047	0.266642311	true	54
422	80	23	12	false	true	false	True	77	0.047	0.266642311	true	56
423	80	23	12	false	true	true	False	77	0.047	0.266642311	true	66
424	80	23	12	false	true	true	True	77	0.047	0.266642311	true	68
425	80	23	12	true	false	false	False	77	0.047	0.266642311	true	66
426	80	23	12	true	false	false	True	77	0.047	0.266642311	true	68
427	80	23	12	true	false	true	False	77	0.047	0.266642311	true	78
428	80	23	12	true	false	true	True	77	0.047	0.266642311	true	80
429	80	23	12	true	true	false	False	77	0.047	0.266642311	true	72
430	80	23	12	true	true	false	True	77	0.047	0.266642311	true	74
431	80	23	12	true	true	true	False	77	0.047	0.266642311	true	84
432	80	23	12	true	true	true	True	77	0.047	0.266642311	true	86
433	97	23	12	false	false	false	False	64	0.169	0.336317901	false	20
434	97	23	12	false	false	false	True	64	0.169	0.336317901	false	22
435	97	23	12	false	false	true	False	64	0.169	0.336317901	false	32
436	97	23	12	false	false	true	True	64	0.169	0.336317901	false	34
437	97	23	12	false	true	false	False	64	0.169	0.336317901	false	26
438	97	23	12	false	true	false	True	64	0.169	0.336317901	false	28
439	97	23	12	false	true	true	False	64	0.169	0.336317901	false	38
440	97	23	12	false	true	true	True	64	0.169	0.336317901	false	40
441	97	23	12	true	false	false	False	64	0.169	0.336317901	false	38
442	97	23	12	true	false	false	True	64	0.169	0.336317901	false	40
443	97	23	12	true	false	true	False	64	0.169	0.336317901	false	50
444	97	23	12	true	false	true	True	64	0.169	0.336317901	false	52
445	97	23	12	true	true	false	False	64	0.169	0.336317901	false	44
446	97	23	12	true	true	false	True	64	0.169	0.336317901	false	46
447	97	23	12	true	true	true	False	64	0.169	0.336317901	false	56
448	97	23	12	true	true	true	True	64	0.169	0.336317901	false	58
449	92	23	12	false	false	false	False	64	0.169	0.336317901	false	26
450	92	23	12	false	false	false	True	64	0.169	0.336317901	false	28
451	92	23	12	false	false	true	False	64	0.169	0.336317901	false	38
452	92	23	12	false	false	true	True	64	0.169	0.336317901	false	40
453	92	23	12	false	true	false	False	64	0.169	0.336317901	false	32
454	92	23	12	false	true	false	True	64	0.169	0.336317901	false	34
455	92	23	12	false	true	true	False	64	0.169	0.336317901	false	44
456	92	23	12	false	true	true	True	64	0.169	0.336317901	false	46
457	92	23	12	true	false	false	False	64	0.169	0.336317901	false	44
458	92	23	12	true	false	false	True	64	0.169	0.336317901	false	46
459	92	23	12	true	false	true	False	64	0.169	0.336317901	false	56
460	92	23	12	true	false	true	True	64	0.169	0.336317901	false	58
461	92	23	12	true	true	false	False	64	0.169	0.336317901	false	50
462	92	23	12	true	true	false	True	64	0.169	0.336317901	false	52
463	92	23	12	true	true	true	False	64	0.169	0.336317901	false	62
464	92	23	12	true	true	true	True	64	0.169	0.336317901	false	64
465	97	15	10	false	false	false	False	64	0.169	0.336317901	false	14
466	97	15	10	false	false	false	True	64	0.169	0.336317901	false	16

TABLE 21. *(Continued.)* **Dataset samples of 500 patients and 4LRTPL algorithm results.**

467	97	15	10	false	false	true	False	64	0.169	0.336317901	false	26
468	97	15	10	false	false	true	True	64	0.169	0.336317901	false	28
469	97	15	10	false	true	false	False	64	0.169	0.336317901	false	20
470	97	15	10	false	true	false	True	64	0.169	0.336317901	false	22
471	97	15	10	false	true	true	False	64	0.169	0.336317901	false	32
472	97	15	10	false	true	true	True	64	0.169	0.336317901	false	34
473	97	15	10	true	false	false	False	64	0.169	0.336317901	false	32
474	97	15	10	true	false	false	True	64	0.169	0.336317901	false	34
475	97	15	10	true	false	true	False	64	0.169	0.336317901	false	44
476	97	15	10	true	false	true	True	64	0.169	0.336317901	false	46
477	97	15	10	true	true	false	False	64	0.169	0.336317901	false	38
478	97	15	10	true	true	false	True	64	0.169	0.336317901	false	40
479	97	15	10	true	true	true	False	64	0.169	0.336317901	false	50
480	97	15	10	true	true	true	True	64	0.169	0.336317901	false	52
481	92	15	10	false	false	false	False	64	0.169	0.336317901	false	20
482	92	15	10	false	false	false	True	64	0.169	0.336317901	false	22
483	92	15	10	false	false	true	False	64	0.169	0.336317901	false	32
484	92	15	10	false	false	true	True	64	0.169	0.336317901	false	34
485	92	15	10	false	true	false	False	64	0.169	0.336317901	false	26
486	92	15	10	false	true	false	True	64	0.169	0.336317901	false	28
487	92	15	10	false	true	true	False	64	0.169	0.336317901	false	38
488	92	15	10	false	true	true	True	64	0.169	0.336317901	false	40
489	92	15	10	true	false	false	False	64	0.169	0.336317901	false	38
490	92	15	10	true	false	false	True	64	0.169	0.336317901	false	40
491	92	15	10	true	false	true	False	64	0.169	0.336317901	false	50
492	92	15	10	true	false	true	True	64	0.169	0.336317901	false	52
493	92	15	10	true	true	false	False	64	0.169	0.336317901	false	44
494	92	15	10	true	true	false	True	64	0.169	0.336317901	false	46
495	92	15	10	true	true	true	False	64	0.169	0.336317901	false	56
496	92	15	10	true	true	true	True	64	0.169	0.336317901	false	58
497	97	12	8	false	false	false	False	64	0.169	0.336317901	false	8
498	97	12	8	false	false	false	True	64	0.169	0.336317901	false	10
499	97	12	8	false	false	true	False	64	0.169	0.336317901	false	20
500	97	12	8	false	false	true	True	64	0.169	0.336317901	false	22

Notes: S = spo2 level, HBP= high blood pressure, LBP= low blood pressure, CP= chest pain, SOB= shortness of breath, PAL= palpitation, PIR= patient in rest, P= peaks, QRSW = QRS width, PP= peak to peak interval, STE= ST elevation and TC= triage code.

and twentieth patient. Hospital 11 was suitable and selected with a percentage of 15% (n = 3/20) for the fifth, fourteenth and ninth patient. Hospital 10 was suitable and selected with a percentage of 15% (n = 3/20) for the eighth, twelfth and eighteenth patient, whereas hospital 5 was suitable and selected with a percentage of 10% (n = 2/20) for the tenth and seventeenth patient. The third part of Table 15 shows hospitals ranking result for 20 patients with sick level (package 3), hospital 11 was suitable and selected with a percentage of 15% (n = 3/20) for the first, fifth and seventeenth patient. Hospital 12 was suitable and selected with a percentage of 10% (n = 2/20) for the second and thirteenth patient, whereas hospital 10 was suitable and selected with a percentage of 10% (n = 2/20) for the third and sixteenth patient. Hospital 8 was suitable and selected with a percentage of 10% (n = 2/20) for the sixth and eleventh patient, hospital 2 was suitable and selected with a percentage of 10% (n = 2/20) for the seventh and eighteenth patient, whereas hospital 7 was suitable and selected with a percentage of 10% (n = 2/20) for the eighth and nineteenth patient, and hospital 5 was suitable and selected with a percentage of 10% (n = 2/20) for the fourth and fifteenth patient. Hospitals 4, 9, 6, 1 and 3 were suitable and selected only one time with a percentage of 5% (n = 1/20) each for the ninth, tenth, twelfth, fourteenth and twentieth, respectively.

Finally, the following observations are noted:

- The increasing demand for health-care services was accommodated and managed through Tier 4 by managing and controlling the load on health-care services amongst hospitals.
- Tier 4 assigned specific weights to each service in the health-care packages by using AHP technique and set of experts to rank the hospitals.
- AHP technique proved that it is an effective technique to eliminate the main weakness in the VIKOR technique, which is the lack of weight provision for different criteria.
- Based on the hospital capacity and availability, Tier 4 selected and ranked hospitals to provide health-care services to patients with chronic heart disease, such selection and ranking process was done based on VIKOR technique.

TABLE 22. AHP measurement process for the weight preferences of the criteria (healthcare services) for the three packages (second expert).

Healthcare services criteria for package 1 (Risk Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PSR	PST	PSD	POS	SA	PM	PSR	PST	PSD	POS	SA	PM		
PSR	1.00	0.20	1.00	0.33	0.33	0.20	0.06	0.02	0.06	0.06	0.05	0.08	0.33	0.05
PST	5.00	1.00	3.00	0.33	1.00	0.33	0.28	0.12	0.19	0.06	0.15	0.13	0.92	0.15
PSD	1.00	0.33	1.00	0.20	0.33	0.33	0.06	0.04	0.06	0.03	0.05	0.13	0.37	0.06
POS	3.00	3.00	5.00	1.00	1.00	0.33	0.17	0.35	0.31	0.17	0.15	0.13	1.28	0.21
SA	3.00	1.00	3.00	1.00	1.00	0.33	0.17	0.12	0.19	0.17	0.15	0.13	0.92	0.15
PM	5.00	3.00	3.00	3.00	3.00	1.00	0.28	0.35	0.19	0.51	0.45	0.39	2.17	0.36
Sum	18.00	8.53	16.00	5.87	6.67	2.53								1.00
Healthcare services criteria for package 2 (Urgent Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PER	PSC	PD	POS	SA	PM	PER	PSC	PD	POS	SA	PM		
PSR	1.00	5.00	0.14	0.14	0.14	1.00	0.04	0.14	0.05	0.05	0.02	0.05	0.36	0.06
PST	0.20	1.00	0.11	0.11	0.11	0.33	0.01	0.03	0.04	0.04	0.01	0.02	0.15	0.02
PSD	7.00	9.00	1.00	1.00	3.00	7.00	0.30	0.25	0.37	0.37	0.40	0.36	2.04	0.34
POS	7.00	9.00	1.00	1.00	3.00	7.00	0.30	0.25	0.37	0.37	0.40	0.36	2.04	0.34
SA	7.00	9.00	0.33	0.33	1.00	3.00	0.30	0.25	0.12	0.12	0.13	0.16	1.08	0.18
PM	1.00	3.00	0.14	0.14	0.33	1.00	0.04	0.08	0.05	0.05	0.04	0.05	0.33	0.05
Sum	23.20	36.00	2.73	2.73	7.59	19.33								1.00
Healthcare services criteria for package 3 (Sick Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PCS	POS	PD		PM		PCS	POS	PD		PM			
PCS	1.00	0.20	0.33		7.00		0.11	0.09	0.14		0.27		0.60	0.15
POS	5.00	1.00	1.00		9.00		0.55	0.43	0.41		0.35		1.73	0.43
PD	3.00	1.00	1.00		9.00		0.33	0.43	0.41		0.35		1.52	0.38
PM	0.14	0.11	0.11		1.00		0.02	0.05	0.05		0.04		0.15	0.04
Sum	5.33	14.00	1.87		5.20									1.00

- VIKOR technique proved that it has the capability to rapidly determine the best hospital based on various attributes.
- After the selection process, the number of health-care services decreased across all hospitals.
- The selection process was not random but was based on the number of health-care services in each hospital. The hospital with the greatest number of services was chosen for patients with risk, urgent and sick levels, whilst considering the weights obtained from the perspective of the doctors for each service.
- Crowding and acute shortage of health-care services, which may occur due to scalability challenges, have been settled and balanced through Tier 4 by managing and controlling the health-care service provision amongst hospitals.

