

PERFORMANCE MODELLING FOR MAINTENANCE OUTSOURCING PROVIDERS BASED ON THE KANO MODEL

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ABSTRACT

Usually, maintenance activities are carried out by the maintenance department in a company, but now, some companies are outsourcing their maintenance activities. Outsourcing is the delegation of business functions to another company. The advantages of outsourcing include enabling a company to focus on its core business by outsourcing support activities, and changing fixed costs to variable costs. The aim of this research is to develop a multi-criteria performance measurement to assess the performance of maintenance outsourcing providers. Several previous studies have identified suitable performance criteria for maintenance outsourcing providers. However, those studies did not classify the criteria for achieving the desired level of performance. To address these shortcomings, this research has classified the criteria based on the Kano criteria. The criteria are: basic, one-dimensional, indifferent, reverse, and attractive. A managed case study analysis was performed at five Class B private hospitals in East Java to better understand the criteria in terms of the needs of a real hospital maintenance department. Previous research studies focused on understanding the relationship between each criterion and the associated level of performance, whereas the current research has focused instead on the relationship links between the criteria and the weighting of each criterion using DEMATEL-ANP. The outcome of this study is a simple instrument that can be directly used to evaluate the performance of maintenance outsourcing providers.

Keywords: Case study analysis; ICU; KANO; Medical devices; Outsourcing

1. INTRODUCTION

Maintenance activities can be categorised into corrective and preventive. The term corrective maintenance refers to activities that are performed after a system breakdown (Nossohi & Hejazi, 2011). On the other hand, preventive maintenance, includes inspection and spare part replacement, and is performed before system breakdown. The goal of preventive maintenance is to improve on one or more criteria, such as reliability, availability, and maintenance cost. All maintenance activities usually are performed by an internal maintenance department. Nevertheless, it is now common to outsource the performance of these activities. Outsourcing is defined as delegating a business function to other companies (Gomez et al., 2009). The Intensive Care Unit (ICU) in a hospital is a department which has a high degree of uncertainty. Medical equipment in ICU requires high availability and reliability to ensure patient safety.

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Patient safety is a construct that implies behaviour that is intended to minimise the risk of harm to patients through both system effectiveness and individual performance, and is designed to avoid injuries to patients from the care that is intended to help them. Harm is an unintended physical injury resulting from or contributed to by medical care that requires additional monitoring, treatment, or hospitalisation, or that results in death (Albrecht, 2015). It is crucial that the maintenance service provider has a high enough performance level in order to achieve that goal. The aim of this study is to develop a performance measurement model to assess maintenance outsourcing providers. In the healthcare industry in Indonesia, the performance measurement of maintenance service providers has not been performed and there is no systematic method of performance measurement. Performance measurement of the maintenance service provider is important. If the maintenance service provider has a good level of performance, then the availability and reliability of the medical equipment can be maintained. If the performance or performance of the maintenance service provider is not measured and evaluated, then there is the possibility of the service providers not improving their performance. According to Jackson and Pascual (2008) in Cruz and Rincon (2012), research on maintenance service outsourcing focusing on the integration of provider maintenance selection, performance evaluation and measurement has not been performed. Cruz and Rincon (2012) conducted a themed mapping review on previous studies on outsourced maintenance in the healthcare industry area. These earlier studies are broadly divided into four categories, namely mathematical models, conceptual research, empirical research on maintenance outsourcing for medical equipment, and empirical research on maintenance outsourcing in other fields. Almeida (2005) conducted a study on maintenance contract issues related to decision-making. In making decisions, decision makers choose alternatives based on the main criteria of cost and performance. Cruz et al. (2013) conducted research on the performance criteria of the maintenance service providers. The object of this research is more specific, as it is about the maintenance of medical equipment.

2. METHODS

2.1. Performance Measurement

Performance measurement is defined as a quantitative indicator that can be used to measure a particular goal (Dewangan & Godse, 2014; Yildiz & Demirel, 2014). In hospital, the performance of the maintenance outsourcing providers is directly related to patient safety. So, the performance of the maintenance outsourcing providers should be managed. The first step is to gather suitable criteria to use in the measurement process.

2.2. Criteria Development

The initial criteria in this study were gathered from a review of the literature. Then, the list of criteria was grouped into similar criteria (Almeida, 2005; 2007). Service quality is defined as the degree of error that occurs when a repair has been carried out, the expected condition of the equipment, and average customer satisfaction (Almeida, 2005; Almeida, 2007; Singgih & Dalulia, 2016). Therefore, service quality can be understood to have a comprehensive meaning, which refers to the level of customer satisfaction with the services of the maintenance outsourcing provider that can be identified by the degree of error when the maintenance activities have been carried out. The details of the criteria obtained from a review of the previous research has been illustrated in Table 1.