V. VALIDATION AND EVALUATION

This section discusses in detail the proposed framework validation and evaluation. The validation process is shown in Section 5.1, in which the ranking have been objectively validated based on the statistical methods (mean ± standard deviation). The process of validation was crucial for various empirical studies to prove the accuracy and validity of results. Section 5.2 characterizes the evaluation process by means of a checklist benchmarking procedure. Validation and evaluation processes are shown in Figure 15 and are clarified in the following sections.

A. VALIDATION

The selection of hospitals was a complicated procedure due to the availability of health-care services, which varied from one hospital to another. The type and number of services played significant roles in these processes based on accuracy. In terms of validating the results of the hospital selection, it will be performed by using objective validation, which is displayed in Figure 16. Statistical methods were utilized (mean ± standard deviation) to ensure the systematic ranking of hospital selection. The validation meant for hospital

TABLE 23. AHP measurement process for the weight preferences of the criteria (healthcare services) for the three packages (third expert).

Healthcare services criteria for package 1 (Risk Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PSR	PST	PSD	POS	SA	PM	PSR	PST	PSD	POS	SA	PM		
PSR	1.00	0.33	0.33	1.00	5.00	3.00	0.12	0.10	0.10	0.09	0.21	0.28	0.91	0.15
PST	3.00	1.00	1.00	3.00	5.00	3.00	0.35	0.31	0.31	0.26	0.21	0.28	1.73	0.29
PSD	3.00	1.00	1.00	3.00	5.00	3.00	0.35	0.31	0.31	0.26	0.21	0.28	1.73	0.29
POS	1.00	0.33	0.33	1.00	3.00	0.33	0.12	0.10	0.10	0.09	0.13	0.03	0.57	0.10
SA	0.20	0.20	0.20	0.33	1.00	0.20	0.02	0.06	0.06	0.03	0.04	0.02	0.24	0.04
PM	0.33	0.33	0.33	3.00	5.00	1.00	0.04	0.10	0.10	0.26	0.21	0.09	0.82	0.14
Sum	8.53	3.20	3.20	11.33	24.00	10.53								1.00
Healthcare services criteria for package 2 (Urgent Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PER	PSC	PD	POS	SA	PM	PER	PSC	PD	POS	SA	PM		
PSR	1.00	7.00	0.33	1.00	5.00	1.00	0.16	0.35	0.11	0.08	0.25	0.28	1.22	0.20
PST	0.14	1.00	0.20	1.00	1.00	0.20	0.02	0.05	0.07	0.08	0.05	0.06	0.32	0.05
PSD	3.00	5.00	1.00	5.00	5.00	1.00	0.47	0.25	0.34	0.38	0.25	0.28	1.97	0.33
POS	1.00	1.00	0.20	1.00	3.00	0.20	0.16	0.05	0.07	0.08	0.15	0.06	0.56	0.09
SA	0.20	1.00	0.20	0.33	1.00	0.20	0.03	0.05	0.07	0.03	0.05	0.06	0.28	0.05
PM	1.00	5.00	1.00	5.00	5.00	1.00	0.16	0.25	0.34	0.38	0.25	0.28	1.65	0.28
Sum	6.34	20.00	2.93	13.33	20.00	3.60								1.00
Criteria of health-care services for package 3 (Sick Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PCS	POS	PD	PM			PCS	POS	PD	PM				
PCS	1.00	0.33	0.20	0.14			0.06	0.05	0.04	0.08			0.23	0.06
POS	3.00	1.00	0.33	0.33			0.19	0.14	0.07	0.18			0.58	0.15
PD	5.00	3.00	1.00	0.33			0.31	0.41	0.22	0.18			1.13	0.28
PM	7.00	3.00	3.00	1.00			0.44	0.41	0.66	0.55			2.06	0.52
Sum	16.00	7.33	4.53	1.81										1.00

ranking results for patients at risk, urgent and sick levels were obtained by dividing each ranking to three equal groups. Each group showed 4 hospitals. Mean ± standard deviation was calculated for each group in each rank (as in the study of Kalid *et al.* [13]) to ensure that the hospital ranking for each patient undergoes systematic ranking. Mean ($\bar{x}$) is the average and is computed as the sum of all observed outcomes from the sample divided by the total number, as presented in Equation (14):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{14}$$

where

x_i = all of the x-values

n = the number of items

Standard deviation (S) quantifies the amount of variation or dispersion of a set of data values, as presented in Equation (15):

$$S = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2} \tag{15}$$

where

N = the number of data points

x_i = *each of the values of the data*

$\bar{x}$ = *the mean of the* x_i

Validation was fulfilled by using two statistically platform-based methods, which confirmed that the first group must reach the lowest value. The way this occurred was by measuring the mean and standard deviation. The first group exhibited the lowest mean and standard deviation, the comparison with the other three groups was considered towards the validation of the result. The mean and standard deviation for the

TABLE 24. AHP measurement process for weight preferences of criteria (healthcare services) for the three packages (fourth expert).

Criteria of health-care services for package 1 (Risk Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PSR	PST	PSD	POS	SA	PM	PSR	PST	PSD	POS	SA	PM		
PSR	1.00	0.20	3.00	0.20	3.00	1.00	0.08	0.07	0.19	0.07	0.17	0.06	0.64	0.11
PST	5.00	1.00	3.00	1.00	5.00	7.00	0.39	0.35	0.19	0.37	0.29	0.39	1.98	0.33
PSD	0.33	0.33	1.00	0.14	1.00	1.00	0.03	0.12	0.06	0.05	0.06	0.06	0.37	0.06
POS	5.00	1.00	7.00	1.00	7.00	5.00	0.39	0.35	0.44	0.37	0.40	0.28	2.23	0.37
SA	0.33	0.20	1.00	0.14	1.00	3.00	0.03	0.07	0.06	0.05	0.06	0.17	0.44	0.07
PM	1.00	0.14	1.00	0.20	0.33	1.00	0.08	0.05	0.06	0.07	0.02	0.06	0.34	0.06
Sum	12.67	2.88	16.00	2.69	17.33	18.00								1.00
Criteria of health-care services for package 2 (Urgent Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PER	PSC	PD	POS	SA	PM	PER	PSC	PD	POS	SA	PM		
PSR	1.00	3.00	1.00	3.00	5.00	1.00	0.26	0.14	0.28	0.16	0.21	0.30	1.34	0.22
PST	0.33	1.00	0.14	1.00	3.00	0.11	0.09	0.05	0.04	0.05	0.13	0.03	0.38	0.06
PSD	1.00	7.00	1.00	7.00	3.00	1.00	0.26	0.33	0.28	0.36	0.13	0.30	1.65	0.27
POS	0.33	1.00	0.14	1.00	3.00	0.14	0.09	0.05	0.04	0.05	0.13	0.04	0.39	0.07
SA	0.20	0.33	0.33	0.33	1.00	0.11	0.05	0.02	0.09	0.02	0.04	0.03	0.25	0.04
PM	1.00	9.00	1.00	7.00	9.00	1.00	0.26	0.42	0.28	0.36	0.38	0.30	1.99	0.33
Sum	3.87	21.33	3.62	19.33	24.00	3.37								1.00
Criteria of health-care services for package 3 (Sick Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PCS	POS	PD		PM		PCS	POS	PD		PM			
PCS	1.00	1.00	3.00		5.00		0.39	0.30	0.58		0.36		1.63	0.41
POS	1.00	1.00	1.00		3.00		0.39	0.30	0.19		0.21		1.10	0.28
PD	0.33	1.00	1.00		5.00		0.13	0.30	0.19		0.36		0.98	0.25
PM	0.20	0.33	0.20		1.00		0.08	0.10	0.04		0.07		0.29	0.07
Sum	2.53	3.33	5.20		14.00									1.00

results of the second group must be higher than or equal to those of the first group, and lowest or equal to the third group. Finally, the results for the means and standard deviation for the third group must be higher compared with those of the first and second groups or equal to the second group. Based on the systematic ranking results, the first group must be statistically proven to be the lowest group amongst other groups.

1) VALIDATION FOR HOSPITALS RANKING RESULTS FOR RISK PATIENTS'

In this section, the results of the statistical analysis for the three groups of the selected hospitals for 20 patients with risk level are presented in Table 16.

In Table 16, the means and standard deviations of the scores of the groups per patient were compared. The comparison indicated that the first group scored the best group in all ranking results for all 20 patients. For the second group, the comparison indicated that its second-best group in the ranking results for the 1st, 2nd, 3th, 4th, 5th, 6th, 7th, 9th, 10th, 11th, 12th, 13th, 14th, 15th, 16th, 19th and 20th patient, whereas the third group was the worst among the other groups in the ranking results for those patients. However, the third group was the second-best group in the ranking results for the 8th patient, whereas the second group gained worst among the other groups in the ranking results for this patient. Finally, the scores of the second and third groups were nearly identical in the ranking results for 17th and 18th patient. In conclusion, the first group was the best among the three groups; thus, the statistical results indicated that the hospitals ranking results for patients with risk level undergone a systematic ranking.

TABLE 25. AHP measurement process for weight preferences of the criteria (healthcare services) for the three packages (fifth expert).

Criteria of health-care services for package 1 (Risk Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PSR	PST	PSD	POS	SA	PM	PSR	PST	PSD	POS	SA	PM		
PSR	1.00	3.00	5.00	9.00	1.00	7.00	0.36	0.54	0.48	0.25	0.23	0.27	2.13	0.35
PST	0.33	1.00	3.00	9.00	1.00	9.00	0.12	0.18	0.29	0.25	0.23	0.35	1.41	0.24
PSD	0.20	0.33	1.00	9.00	1.00	3.00	0.07	0.06	0.10	0.25	0.23	0.12	0.82	0.14
POS	0.11	0.11	0.11	1.00	0.14	1.00	0.04	0.02	0.01	0.03	0.03	0.04	0.17	0.03
SA	1.00	1.00	1.00	7.00	1.00	5.00	0.36	0.18	0.10	0.19	0.23	0.19	1.25	0.21
PM	0.14	0.11	0.33	1.00	0.20	1.00	0.05	0.02	0.03	0.03	0.05	0.04	0.22	0.04
Sum	2.79	5.56	10.44	36.00	4.34	26.00								1.00
Criteria of health-care services for package 2 (Urgent Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PER	PSC	PD	POS	SA	PM	PER	PSC	PD	POS	SA	PM		
PSR	1.00	5.00	3.00	5.00	1.00	3.00	0.33	0.28	0.35	0.38	0.31	0.30	1.94	0.32
PST	0.20	1.00	0.33	0.33	0.20	1.00	0.07	0.06	0.04	0.03	0.06	0.10	0.35	0.06
PSD	0.33	3.00	1.00	3.00	0.33	1.00	0.11	0.17	0.12	0.23	0.10	0.10	0.82	0.14
POS	0.20	3.00	0.33	1.00	0.33	1.00	0.07	0.17	0.04	0.08	0.10	0.10	0.55	0.09
SA	1.00	5.00	3.00	3.00	1.00	3.00	0.33	0.28	0.35	0.23	0.31	0.30	1.79	0.30
PM	0.33	1.00	1.00	1.00	0.33	1.00	0.11	0.06	0.12	0.08	0.10	0.10	0.56	0.09
Sum	3.07	18.00	8.67	13.33	3.20	10.00								1.00
Criteria of health-care services for package 3 (Sick Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PCS	POS	PD		PM		PCS	POS	PD		PM			
PCS	1.00	0.33	0.14		0.33		0.07	0.05	0.08		0.07		0.27	0.07
POS	3.00	1.00	0.33		0.33		0.21	0.14	0.18		0.07		0.61	0.15
PD	7.00	3.00	1.00		3.00		0.50	0.41	0.55		0.64		2.10	0.53
PM	3.00	3.00	0.33		1.00		0.21	0.41	0.18		0.21		1.02	0.26
Sum	14.00	7.33	1.81		4.67									1.00

2) VALIDATION FOR HOSPITALS RANKING RESULTS FOR URGENT PATIENTS'

In this section, the results of the statistical analysis for the three groups of the selected hospitals for 20 patients with risk level presented in Table 17.

In Table 17, the means and standard deviations of the scores of the groups per patient were compared. The comparison indicated that the first group scored the best group in all ranking results for all 20 patients. For the second group, the comparison indicated that its second-best group in the ranking results for the 1st, 2nd, 3th, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th and 19th patient, whereas the third group gained the worst among the other groups in the ranking results for those patients. Finally, the scores of the second and third groups were nearly identical in the ranking results for 15th, 16th, 17th, 18th and 20th patient. In conclusion, the first group was the best among the three groups; thus, the statistical results indicated that the hospitals ranking results for patients with risk level undergone a systematic ranking.

3) VALIDATION FOR HOSPITALS RANKING RESULTS FOR SICK PATIENTS'

In this section, the results of the statistical analysis for the three groups of the selected hospitals for 20 patients with sick level are presented in Table 18.

In Table 18, the means and standard deviations of the scores of the groups per patient were compared. The comparison indicated that the first group scored the best group in all ranking results for all patients except the 6th patient, which was nearly identical with the second group. For the second group, the comparison indicated that it is the second-best group in all ranking results for all patients, whereas the third

TABLE 26. AHP measurement process for weight preferences of criteria (healthcare services) for the three packages (sixth expert).

Criteria of health-care services for package 1 (Risk Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PSR	PST	PSD	POS	SA	PM	PSR	PST	PSD	POS	SA	PM		
PSR	1.00	0.33	0.33	1.00	0.20	0.20	0.06	0.07	0.07	0.17	0.02	0.04	0.43	0.07
PST	3.00	1.00	1.00	1.00	3.00	1.00	0.17	0.21	0.21	0.17	0.33	0.19	1.28	0.21
PSD	3.00	1.00	1.00	1.00	3.00	1.00	0.17	0.21	0.21	0.17	0.33	0.19	1.28	0.21
POS	1.00	1.00	1.00	1.00	1.00	1.00	0.06	0.21	0.21	0.17	0.11	0.19	0.95	0.16
SA	5.00	0.33	0.33	1.00	1.00	1.00	0.28	0.07	0.07	0.17	0.11	0.19	0.89	0.15
PM	5.00	1.00	1.00	1.00	1.00	1.00	0.28	0.21	0.21	0.17	0.11	0.19	1.17	0.20
Sum	18.00	4.67	4.67	6.00	9.20	5.20								1.00
Criteria of health-care services for package 2 (Urgent Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PER	PSC	PD	POS	SA	PM	PER	PSC	PD	POS	SA	PM		
PSR	1.00	0.33	0.33	1.00	1.00	1.00	0.10	0.06	0.13	0.06	0.08	0.15	0.58	0.10
PST	3.00	1.00	0.33	3.00	3.00	1.00	0.30	0.17	0.13	0.19	0.23	0.15	1.16	0.19
PSD	3.00	3.00	1.00	3.00	5.00	3.00	0.30	0.50	0.39	0.19	0.38	0.46	2.22	0.37
POS	1.00	0.33	0.33	1.00	0.33	0.20	0.10	0.06	0.13	0.06	0.03	0.03	0.41	0.07
SA	1.00	0.33	0.20	3.00	1.00	0.33	0.10	0.06	0.08	0.19	0.08	0.05	0.55	0.09
PM	1.00	1.00	0.33	5.00	3.00	1.00	0.10	0.17	0.13	0.31	0.23	0.15	1.09	0.18
Sum	10.00	6.00	2.53	16.00	13.33	6.53								1.00
Criteria of health-care services for package 3 (Sick Level)														
	Original DM						Normalised DM						Aggregation	Weight
Criteria	PCS	POS	PD	PM			PCS	POS	PD	PM				
PCS	1.00	3.00	9.00	3.00			0.56	0.67	0.45	0.41			2.09	0.52
POS	0.33	1.00	7.00	3.00			0.19	0.22	0.35	0.41			1.17	0.29
PD	0.11	0.14	1.00	0.33			0.06	0.03	0.05	0.05			0.19	0.05
PM	0.33	0.33	3.00	1.00			0.19	0.07	0.15	0.14			0.55	0.14
Sum	1.78	4.48	20.00	7.33										1.00

group was the worst among the other groups in the ranking results. In conclusion, the first group was the best among the three groups; thus, the statistical results indicated that the hospitals ranking results for patients with sick level undergone a systematic ranking.

B. EVALUATION PROCESS

The most relevant existing work related to hospital selection was found in [25]. In this section, the performance of the proposed framework are evaluated and compared with the relevant study. The evaluation process requires the provision of scenarios and checklist benchmarking. These parameters must contain points of comparison for the evaluation of the health recommender framework for hospital selection according to various characteristics that are important for the telemedicine environment, as in [13]. Each scenario reflects issues that must be defined and addressed in hospital selection frameworks. Furthermore, these issues are considered points of comparison for the proposed framework with the most relevant existing work in checklist with benchmarking. Checklist benchmarking provides a useful way to measure how effective the proposed work is compared with other methods. The comparisons are done based on whether the compared works covered the issues addressed in the comparison scenario. Three scenarios are illustrated as follows to demonstrate the comparison points in the checklist benchmarking.

In the first scenario, the procedure to compare between the proposed and benchmark work is based on the case studies and related comparison points. Ideally, in medical research, case studies must detail a particular medical case (disease), describing the background of the patient and specific healthcare services as treatment. The case studies must discuss the

TABLE 27. Hospital ranking results for 16 patients with risk level (package 1).

5th Patient			6th Patient		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 2	0	1	Hospital 4	0.034370	1
Hospital 4	0.073935	2	Hospital 8	0.073151	2
Hospital 8	0.109312	3	Hospital 6	0.092818	3
Hospital 6	0.127313	4	Hospital 5	0.126285	4
Hospital 5	0.168643	5	Hospital 2	0.308785	5
Hospital 3	0.39795	6	Hospital 3	0.376816	6
Hospital 9	0.40782	7	Hospital 1	0.377116	7
Hospital 1	0.415814	8	Hospital 9	0.393184	8
Hospital 7	0.559283	9	Hospital 7	0.556925	9
Hospital 12	0.589302	10	Hospital 12	0.570505	10
Hospital 10	0.693207	11	Hospital 10	0.693207	11
Hospital 11	0.998043	12	Hospital 11	0.997862	12
7th Patient			**8th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 8	0.073151	1	Hospital 6	0.092818	1
Hospital 6	0.092818	2	Hospital 5	0.126285	2
Hospital 5	0.126285	3	Hospital 4	0.228506	3
Hospital 4	0.228506	4	Hospital 2	0.308785	4
Hospital 2	0.308785	5	Hospital 3	0.376816	5
Hospital 3	0.376816	6	Hospital 1	0.377116	6
Hospital 1	0.377116	7	Hospital 9	0.393184	7
Hospital 9	0.393184	8	Hospital 8	0.428215	8
Hospital 7	0.556925	9	Hospital 7	0.556925	9
Hospital 12	0.570505	10	Hospital 12	0.570505	10
Hospital 10	0.693207	11	Hospital 10	0.693207	11
Hospital 11	0.997862	12	Hospital 11	0.997862	12
9th Patient			**10th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 5	0.099300	1	Hospital 4	0.147091	1
Hospital 4	0.176855	2	Hospital 2	0.241162	2
Hospital 2	0.277072	3	Hospital 5	0.288608	3
Hospital 3	0.336030	4	Hospital 3	0.311967	4
Hospital 9	0.345631	5	Hospital 1	0.321911	5
Hospital 1	0.363765	6	Hospital 9	0.328702	6
Hospital 8	0.392749	7	Hospital 8	0.367266	7
Hospital 6	0.399941	8	Hospital 6	0.374413	8
Hospital 7	0.506175	9	Hospital 7	0.501766	9
Hospital 12	0.540845	10	Hospital 12	0.518009	10
Hospital 10	0.643485	11	Hospital 10	0.640594	11
Hospital 11	1.000000	12	Hospital 11	1.000000	12
11th Patient			**12th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 2	0.216700	1	Hospital 8	0.180717	1

TABLE 27. *(Continued.)* **Hospital ranking results for 16 patients with risk level (package 1).**

Hospital 5	0.264145	2	Hospital 6	0.187864	2
Hospital 3	0.282169	3	Hospital 5	0.242045	3
Hospital 9	0.294092	4	Hospital 1	0.319993	4
Hospital 1	0.308667	5	Hospital 9	0.323689	5
Hospital 4	0.311288	6	Hospital 3	0.354134	6
Hospital 8	0.342804	7	Hospital 4	0.356378	7
Hospital 6	0.349951	8	Hospital 2	0.370826	8
Hospital 7	0.468657	9	Hospital 10	0.454045	9
Hospital 12	0.501454	10	Hospital 7	0.512465	10
Hospital 10	0.616132	11	Hospital 12	0.515611	11
Hospital 11	1.000000	12	Hospital 11	1.000000	12
13th Patient			**14th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 6	0.187864	1	Hospital 5	0.234814	1
Hospital 5	0.242045	2	Hospital 9	0.311291	2
Hospital 1	0.319993	3	Hospital 1	0.319993	3
Hospital 9	0.323689	4	Hospital 4	0.334132	4
Hospital 3	0.354134	5	Hospital 3	0.342676	5
Hospital 4	0.356378	6	Hospital 2	0.356386	6
Hospital 2	0.370826	7	Hospital 10	0.432859	7
Hospital 10	0.454045	8	Hospital 6	0.477083	8
Hospital 8	0.496931	9	Hospital 8	0.479098	9
Hospital 7	0.512465	10	Hospital 7	0.495536	10
Hospital 12	0.515611	11	Hospital 12	0.504652	11
Hospital 11	1.000000	12	Hospital 11	1.000000	12
15th Patient			**16th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 9	0.311655	1	Hospital 4	0.275102	1
Hospital 1	0.319993	2	Hospital 3	0.309216	2
Hospital 4	0.333491	3	Hospital 1	0.314175	3
Hospital 3	0.342570	4	Hospital 2	0.334341	4
Hospital 2	0.356169	5	Hospital 5	0.401188	5
Hospital 5	0.418365	6	Hospital 10	0.423072	6
Hospital 10	0.432591	7	Hospital 9	0.424401	7
Hospital 6	0.476069	8	Hospital 8	0.458901	8
Hospital 8	0.478752	9	Hospital 6	0.465822	9
Hospital 7	0.495571	10	Hospital 7	0.467347	10
Hospital 12	0.503471	11	Hospital 12	0.486555	11
Hospital 11	1.000000	12	Hospital 11	1.000000	12
17th Patient			**18th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 3	0.306105	1	Hospital 1	0.327261	1
Hospital 1	0.312793	2	Hospital 2	0.389046	2
Hospital 2	0.331886	3	Hospital 10	0.435112	3
Hospital 5	0.398769	4	Hospital 5	0.455553	4

TABLE 27. *(Continued.)* **Hospital ranking results for 16 patients with risk level (package 1).**

Hospital 10	0.419379	5	Hospital 9	0.473013	5
Hospital 9	0.420927	6	Hospital 7	0.484328	6
Hospital 4	0.449182	7	Hospital 4	0.485537	7
Hospital 8	0.456446	8	Hospital 3	0.494861	8
Hospital 6	0.463367	9	Hospital 12	0.502912	9
Hospital 7	0.463891	10	Hospital 8	0.513606	10
Hospital 12	0.484827	11	Hospital 6	0.520527	11
Hospital 11	1.000000	12	Hospital 11	1.000000	12
19th Patient			**20th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 2	0.266552	1	Hospital 5	0.350380	1
Hospital 5	0.350380	2	Hospital 1	0.370445	2
Hospital 1	0.370445	3	Hospital 2	0.382330	3
Hospital 12	0.388228	4	Hospital 12	0.388228	4
Hospital 10	0.411507	5	Hospital 10	0.411507	5
Hospital 3	0.441582	6	Hospital 3	0.441582	6
Hospital 8	0.445025	7	Hospital 8	0.445025	7
Hospital 6	0.446747	8	Hospital 6	0.446747	8
Hospital 9	0.451839	9	Hospital 9	0.451839	9
Hospital 7	0.458781	10	Hospital 7	0.458781	10
Hospital 4	0.469084	11	Hospital 4	0.469084	11
Hospital 11	1.000000	12	Hospital 11	1.000000	12

investigations performed to determine a diagnosis or differentiate between possible diagnoses [13]. In summary, case studies must be an informative and useful part of every medical research. For each disease, real-time remote monitoring patients who live far from hospitals is an important and essential factor [4], [70]. In monitoring patients, medical sensors measure the vital signs and triage of the patient and prioritize them [71]. Measuring vital signs are useful in monitoring and plays a key role in health-care monitoring [16]. In addition, text data, that is, complaints, can be used as another medical source to improve the accuracy of diagnosis [8].

In the second scenario, the compression has been done based on the hospital selection procedure and related comparison points. The availability of health-care services in hospitals dynamically changes and can decrease at any time because of scalability concerns [38]. Thus, monitoring hospitals and their availability is important. Such selection must depend on health-care availability [13]. Therefore, hospital selection and health-care service management are important in sharing medical resources and avoiding acute shortage of health-care services, which are most useful in cases of increased demand for these services [38]. The selection process involves simultaneously considering the number of health-care services by various attributes, which creates varied data; hence, different weights are generally given for the attributes [38]. Thus, the process requires in multi-attribute decision making [13].

In the third scenario, compression has been done based on the validation and evaluation of both works. Validation is the process of checking whether or not a proposed work is valid and appropriate for its purpose, if it meets all constraints and if it will perform as expected [72]. Evaluation is the process of comparing and computing the performance and accuracy of the proposed work [73], [86], [107], [108].

After the comparison scenarios are described, several comparison points were recognized and highlighted for each scenario it must consider in the hospital selection process. The comparison points were extracted, and Figure 17 describes the connections between each scenario and the related points.

These issues are defined as points of comparison in the checklist benchmarking. The descriptions of the checklist comparison points are presented as follows:

- **Case study:** Targeting a designated disease as a case study to apply to hospital selection is helpful in identifying and recognizing the vital signs and complaint that accurately indicate the triage and prioritization for patients [8].
- **Remote environment:** This point presents whether the statuses of the patients, which are necessary in the hospital selection, are monitored in the remote environment

TABLE 28. Hospital ranking results for 16 patients with urgent level (package 2).

5th Patient			6th Patient		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 11	0.069751	1	Hospital 1	0.080343	1
Hospital 1	0.105917	2	Hospital 10	0.115643	2
Hospital 10	0.143008	3	Hospital 6	0.149162	3
Hospital 6	0.173855	4	Hospital 11	0.150516	4
Hospital 5	0.205338	5	Hospital 5	0.163463	5
Hospital 9	0.518567	6	Hospital 8	0.493533	6
Hospital 8	0.522372	7	Hospital 9	0.499167	7
Hospital 3	0.571838	8	Hospital 3	0.548360	8
Hospital 7	0.591448	9	Hospital 7	0.576895	9
Hospital 2	0.686119	10	Hospital 2	0.670599	10
Hospital 12	0.766805	11	Hospital 12	0.767751	11
Hospital 4	1.000000	12	Hospital 4	1.000000	12
7th Patient			**8th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 6	0.138798	1	Hospital 10	0.115643	1
Hospital 10	0.141393	2	Hospital 1	0.143001	2
Hospital 1	0.176498	3	Hospital 11	0.162900	3
Hospital 11	0.194813	4	Hospital 5	0.171221	4
Hospital 5	0.203135	5	Hospital 6	0.234841	5
Hospital 9	0.518448	6	Hospital 8	0.494341	6
Hospital 8	0.522266	7	Hospital 9	0.496176	7
Hospital 3	0.572089	8	Hospital 3	0.544165	8
Hospital 7	0.592464	9	Hospital 7	0.573671	9
Hospital 2	0.684984	10	Hospital 2	0.677006	10
Hospital 12	0.765336	11	Hospital 12	0.765336	11
Hospital 4	1.000000	12	Hospital 4	1.000000	12
9th Patient			**10th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 11	0.091362	1	Hospital 5	0.062966	1
Hospital 1	0.093467	2	Hospital 1	0.082643	2
Hospital 5	0.099584	3	Hospital 10	0.132057	3
Hospital 10	0.133636	4	Hospital 6	0.169038	4
Hospital 6	0.175262	5	Hospital 11	0.202099	5
Hospital 8	0.466422	6	Hospital 8	0.460701	6
Hospital 9	0.470231	7	Hospital 9	0.472491	7
Hospital 3	0.520319	8	Hospital 3	0.528255	8
Hospital 7	0.551755	9	Hospital 7	0.556892	9
Hospital 2	0.644424	10	Hospital 2	0.617979	10
Hospital 12	0.738692	11	Hospital 12	0.736273	11
Hospital 4	1.000000	12	Hospital 4	1.000000	12
11th Patient			**12th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 1	0.072471	1	Hospital 10	0.124416	1

TABLE 28. ***(Continued.)*** **Hospital ranking results for 16 patients with urgent level (package 2).**

Hospital 10	0.124416	2	Hospital 1	0.125423	2
Hospital 6	0.158865	3	Hospital 6	0.159854	3
Hospital 11	0.193013	4	Hospital 11	0.189214	4
Hospital 5	0.215331	5	Hospital 5	0.214782	5
Hospital 8	0.451836	6	Hospital 8	0.449580	6
Hospital 9	0.465710	7	Hospital 9	0.473794	7
Hospital 3	0.519324	8	Hospital 3	0.515953	8
Hospital 7	0.551185	9	Hospital 7	0.551693	9
Hospital 2	0.615383	10	Hospital 2	0.613784	10
Hospital 12	0.736273	11	Hospital 12	0.745522	11
Hospital 4	1.000000	12	Hospital 4	1.000000	12
13th Patient			**14th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 1	0.039566	1	Hospital 11	0.084194	1
Hospital 6	0.085659	2	Hospital 6	0.087369	2
Hospital 11	0.086916	3	Hospital 1	0.102724	3
Hospital 5	0.114974	4	Hospital 5	0.115254	4
Hospital 10	0.134979	5	Hospital 10	0.134979	5
Hospital 8	0.417068	6	Hospital 8	0.415187	6
Hospital 9	0.422936	7	Hospital 9	0.430983	7
Hospital 3	0.496023	8	Hospital 3	0.492914	8
Hospital 7	0.508951	9	Hospital 7	0.509796	9
Hospital 2	0.557163	10	Hospital 2	0.556271	10
Hospital 12	0.703483	11	Hospital 12	0.712836	11
Hospital 4	1.000000	12	Hospital 4	1.000000	12
15th Patient			**16th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 6	0.084994	1	Hospital 1	0.100296	1
Hospital 1	0.100296	2	Hospital 5	0.111961	2
Hospital 5	0.111961	3	Hospital 10	0.133497	3
Hospital 10	0.133497	4	Hospital 6	0.173164	4
Hospital 11	0.263030	5	Hospital 11	0.263030	5
Hospital 8	0.414888	6	Hospital 8	0.414888	6
Hospital 9	0.430852	7	Hospital 9	0.430852	7
Hospital 3	0.490420	8	Hospital 3	0.490420	8
Hospital 7	0.511070	9	Hospital 7	0.511070	9
Hospital 2	0.554369	10	Hospital 2	0.554369	10
Hospital 12	0.710548	11	Hospital 12	0.710548	11
Hospital 4	1.000000	12	Hospital 4	1.000000	12
17th Patient			**18th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 5	0.112188	1	Hospital 10	0.133497	1
Hospital 10	0.133497	2	Hospital 1	0.162486	2
Hospital 1	0.162486	3	Hospital 6	0.173540	3
Hospital 6	0.173540	4	Hospital 11	0.259792	4

TABLE 28. *(Continued.)* Hospital ranking results for 16 patients with urgent level (package 2).

Hospital 11	0.259792	5	Hospital 5	0.294203	5
Hospital 8	0.413308	6	Hospital 8	0.413308	6
Hospital 9	0.437610	7	Hospital 9	0.437610	7
Hospital 3	0.487810	8	Hospital 3	0.487810	8
Hospital 7	0.511783	9	Hospital 7	0.511783	9
Hospital 2	0.553615	10	Hospital 2	0.553615	10
Hospital 12	0.718394	11	Hospital 12	0.718394	11
Hospital 4	1.000000	12	Hospital 4	1.000000	12
19th Patient			**20th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 1	0.109253	1	Hospital 6	0.103238	1
Hospital 6	0.121134	2	Hospital 10	0.130145	2
Hospital 10	0.144245	3	Hospital 1	0.179920	3
Hospital 11	0.218867	4	Hospital 11	0.200197	4
Hospital 5	0.256208	5	Hospital 5	0.239869	5
Hospital 8	0.394381	6	Hospital 8	0.375709	6
Hospital 9	0.415894	7	Hospital 9	0.409642	7
Hospital 7	0.476038	8	Hospital 3	0.461754	8
Hospital 3	0.481594	9	Hospital 7	0.466086	9
Hospital 2	0.507721	10	Hospital 2	0.502275	10
Hospital 12	0.675604	11	Hospital 12	0.683766	11
Hospital 4	1.000000	12	Hospital 4	1.000000	12

or not. Monitoring is important in continuously providing the care of patients in a pervasive environment. In a remote environment, the overwhelming heterogeneous data from patients cause difficulties in the triage process [8].

- **Support vital signs:** Hospital selection must consider the vital signs to identify triaging, prioritization and the treatment process because vital signs are important in evaluating the patient condition [8], [77].
- **Support chief complaints:** This means the chief complaints, which have been considered and used in the triage patient process, in health-care monitoring, non-sensory data are accepted [8].
- **Triage:** An experienced triage system evaluates the status of the patient depending on the severity of their status to select a suitable hospital, notes any changes and determines the emergency level for admission to the ED and for important treatments [74].
- **Prioritization mechanism:** In the process of hospital selection, the prioritization of patients is important because it ensures that care is given appropriately [74]. A major goal of patient prioritization is to identify patients who can safely wait from those who cannot [13].
- **Health-care services provision:** Health-care services can be supplied from a proper hospital as rapidly and accurately as possible to patients with the most urgent emergency cases. Different services can be supplied to patients with different types of diseases, and amongst them are patients with chronic diseases [38].
- **Targeted tier:** The important factor is to identify the tier in the hospital selection process. Remote health-care monitoring and telemedicine architecture are structured in three tiers, namely, Tiers 1, 2 and 3 as sensors, base station and medical center, respectively [8], [12].
- **Support scalability:** This point shows whether scalability has been accommodated and handled. Scalability is the increase in the number of patients. Scalability is of considerable concern in remote health-care monitoring that leads to manage the health-care services load amongst hospitals and provide services from distributed hospitals [13].
- **Health-care services weighting:** This point shows the technique used to weight the importance of health-care services. The medical center that aims to select hospital may provide more weight to the service rather than to others in the selection process. Judgements and preferences of experts are important as they are used to extract the weights of the health-care services [38].
- **Handling data variation:** This point is associated with handling overwhelming data from the multiple attributes

that generate data variation. Supporting data variation is important because this variation may cause difficulty in prioritizing numerous hospitals [38].

- **Multi-criteria ranking:** This point displays whether the study addressed the multi-criteria in the hospital selection. This selection is a complicated decision-making problem and the decision is made based on a set of attributes [75].
- **Hospital selection procedure:** This term means choosing the appropriate hospital after the evaluation of their availability to obtain the treatment and suitable health-care services for patients [13].
- **Health-care service balancing amongst hospitals:** Health-care services in hospitals are affected by different issues, such as aging population and disaster. Therefore, the availability of services can decrease at any time in accordance with the demand of patients [13], [17], [18], [25]. Health-care systems must be connected with several hospitals to boost availability of health-care service, share medical resources and evade acute shortage of health-care services. These factors are done by managing and balancing these services in real-time.
- **Validation:** This point demonstrates whether a validation has been provided or not and whether the results are validated or not.
- **Evaluation:** This point demonstrates whether an evaluation has been provided or not and whether the proposed work is evaluated or not.

After identifying and defining the checklist comparison points, the comparison procedure is presented. In those scenarios, 7, 7 and 2 out of 16 issues were highlighted for the first, second and last scenarios, respectively. Each comparison point within each scenario gained 6.25% from the overall performance (100 divided by 16 issues). The checklist comparison between the proposed and the benchmark study are presented in Table 19 as follows:

Table 19 presents the checklist of benchmarking points, which have been deliberated between the benchmark and the proposed framework. For the first scenario, four issues include the following: case study, support vital signs, triage and health-care services provision, which are addressed by both frameworks. Only remote environment and support chief complaints were addressed by the proposed framework, whereas the benchmarking framework addressed only the prioritization mechanism. Therefore, out of the seven major comparison points associated with the first scenario, 2 issues have not been considered by the benchmark framework, whereas only one issue has not been considered by the framework. Therefore, in this scenario, the benchmark framework gained 31.25% out of 43.75% (6.25% for each issue). By contrast, the proposed framework addressed six out of seven issues covered in this scenario and acquired 37.5% out of 43.75% (6.25% for each issue).

For the second scenario, both frameworks addressed only the targeted tier, whereas supporting scalability, weighting health-care services, data variation, multi-criteria ranking, procedure of hospital selection and balancing health-care services amongst hospitals, which are addressed by the proposed framework. Therefore, the benchmark framework gained only 6.25% out of 43.75% in this scenario. All issues in this scenario were addressed by the proposed framework, and gained 43.75% (6.25% for each issue). As for the proposed framework in the third scenario, validation and evaluation were considered, whereas processes of validation and evaluation have not been addressed by the benchmark framework. In this scenario, the benchmark framework did not cover all the third scenario. All the issues in this scenario were addressed by the proposed framework and have acquired 12.5% (6.25% for each issue). The differences in frameworks were based on the scenarios and related comparison points (Table 20).

Table 20 shows that the proposed framework has covered 15 out of 16 issues in all scenarios (with a total performance of 93.75%), whereas the benchmark framework has covered six out of 16 issues in all scenarios (with a total performance of 37.5%). The advantages and strengths of the issues that have been considered by the proposed framework and ignored by the benchmark are as follows.

- **Remote environment:** Monitoring the status of patients and providing services in various environments and conditions are important. Remote monitoring transmits in real-time the vital data of the patients to the medical center through advanced technology to select a suitable hospital for each patient at a distance [76].
- **Support chief complaints:** Triage is performed based on the chief complaints and physiological status of the patients. Thus, patient complaints are a valuable resource for monitoring and improving triage process. For triage in the hospital selection process over remote health-care monitoring, non-sensory data are necessary [8].
- **Support scalability:** Health-care services scalability is critical in telemedicine because health-care services in hospitals are affected by disasters and population aging. Thus, the availability of services can decrease at any time [8].
- **Health-care service weighting:** A service weighting technique extracts the importance of the availability of each service against others in the hospital selection process, involving the judgements of experts to specify a fixed weight for each one [27].
- **Handling data variation:** Handling data variation is important as it facilitates the selection decision with overwhelming data [38].
- **Multi-criteria ranking:** Multi-criteria ranking is crucial for hospital selection as it is a complex decision-making problem based on multiple attributes [27].
- **Hospital selection procedure:** Proper hospital cannot be chosen based on the number of patients in each hospital. For instance, if hospital (A) shows nine patients requiring an emergency room service, and hospital (B) shows eight patients requiring the same service,

TABLE 29. Hospital ranking results for 16 patients with sick level (package 3).

5th Patient			6th Patient		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 11	0.019229	1	Hospital 8	0.047125	1
Hospital 8	0.047125	2	Hospital 2	0.068308	2
Hospital 2	0.068308	3	Hospital 7	0.126876	3
Hospital 7	0.126876	4	Hospital 4	0.215208	4
Hospital 4	0.215208	5	Hospital 9	0.306093	5
Hospital 9	0.306093	6	Hospital 6	0.500000	6
Hospital 6	0.500000	7	Hospital 12	0.500066	7
Hospital 12	0.500066	8	Hospital 1	0.593730	8
Hospital 1	0.593730	9	Hospital 10	0.681064	9
Hospital 10	0.681064	10	Hospital 5	0.689217	10
Hospital 5	0.689217	11	Hospital 11	0.814676	11
Hospital 3	1.000000	12	Hospital 3	1.000000	12
7th Patient			**8th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 2	0.011236	1	Hospital 7	0.073181	1
Hospital 7	0.073181	2	Hospital 4	0.124186	2
Hospital 4	0.124186	3	Hospital 9	0.227283	3
Hospital 9	0.227283	4	Hospital 8	0.373423	4
Hospital 8	0.373423	5	Hospital 6	0.615556	5
Hospital 6	0.615556	6	Hospital 12	0.615606	6
Hospital 12	0.615606	7	Hospital 1	0.687623	7
Hospital 1	0.687623	8	Hospital 10	0.754774	8
Hospital 10	0.754774	9	Hospital 5	0.761043	9
Hospital 5	0.761043	10	Hospital 11	0.857506	10
Hospital 11	0.857506	11	Hospital 2	0.895243	11
Hospital 3	1.000000	12	Hospital 3	1.000000	12
9th Patient			**10th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 4	0.052304	1	Hospital 9	0.000000	1
Hospital 9	0.143726	2	Hospital 8	0.178363	2
Hospital 8	0.318045	3	Hospital 12	0.544758	3
Hospital 12	0.545597	4	Hospital 6	0.545082	4
Hospital 6	0.545927	5	Hospital 1	0.625523	5
Hospital 1	0.627875	6	Hospital 10	0.701747	6
Hospital 10	0.705527	7	Hospital 5	0.716741	7
Hospital 5	0.720803	8	Hospital 11	0.829159	8
Hospital 11	0.835326	9	Hospital 7	0.850951	9
Hospital 7	0.857527	10	Hospital 2	0.869838	10
Hospital 2	0.876768	11	Hospital 3	0.990803	11
Hospital 3	1.000000	12	Hospital 4	1.000000	12

TABLE 29. ***(Continued.)*** **Hospital ranking results for 16 patients with sick level (package 3).**

11th Patient			12th Patient		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 8	0.111560	1	Hospital 6	0.000000	1
Hospital 12	0.500000	2	Hospital 12	0.065870	2
Hospital 6	0.503983	3	Hospital 1	0.158437	3
Hospital 1	0.599362	4	Hospital 5	0.241812	4
Hospital 10	0.682786	5	Hospital 10	0.290883	5
Hospital 5	0.686881	6	Hospital 11	0.393363	6
Hospital 11	0.812586	7	Hospital 2	0.418689	7
Hospital 7	0.849625	8	Hospital 7	0.441523	8
Hospital 2	0.861693	9	Hospital 3	0.484712	9
Hospital 9	0.937159	10	Hospital 4	0.490016	10
Hospital 3	0.989716	11	Hospital 9	0.538214	11
Hospital 4	1.000000	12	Hospital 8	1.000000	12
13th Patient			**14th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 12	0.000000	1	Hospital 1	0.000000	1
Hospital 1	0.100191	2	Hospital 5	0.103439	2
Hospital 5	0.190025	3	Hospital 10	0.161125	3
Hospital 10	0.245772	4	Hospital 11	0.278779	4
Hospital 11	0.355821	5	Hospital 2	0.305403	5
Hospital 2	0.381295	6	Hospital 7	0.348158	6
Hospital 7	0.407593	7	Hospital 3	0.374811	7
Hospital 3	0.447704	8	Hospital 4	0.380387	8
Hospital 4	0.453039	9	Hospital 9	0.443137	9
Hospital 9	0.509918	10	Hospital 12	0.717144	10
Hospital 6	0.751390	11	Hospital 6	0.719303	11
Hospital 8	1.000000	12	Hospital 8	1.000000	12
15th Patient			**16th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 5	0.009762	1	Hospital 10	0.000000	1
Hospital 10	0.083411	2	Hospital 11	0.144465	2
Hospital 11	0.217646	3	Hospital 2	0.173253	3
Hospital 2	0.244132	4	Hospital 7	0.228189	4
Hospital 7	0.285302	5	Hospital 3	0.253169	5
Hospital 3	0.322890	6	Hospital 4	0.259418	6
Hospital 4	0.328878	7	Hospital 9	0.353151	7
Hospital 9	0.400459	8	Hospital 6	0.686741	8
Hospital 12	0.689900	9	Hospital 12	0.686780	9
Hospital 6	0.690111	10	Hospital 1	0.741719	10
Hospital 1	0.742484	11	Hospital 5	0.797728	11
Hospital 8	1.000000	12	Hospital 8	1.000000	12
17th Patient			**18th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 11	0.000000	1	Hospital 2	0.010677	1
Hospital 2	0.034139	2	Hospital 7	0.073181	2

TABLE 29. *(Continued.)* **Hospital ranking results for 16 patients with sick level (package 3).**

Hospital 7	0.097155	3	Hospital 3	0.110220	3
Hospital 3	0.128909	4	Hospital 4	0.118005	4
Hospital 4	0.136321	5	Hospital 9	0.223124	5
Hospital 9	0.243291	6	Hospital 6	0.609804	6
Hospital 6	0.628513	7	Hospital 12	0.609852	7
Hospital 12	0.628559	8	Hospital 1	0.678285	8
Hospital 1	0.693710	9	Hospital 10	0.742093	9
Hospital 10	0.754459	10	Hospital 5	0.748050	10
Hospital 5	0.760131	11	Hospital 11	0.839713	11
Hospital 8	1.000000	12	Hospital 8	1.000000	12
19th Patient			**20th Patient**		
Hospital Ranking	**Q**	**Order**	**Hospital Ranking**	**Q**	**Order**
Hospital 7	0.073181	1	Hospital 3	0.040443	1
Hospital 3	0.110220	2	Hospital 4	0.049268	2
Hospital 4	0.118005	3	Hospital 9	0.143726	3
Hospital 9	0.223124	4	Hospital 12	0.542950	4
Hospital 6	0.609804	5	Hospital 6	0.543261	5
Hospital 12	0.609852	6	Hospital 1	0.620453	6
Hospital 1	0.678285	7	Hospital 10	0.693599	7
Hospital 10	0.742093	8	Hospital 5	0.707987	8
Hospital 5	0.748050	9	Hospital 11	0.815864	9
Hospital 11	0.839713	10	Hospital 7	0.836776	10
Hospital 2	0.875571	11	Hospital 2	0.854900	11
Hospital 8	1.000000	12	Hospital 8	1.000000	12

the benchmark framework selects hospital (B) because this hospital has less patients than hospital (A). However, what if hospital (A) contains more emergency rooms with facilities than hospital (B)? In this case, selecting hospital (A) is proper because health-care services are available in this hospital more than hospital (B). The process of hospital selection in the benchmark framework did not consider the services availability in each hospital. For accuracy, the hospital selection process must be performed based on the number of available services because these vary from one hospital to another [38]. In the selection process, the number of available services is a more important factor than the number of patients in each hospital.

- **Health-care service balancing amongst hospitals:** The management and control of health-care services load amongst hospitals is critical due to scalability concerns. This balancing has been accomplished in this research by Tier 4, which is responsible for sharing the medical resources and avoiding the acute shortage of health-care services in hospitals.
- **Validation:** Hospital selection is critical for the patient. Thus, to determine if the selected hospital is valid or not is important.
- **Evaluation:** Evaluation is also significant because it determines the performance of the hospital selection process by comparing the proposed work with the most relevant study and finds differences between them.

In summary, a statistical result for the evaluation process illustrated that the proposed health recommender framework exhibited an advantage over the benchmark framework by 56.25%.

VI. LIMITATIONS

In this research, two limitations can be solved in future research. Firstly, this research focused on hospital selection for individual patients, which included limitation in terms of patient prioritization. This term introduced the limitation on the selection of the hospitals for patients with chronic heart disease when many patients require health-care services at the same time. Therefore, this research selected the best hospital according to quantitative services within hospitals and triage level of patients with chronic heart disease individually without prioritizing and accommodating the ranking for patients. Secondly, the first generation of the telemedicine architecture (Tier 1–Tier 2–Tier 3) was not yet upgraded to the next generation. Thus, this research can be considered the proposed health recommender framework for the next generation (Tier 1–Tier 2–Tier 3–Tier 4) of the telemedicine environment.

VII. RECOMMENDATIONS FOR FUTURE WORK

This study presented several recommendations for future work as follows:

- Chronic heart diseases exhibit various complications, such as high BP and diabetes. A future trend in research is to consider one of these types as another case study. Therefore, the type and number of health-care services involved must be investigated.
- Achieving the above will pave the way for the design of an adaptive decision-making platform for multi-chronic diseases, such as diabetes and high BP. The platform can be used to select the best hospital for multi-chronic patients, considering the diversity of diseases and emergency levels of each patient.
- The patients with the highest risk level must be prioritized and provided health-care services before attending to other patients (urgent and sick levels). Our future work direction will use the new telemedicine design for multi-patients with multi-chronic disease based on their priority.
- Implement the proposed telemedicine architecture (Tier 1–Tier 2–Tier 3–Tier 4) and the framework in real-time processing.
- The quality of the data collection and related issues, that is, sensor model, deterministic errors, stochastic errors, accuracy, energy efficiency, security and privacy, quality of service, reliability and so on, within Tier 1 is also set to be our future work direction during the implementation of the proposed telemedicine architecture and the framework.

VIII. CONCLUSION

Existing telemedicine applications exhibited different limitations based on the health-care service provision because of scalability challenges. The increasing health-care services demand has highlighted the need to provide health-care services from multiple hospitals to cope with growing demand. This research presented a smart real-time health recommender framework based on wearable medical sensors for remote chronic heart services provision in a telemedicine environment during scalability challenges. Tier 4 showed categorized patient conditions through the proposed 4LRTPL algorithm and has then managed a load of health-care services amongst hospitals that are connected to Tier 3 and identified an appropriate hospital for patients to handle and provide accurate health-care services. The method involved the integrated MCDM techniques for ranking hospitals in Tier 4. AHP was applied to obtain the weights for each expert. The final weights result from six experts for three packages were presented, which showed the importance of the health-care services criteria from the viewpoint of the average of the preferences of the six experts. Subsequently, the VIKOR technique is used to rank and select the hospitals based on the quantitative information through which criteria are measured. In addition, the hospitals are ranked based on their number of available services from the highest to the lowest levels. The validation of the results was then achieved objectively in this research. For evaluation, three main scenarios and checklist benchmarking were provided to demonstrate the performance of the proposed health recommender framework for hospital selection.

APPENDIX

See Figs. 18 and 19 and Tables 21–29.

REFERENCES

[1] F. Miao, Y. Cheng, Y. He, Q. He, and Y. Li, "A wearable context-aware ECG monitoring system integrated with built-in kinematic sensors of the smartphone," *Sensors*, vol. 15, no. 5, pp. 11465–11484, May 2015.

[2] J. N. Cohn, "Current therapy of the failing heart," *Circulation*, vol. 78, no. 5, pp. 1099–1107, 1988.

[3] T. Nguyen, A. Khosravi, D. Creighton, and S. Nahavandi, "Classification of healthcare data using genetic fuzzy logic system and wavelets," *Expert Syst. Appl.*, vol. 42, no. 4, pp. 2184–2197, 2015.

[4] M. M. Baig and H. Gholamhosseini, "Smart health monitoring systems: An overview of design and modeling," *J. Med. Syst.*, vol. 37, no. 2, p. 9898, 2013.

[5] N. D. Brunetti *et al.*, "Telemedicine for cardiovascular disease continuum: A position paper from the Italian society of cardiology working group on telecardiology and informatics," *Int. J. Cardiol.*, vol. 184, pp. 452–458, Apr. 2015.

[6] S. Winkler *et al.*, "A new telemonitoring system intended for chronic heart failure patients using mobile telephone technology—Feasibility stud," *Int. J. Cardiol.*, vol. 153, no. 1, pp. 55–58, 2011.

[7] R. Gilpin and J. M. Gilpin, *The Challenge of Global Capitalism: The World Economy in the 21st Century*, vol. 5. Princeton, NJ, USA: Princeton Univ. Press, 2000.

[8] O. H. Salman, M. F. A. Rasid, M. I. Saripan, and S. K. Subramaniam, "Multi-sources data fusion framework for remote triage prioritization in telehealth," *J. Med. Syst.*, vol. 38, no. 9, p. 103, Sep. 2014.

[9] T. H. Sanders, A. Devergnas, T. Wichmann, and M. A. Clements, "Remote smartphone monitoring for management of Parkinson's disease," in *Proc. 6th Int. Conf. Pervasive Technol. Rel. Assistive Environ.*, 2013, p. 42.

[10] J. Mirkovic, H. Bryhni, and C. M. Ruland, "A framework for the development of ubiquitous patient support systems," in *Proc. 6th Int. Conf. Pervasive Comput. Technol. Healthcare (PervasiveHealth)*, May 2012, pp. 81–88.

[11] A. Moghadas, M. Jamshidi, and M. Shaderam, "Telemedicine in healthcare system," in *Proc. World Autom. Congr. (WAC)*, Sep. 2008, pp. 1–6.

[12] M. Chowdhury, W. Mciver, and J. Light, "Data association in remote health monitoring systems," *IEEE Commun. Mag.*, vol. 50, no. 6, pp. 144–149, Jun. 2012.

[13] N. Kalid *et al.*, "Based on real time remote health monitoring systems: A new approach for prioritization 'large scales data' patients with chronic heart diseases using body sensors and communication technology," *J. Med. Syst.*, vol. 42, no. 4, p. 69, 2018.

[14] L. van Dyk, "A review of telehealth service implementation frameworks," *Int. J. Environ. Res. Public Health*, vol. 11, no. 2, pp. 1279–1298, 2014.

[15] S. Jeong, C.-H. Youn, E. B. Shim, M. Kim, Y. M. Cho, and L. Peng, "An integrated healthcare system for personalized chronic disease care in home–hospital environments," *IEEE Trans. Inf. Technol. Biomed.*, vol. 16, no. 4, pp. 572–585, Jul. 2012.

[16] A. Rocha *et al.*, "Innovations in health care services: The CAALYX system," *Int. J. Med. Inform.*, vol. 82, no. 11, pp. e307–e320, 2013.

[17] R. Busse, J. Schreyögg, and P. C. Smith, "Variability in healthcare treatment costs amongst nine EU countries—Results from the HealthBASKET project," *Health Econ.*, vol. 17, pp. S1–S8, Jan. 2008.

[18] L. H. Wizig, "Method and system for providing a user-selected healthcare services package and healthcare services panel customized based on a user's selections," U.S. Patent 6 735 569, May 11, 2004.

[19] C.-T. Liu, A.-G. Long, Y.-C. Li, K.-C. Tsai, and H.-S. Kuo, "Sharing patient care records over the world wide Web," *Int. J. Med. Inform.*, vol. 61, nos. 2–3, pp. 189–205, 2001.

[20] J. Wang, M. Qiu, and B. Guo, "Enabling real-time information service on telehealth system over cloud-based big data platform," *J. Syst. Archit.*, vol. 72, pp. 69–79, Jan. 2017.

[21] M.-Y. Chang, C. Pang, J. M. Tarn, T.-S. Liu, and D. C. Yen, "Exploring user acceptance of an e-hospital service: An empirical study in Taiwan," *Comput. Standards Interfaces*, vol. 38, pp. 35–43, Feb. 2015.

[22] A. M. R. Khan, P. N. Prasad, and S. Rajamanoharane, "A decision-making framework for service quality measurements in hospitals," *Int. J. Enterprise Netw. Manage.*, vol. 4, no. 1, pp. 80–91, 2010.
[23] J. Leister and J. Stausberg, "Why do patients select a hospital? A conjoint analysis in two German hospitals," *J. Hospital Marketing Public Relations*, vol. 17, no. 2, pp. 13–31, 2007.
[24] H. F. Lingsma *et al.*, "Comparing and ranking hospitals based on outcome: Results from The Netherlands stroke survey," *QJM, Int. J. Med.*, vol. 103, no. 2, pp. 99–108, 2009.
[25] S. V. Kovalchuk, E. Krotov, P. A. Smirnov, D. A. Nasonov, and A. N. Yakovlev, "Distributed data-driven platform for urgent decision making in cardiological ambulance control," *Future Gener. Comput. Syst.*, vol. 79, pp. 144–154, Feb. 2018.
[26] S. Ben Othman, H. Zgaya, S. Hammadi, A. Quilliot, A. Martinot, and J.-M. Renard, "Agents endowed with uncertainty management behaviors to solve a multiskill healthcare task scheduling," *J. Biomed. Inform.*, vol. 64, pp. 25–43, Dec. 2016.
[27] T. H. Chang, "Fuzzy VIKOR method: A case study of the hospital service evaluation in Taiwan," *Inf. Sci.*, vol. 271, pp. 196–212, Jul. 2014.
[28] V. Vaidehi, M. Vardhini, H. Yogeshwaran, G. Inbasagar, R. Bhargavi, and C. S. Hemalatha, "Agent based health monitoring of elderly people in indoor environments using wireless sensor networks," *Procedia Comput. Sci.*, vol. 19, pp. 64–71, Jan. 2013.
[29] S. Bharatula and M. Meenakshi, "Design of cognitive radio network for hospital management system," *Wireless Pers. Commun.*, vol. 90, no. 2, pp. 1021–1038, Sep. 2016.
[30] K. Ganapathy, V. Vaidehi, B. Kannan, and H. Murugan, "Hierarchical particle swarm optimization with ortho-cyclic circles," *Expert Syst. Appl.*, vol. 41, no. 7, pp. 3460–3476, Jun. 2014.
[31] K. Ganapathy, B. Priya, B. Priya, V. Prashanth, and V. Vaidehi, "SOA framework for geriatric remote health care using wireless sensor network," *Procedia Comput. Sci.*, vol. 19, pp. 1012–1019, Jan. 2013.
[32] J. Mendes, H. Simões, P. Rosa, N. Costa, C. Rabadão, and A. Pereira, "Secure low-cost solution for elder's eCardio surveillance," *Procedia Comput. Sci.*, vol. 27, pp. 46–56, Jan. 2014.
[33] S. V. Zanjal and G. R. Talmale, "Medicine reminder and monitoring system for secure health using IOT," *Procedia Comput. Sci.*, vol. 78, no. 3, pp. 471–476, 2016.
[34] S. J. Miah, J. Hasan, and J. G. Gammack, "On-cloud healthcare clinic: An e-health consultancy approach for remote communities in a developing country," *Telematics Inform.*, vol. 34, no. 1, pp. 311–322, Feb. 2017.
[35] A. Hussain, R. Wenbi, A. L. da Silva, M. Nadher, and M. Mudhish, "Health and emergency-care platform for the elderly and disabled people in the smart city," *J. Syst. Softw.*, vol. 110, pp. 253–263, Dec. 2015.
[36] J. Faulin, A. A. Juan, S. E. Grasman, and M. J. Fry, *Decision Making in Service Industries: A Practical Approach*. Boca Raton, FL, USA: CRC Press, 2012.
[37] H. Akdag, T. Kalaycı, S. Karagöz, H. Zülfikar, and D. Giz, "The evaluation of hospital service quality by fuzzy MCDM," *Appl. Soft Comput.*, vol. 23, pp. 239–248, Oct. 2014.
[38] A. S. Albahri, A. A. Zaidan, O. S. Albahri, B. B. Zaidan, and M. A. Alsalem, "Real-time fault-tolerant mhealth system: Comprehensive review of healthcare services, opens issues, challenges and methodological aspects," *J. Med. Syst.*, vol. 42, no. 8, p. 137, Aug. 2018.
[39] J. Malczewski, *GIS and Multicriteria Decision Analysis*. Hoboken, NJ, USA: Wiley, 1999.
[40] S. Petrovic-Lazarevic and A. Abraham. (2004). "Hybrid fuzzy-linear programming approach for multi criteria decision making problem." [Online]. Available: https://arxiv.org/abs/cs/0405019
[41] S. Zionts, "MCDM—If not a Roman numeral, then what?" *Interfaces*, vol. 9, no. 4, pp. 94–101, 1979.
[42] M. Oliveira, D. B. M. M. Fontes, and T. Pereira, "Multicriteria decision making: A case study in the automobile industry," in *Proc. Int. Symp. Oper. Res. Appl. (ISORAP)*, 2013, pp. 1–20.
[43] A. Jadhav and R. Sonar, "Analytic hierarchy process (AHP), weighted scoring method (WSM), and hybrid knowledge based system (HKBS) for software selection: A comparative study," in *Proc. 2nd Int. Conf. Emerg. Trends Eng. Technol. (ICETET)*, Dec. 2009, pp. 991–997.
[44] V. Diaby, K. Campbell, and R. Goeree, "Multi-criteria decision analysis (MCDA) in health care: A bibliometric analysis," *Oper. Res. Health Care*, vol. 2, no. 1, pp. 20–24, 2013.
[45] P. Thokala *et al.*, "Multiple criteria decision analysis for health care decision making—An introduction: Report 1 of the ISPOR MCDA emerging good practices task force," *Value Health*, vol. 19, no. 1, pp. 1–13, 2016.
[46] G. Adunlin, V. Diaby, and H. Xiao, "Application of multicriteria decision analysis in health care: A systematic review and bibliometric analysis," *Health Expectations*, vol. 18, no. 6, pp. 1894–1905, 2015.
[47] A. C. Mühlbacher and A. Kaczynski, "Making good decisions in healthcare with multi-criteria decision analysis: The use, current research and future development of MCDA," *Appl. Health Econ. Health Policy*, vol. 14, no. 1, pp. 29–40, 2016.
[48] S. Opricovic and G.-H. Tzeng, "Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS," *Eur. J. Oper. Res.*, vol. 156, no. 2, pp. 445–455, Jul. 2004.
[49] M. Mansooreh and J. Pet-Edwards, "Technical briefing: Making multiple-objective decisions," Inst. Elect. Electron. Eng., Piscataway, NJ, USA, Tech. Rep., 1997.
[50] E. Triantaphyllou, *Multi-Criteria Decision Making Methods: A Comparative Study*, vol. 44. Boston, MA, USA: Springer, 2000.
[51] M. Aruldoss, T. M. Lakshmi, and V. P. Venkatesan, "A survey on multi criteria decision making methods and its applications," *Amer. J. Inf. Syst.*, vol. 1, no. 1, pp. 31–43, 2013.
[52] K. P. Yoon and C.-L. Hwang, *Multiple Attribute Decision Making: An Introduction*, vol. 104. New York, NY, USA: SAGE, 1995.
[53] E. Triantaphyllou, B. Shu, S. N. Sanchez, and T. Ray, "Multi-criteria decision making: An operations research approach," *Encyclopedia Elect. Electron. Eng.*, vol. 15, no. 1998, pp. 175–186, 1998.
[54] H. Nilsson, E.-M. Nordström, and K. Öhman, "Decision support for participatory forest planning using AHP and TOPSIS," *Forests*, vol. 7, no. 5, p. 100, 2016.
[55] T. L. Saaty and M. S. Ozdemir, "Why the magic number seven plus or minus two," *Math. Comput. Model.*, vol. 38, nos. 3–4, pp. 233–244, 2003.
[56] M. A. Ortiz, J. P. Cómbita, A. D. L. La Hoz, F. De Felice, and A. Petrillo, "An integrated approach of AHP-DEMATEL methods applied for the selection of allied hospitals in outpatient service," *Int. J. Med. Eng. Inform.*, vol. 8, no. 2, pp. 87–107, 2016.
[57] M. A. O. Barrios, F. De Felice, K. P. Negrete, B. A. Romero, A. Y. Arenas, and A. Petrillo, "An AHP-topsis integrated model for selecting the most appropriate tomography equipment," *Int. J. Inf. Technol. Decis. Making*, vol. 15, no. 4, pp. 861–885, 2016.
[58] H. Çalışkan, "Selection of boron based tribological hard coatings using multi-criteria decision making methods," *Mater. Des.*, vol. 50, pp. 742–749, Sep. 2013.
[59] H.-P. Fu, K.-K. Chu, P. Chao, H.-H. Lee, and Y.-C. Liao, "Using fuzzy AHP and VIKOR for benchmarking analysis in the hotel industry," *Service Ind. J.*, vol. 31, no. 14, pp. 2373–2389, Nov. 2011.
[60] A. Mohaghar, M. R. Fathi, M. K. Zarchi, and A. Omidian, "A combined VIKOR-fuzzy AHP approach to marketing strategy selection," *Bus. Manage. Strategy*, vol. 3, no. 1, p. 13, Dec. 1969.
[61] G.-N. Zhu, J. Hu, J. Qi, C.-C. Gu, and Y.-H. Peng, "An integrated AHP and VIKOR for design concept evaluation based on rough number," *Adv. Eng. Inform.*, vol. 29, no. 3, pp. 408–418, Aug. 2015.
[62] M. Ilangkumaran, V. Sasirekha, L. Anojkumar, and M. B. Raja, "Machine tool selection using AHP and VIKOR methodologies under fuzzy environment," *Int. J. Model. Oper. Manage.*, vol. 2, no. 4, pp. 409–436, 2012.
[63] H. E. Aktan and P. K. Samut, "Agricultural performance evaluation by integrating fuzzy AHP and VIKOR methods," *Int. J. Appl. Decis. Sci.*, vol. 6, no. 4, pp. 324–344, 2013.
[64] O. S. Albahri, A. A. Zaidan, B. B. Zaidan, M. Hashim, A. S. Albahri, and M. A. Alsalem, "Real-time remote health-monitoring systems in a medical centre: A review of the provision of healthcare services-based body sensor information, open challenges and methodological aspect," *J. Med. Syst.*, vol. 42, no. 9, p. 164, Sep. 2018.
[65] M. Lahby, L. Cherkaoui, and A. Adib, "A novel ranking algorithm based network selection for heterogeneous wireless access," *J. Netw.*, vol. 8, no. 2, pp. 263–272, 2013.
[66] K. Saksrisathaporn, A. Bouras, N. Reeveerakul, and A. Charles, "Application of a decision model by using an integration of AHP and TOPSIS approaches within humanitarian operation life cycle," *Int. J. Inf. Technol. Decis. Making*, vol. 15, no. 4, pp. 887–918, 2016.
[67] T. L. Saaty, *The Analytic Hierarchy Process*. New York, NY, USA: McGraw-Hill, 1980.
[68] V. Sherekar and M. Tatikonda, "Impact of factor affecting on labour productivity in construction projects by AHP method," *Int. J. Eng. Sci. Comput.*, vol. 6, no. 6, pp. 1–5, 2016.
[69] M. Enea and T. Piazza, "Project selection by constrained fuzzy AHP," *Fuzzy Optim. Decis. Making*, vol. 3, no. 1, pp. 39–62, 2004.

[70] T. Okura *et al.*, "The importance of walking for control of blood pressure: Proof using a telemedicine system," *Telemed. e-Health*, vol. 22, no. 12, pp. 1019–1023, 2016.

[71] C. Kateretse, G.-W. Lee, and E.-N. Huh, "A practical traffic scheduling scheme for differentiated services of healthcare systems on wireless sensor networks," *Wireless Pers. Commun.*, vol. 71, no. 2, pp. 909–927, 2013.

[72] A. Minutolo, M. Esposito, and G. De Pietro, "Design and validation of a light-weight reasoning system to support remote health monitoring applications," *Eng. Appl. Artif. Intell.*, vol. 41, pp. 232–248, May 2015.

[73] J. P. Meizoso *et al.*, "Evaluation of miniature wireless vital signs monitor in a trauma intensive care unit," *Mil. Med.*, vol. 181, no. 5S, pp. 199–204, May 2016.

[74] R. Seising and M. Tabacchi, *Fuzziness and Medicine: Philosophical Reflections and Application Systems in Health Care*, vol. 302. Berlin, Germany: Springer, 2013.

[75] L. Abdullah, "Fuzzy multi criteria decision making and its applications: A brief review of category," *Procedia-Soc. Behav. Sci.*, vol. 97, pp. 131–136, Nov. 2013.

[76] G. C. Lamprinakos *et al.*, "An integrated remote monitoring platform towards telehealth and telecare services interoperability," *Inf. Sci.*, vol. 308, pp. 23–37, Mar. 2015.

[77] K. Sakanushi *et al.*, "Electronic triage system for continuously monitoring casualties at disaster scenes," *J. Ambient Intell. Hum. Comput.*, vol. 4, no. 5, pp. 547–558, 2013.

[78] E. Park, J. H. Kim, H. S. Nam, and H. J. Chang, "Requirement analysis and implementation of smart emergency medical service," *IEEE Access*, vol. 6, pp. 42022–42029, 2018.

[79] A. Anzanpour *et al.*, "Self-awareness in remote health monitoring systems using wearable electronics," in *Proc. Conf. Design, Automat. Test Eur.*, 2017, pp. 1056–1061.

[80] G. Gabrani and S. Gupta, "Real time sensor grid based secured health care monitoring," in *Proc. Comput. Conf.*, Jul. 2017, pp. 500–506.

[81] O. H. Salman, A. A. Zaidan, B. B. Zaidan, Naserkalid, and M. Hashim, "Novel methodology for triage and prioritizing using 'big data' patients with chronic heart diseases through telemedicine environmental," *Int. J. Inf. Technol. Decis. Making*, vol. 16, no. 5, pp. 1211–1245, 2017.

[82] M. A. Arasteh, S. Shamshirband, and P. L. Yee, "Using multi-attribute decision-making approaches in the selection of a hospital management system," *Technol. Health Care*, vol. 26, no. 2, pp. 279–295, 2018.

[83] O. S. Albahri *et al.*, "Systematic review of real-time remote health monitoring system in triage and priority-based sensor technology: Taxonomy, open challenges, motivation and recommendation," *J. Med. Syst.*, vol. 42, no. 5, p. 80, 2018.

[84] A. A. Zaidan, "A review on smartphone skin cancer diagnosis apps in evaluation and benchmarking: Coherent taxonomy, open issues and recommendation pathway solution," *Health Technol.*, vol. 8, no. 4, pp. 223–238, Sep. 2018.

[85] M. A. Alsalem *et al.*, "Systematic review of an automated multiclass detection and classification system for acute Leukaemia in terms of evaluation and benchmarking, open challenges, issues and methodological aspects," *J. Med. Syst.*, vol. 42, no. 11, p. 204, 2018.

[86] S. Iqbal *et al.*, "Real-time-based E-health systems: Design and implementation of a lightweight key management protocol for securing sensitive information of patients," *Health Technol.*, vol. 9, no. 2, pp. 93–111, 2018.

[87] A. H. Mohsin *et al.*, "Real-time medical systems based on human biometric steganography: A systematic review," *J. Med. Syst.*, vol. 42, no. 12, p. 245, 2018.

[88] A. H. Mohsin, "Real-time remote health monitoring systems using body sensor information and finger vein biometric verification: A multi-layer systematic review," *J. Med. Syst.*, vol. 42, no. 12, p. 238, 2018.

[89] M. L. Shuwandy, B. B. Zaidan, A. A. Zaidan, and A. S. Albahri, "Sensor-based mhealth authentication for real-time remote healthcare monitoring system: A multilayer systematic review," *J. Med. Syst.*, vol. 43, no. 2, p. 33, 2019.

[90] O. Enaizan, "Electronic medical record systems: Decision support examination framework for individual, security and privacy concerns using multi-perspective analysis," *Health Technol.*, vol. 9, pp. 1–28, Nov. 2018.

[91] A. A. Zaidan *et al.*, "Evaluation and selection of open-source EMR software packages based on integrated AHP and TOPSIS," *J. Biomed. Inform.*, vol. 53, pp. 390–404, Feb. 2015.

[92] A. A. Zaidan, B. B. Zaidan, M. Hussain, A. Haiqi, M. L. M. Kiah, and M. Abdulnabi, "Multi-criteria analysis for OS-EMR software selection problem: A comparative study," *Decis. Support Syst.*, vol. 78, pp. 15–27, Oct. 2015.

[93] B. N. Abdullateef, N. F. Elias, H. Mohamed, A. A. Zaidan, and B. B. Zaidan, "An evaluation and selection problems of OSS-LMS packages," *SpringerPlus*, vol. 5, no. 1, p. 248, Dec. 2016.

[94] Q. M. Yas, A. A. Zadain, B. B. Zaidan, M. B. Lakulu, and B. Rahmatullah, "Towards on develop a framework for the evaluation and benchmarking of skin detectors based on artificial intelligent models using multi-criteria decision-making techniques," *Int. J. Pattern Recognit. Artif. Intell.*, vol. 31, no. 3, Mar. 2017, Art. no. 1759002.

[95] B. B. Zaidan, A. A. Zaidan, H. Abdul Karim, and N. N. Ahmad, "A new digital watermarking evaluation and benchmarking methodology using an external group of evaluators and multi-criteria analysis based on 'large-scale data,'" *Softw., Pract. Exper.*, vol. 47, no. 10, pp. 1365–1392, Oct. 2017.

[96] B. B. Zaidan, A. A. Zaidan, H. Abdul Karim, and N. N. Ahmad, "A new approach based on multi-dimensional evaluation and benchmarking for data hiding techniques," *Int. J. Inf. Technol. Decis. Making*, vol. 16, pp. 1–42, Mar. 2017.

[97] M. A. Qader, B. B. Zaidan, A. A. Zaidan, S. K. Ali, M. A. Kamaluddin, and W. B. Radzi, "A methodology for football players selection problem based on multi-measurements criteria analysis," *Measurement*, vol. 111, pp. 38–50, Dec. 2017.

[98] F. M. Jumaah, A. A. Zaidan, B. B. Zaidan, R. Bahbibi, M. Y. Qahtan, and A. Sali, "Technique for order performance by similarity to ideal solution for solving complex situations in multi-criteria optimization of the tracking channels of GPS baseband telecommunication receiver," *Telecommun. Syst.*, vol. 68, no. 3, pp. 425–443, Jul. 2018.

[99] B. Rahmatullah, A. A. Zaidan, F. Mohamed, and A. Sali, "Multi-complex attributes analysis for optimum GPS baseband receiver tracking channels selection," in *Proc. 4th Int. Conf. Control, Decis. Inf. Technol. (CoDIT)*, Apr. 2017, pp. 1084–1088.

[100] Q. M. Yas, A. A. Zaidan, B. B. Zaidan, B. Rahmatullah, and H. A. Karim, "Comprehensive insights into evaluation and benchmarking of real-time skin detectors: Review, open issues & challenges, and recommended solutions," *Measurement*, vol. 114, pp. 243–260, Jan. 2008.

[101] B. B. Zaidan and A. A. Zaidan, "Comparative study on the evaluation and benchmarking information hiding approaches based multi-measurement analysis using TOPSIS method with different normalisation, separation and context technique," *Measurement*, vol. 117, pp. 277–294, Mar. 2018.

[102] M. M. Salih, B. B. Zaidan, A. A. Zaidan, and Mohamed A. Ahmed, "Survey on fuzzy TOPSIS state-of-the-art between 2007-2017," *Comput. Oper. Res.*, vol. 104, pp. 207–277, Apr. 2018.

[103] N. Kalid *et al.*, "Based real time remote health monitoring systems: A review on patients prioritization and related 'big data' using body sensors information and communication technology," *J. Med. Syst.*, vol. 42, no. 2, p. 30, Feb. 2018.

[104] F. M. Jumaah, A. A. Zadain, B. B. Zaidan, A. K. Hamzah, and R. Bahbibi, "Decision-making solution based multi-measurement design parameter for optimization of GPS receiver tracking channels in static and dynamic real-time positioning multipath environmen," *Measurement*, vol. 118, pp. 83–95, Mar. 2018.

[105] H. A. AlSattar *et al.*, "MOGSABAT: A metaheuristic hybrid algorithm for solving multi-objective optimisation problems," *Neural Comput. Appl.*, vol. 30, pp. 1–15, Oct. 2018.

[106] B. B. Zaidan and A. A. Zaidan, "Software and hardware FPGA-based digital watermarking and steganography approaches: Toward new methodology for evaluation and benchmarking using multi-criteria decision-making techniques," *J. Circuits, Syst. Comput.*, vol. 26, no. 7, Jul. 2017, Art. no. 1750116.

[107] M. Hussain *et al.*, "Conceptual framework for the security of mobile health applications on Android platform," *Telematics Inform.*, vol. 35, no. 5, pp. 1335–1354, Mar. 2018.

[108] M. Hussain *et al.*, "A security framework for mHealth apps on Android platform," *Comput. Secur.*, vol. 75, pp. 191–217, Jun. 2018.

[109] H. O. Alanazi, G. M. Alam, B. B. Zaidan, and A. A. Zaidan, "Securing electronic medical records transmissions over unsecured communications: An overview for better medical governance," *J. Med. Plants Res.*, vol. 4, no. 19, pp. 2059–2074, 2010.

[110] M. S. A. Nabi, M. L. M. Kiah, B. B. Zaidan, A. A. Zaidan, and G. M. Alam, "Suitability of using SOAP protocol to secure electronic medical record databases transmission," *Int. J. Pharmacol.*, vol. 6, no. 6, pp. 959–964, 2010.

[111] M. L. M. Kiah, M. S. Nabi, B. B. Zaidan, and A. A. Zaidan, "An enhanced security solution for electronic medical records based on AES hybrid technique with SOAP/XML and SHA-1," *J. Med. Syst.*, vol. 37, no. 5, p. 9971, Oct. 2013.
[112] M. S. Nabi, M. L. M. Kiah, A. A. Zaidan, and B. B. Zaidan, "Suitability of adopting S/MIME and OpenPGP email messages protocol to secure electronic medical records," in *Proc. 2nd Int. Conf. Future Gener. Commun. Technol. (FGCT)*, Nov. 2013, pp. 93–97.
[113] M. L. M. Kiah, A. Haiqi, B. B. Zaidan, and A. A. Zaidan, "Open source EMR software: Profiling, insights and hands-on analysis," *Comput. Methods Programs Biomed.*, vol. 117, no. 2, pp. 360–382, 2014.
[114] H. O. Alanazi, A. A. Zaidan, B. B. Zaidan, M. L. M. Kiah, and S. H. Al-Bakri, "Meeting the security requirements of electronic medical records in the ERA of high-speed computing," *J. Med. Syst.*, vol. 39, no. 1, p. 165, 2015.
[115] M. Hussain *et al.*, "The landscape of research on smartphone medical apps: Coherent taxonomy, motivations, open challenges and recommendations," *Comput. Methods Programs Biomed.*, vol. 122, no. 3, pp. 393–408, 2015.
[116] M. Abdulnabi, A. Al-Haiqi, M. L. M. Kiah, A. A. Zaidan, B. B. Zaidan, and M. Hussain, "A distributed framework for health information exchange using smartphone technologies," *J. Biomed. Inform.*, vol. 69, pp. 230–250, May 2017.
[117] B. B. Zaidan, A. A. Zaidan, and M. L. M. Kiah, "Impact of data privacy and confidentiality on developing telemedicine applications: A review participates opinion and expert concerns," *Int. J. Pharmacol.*, vol. 7, no. 3, pp. 382–387, 2011.
[118] M. L. M. Kiah, B. B. Zaidan, A. A. Zaidan, M. Nabi, and R. Ibraheem, "MIRASS: Medical informatics research activity support system using information mashup network," *J. Med. Syst.*, vol. 38, no. 4, p. 37, 2014.
[119] M. L. M. Kiah, S. H. Al-Bakri, A. A. Zaidan, B. B. Zaidan, and M. Hussain, "Design and develop a video conferencing framework for real-time telemedicine applications using secure group-based communication architecture," *J. Med. Syst.*, vol. 38, no. 10, p. 133, Oct. 2014.
[120] A. A. Zaidan, B. B. Zaidan, Z. Kadhem, M. Larbani, M. B. Lakulu, and M. Hashim, "Challenges, alternatives, and paths to sustainability: Better public health promotion using social networking pages as key tools," *J. Med. Syst.*, vol. 39, no. 2, p. 7, Feb. 2015.
[121] B. B. Zaidan, A. Haiqi, A. A. Zaidan, M. Abdulnabi, M. L. M. Kiah, and H. Muzamel, "A security framework for nationwide health information exchange based on telehealth strategy," *J. Med. Syst.*, vol. 39, no. 5, p. 51, 2015.

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