The next step after gathering the criteria from the literature was to choose what the suitable criteria are for the ICU hospitals in East Java. This was explored through a case study analysis (Wahjudi et al., 2016) that was conducted in 5 private hospitals, in which the head of the maintenance department in each hospital served as an expert in this research.

Table 1 Criteria obtained from the literature study

Author	Criteria	Definition
Almeida (2005)	Dependability	Response time accomplishment specified in contract document
	Service Quality	Degree of errors that occurs when a repair is carried out
	Cost	Contract cost stated in the contract proposal over a certain period
	Response time	Time required from maintenance service provider called until the maintenance service provider comes to repair.
Almeida (2007)	Delivery time	Time required for repair activities Time promised on contract document Related with customer request, affected by resource and affecting cost calculation
	Cost	Contract cost stated in the contract proposal over a certain period
	Dependability	Response time achievement that has been stated in contract document
Liou & Chuang (2010)	Relationship	Risk and reward sharing, airline and ground service provider collaboration.
	Flexibility	Flexibility to handle abnormal condition, such as flight delays, overbooking and incidents
	Information sharing	Computer system capability and information sharing.
	Knowledge skills	Manpower knowledge of maintenance outsourcing provider
	Customer satisfaction	Average value of customer satisfaction
	On time rate	Ratio equipment delivered or well done repairs.
	Cost Saving	Total cost of outsourcing activities less than the costs stated in the contract proposal.
	Flexibility in billing	Flexibility in payment condition.
	Labor union	Outsourcing will affect on employee laid off.
	Loss of management control	Control functions of management when there is a problem with the provider that resulted in airline customer satisfaction.
Cruz et al. (2013)	Information security	Security on information sharing between provider and customer, related with long term reliance.
	Response time	Time required from maintenance service provider called until maintenance service provider come to repair.
	Service Time	Time required to perform repair or maintenance activities.
	Turn Around Time	Total time begins from equipment stopping operating until it is operating again.
	Firm Capacity & Human Resource	Capability to fulfill maintenance contract agreement.
Cruz et al. (2013)	Service Features	Service characteristic offered by provider.
	Contractual Relationship	Contract types offered by provider.
Cruz et al. (2013)	Equipment Types	The type of equipment which can be handled by the service provider

A questionnaire was developed in order to determine the useful criteria from the experts using the Delphi method. The Delphi method is generally used to solicit opinions from participants who are considered competent in their field (Ciptomulyono, 2001). The Delphi method was

defined as a structured method to guide interactive discussion groups and decision-making processes with the aim of facilitating brainstorming amongst a panel of experts to reach a consensus on a topic (Winkler et al., 2015). This method can be used as a means of exchanging information via brainstorming or through individual interactions in order to obtain an opinion from the group. The brainstorming approach in the Delphi method does not require any direct interaction between the participants. The steps to gather opinions in the Delphi method are as follows: (1) Organise a facilitation team that fully understands the topics; (2) Choose experts who will be involved in the discussion; (3) Provide information to the participants regarding the purpose of the discussion; (4) Distribute questionnaires to the experts regarding the proposed criteria and the determination of important weights; (5) Collect the questionnaires (administered by the moderator), structure the answers, and re-distribute the results to the experts; (6) Create a new questionnaire that includes the list of criteria or objective chosen and the assigned weighting average, and ask each participant to evaluate or give feedback on the results; and (7) Repeat steps number 5 and 6 until consensus is obtained.

2.3. Kano Model

The Kano model classifies the features of products into five categories, namely: 'must be', 'one-dimensional', 'indifference' and 'reverse', and 'attractive' (Basfirinci & Mitra, 2015; Suef et al., 2017). Attributes that are classified 'must be' are defined as the basic attributes of service quality that are related to customer satisfaction. These basic features are essential for every consumer. If the basic features cannot be fulfilled, then it will lead to consumer dissatisfaction. For example, the equipment must function normally. A classification of 'indifference' is applied to attributes that do not affect the level of satisfaction of the consumer, whereas a 'reverse' classification is applied to attributes that lead to consumer dissatisfaction. The Kano model was used because the principles of the basic and special requirements can be identified in detail (Suzianti et al., 2015). In addition to the criteria defined as the basic and special requirements, the principles of Kano can also identify any non-essential criteria that can be removed without affecting the consumer perception of the product or service. In this study, the desired outcome of the case study analysis was to determine what basic and additional criteria are needed. The Kano principles are used to select the attributes or criteria that constitute the basic and additional features of the maintenance service provider. Criteria that do not affect the outcome will be eliminated from the list of criteria that influence the performance of the maintenance service provider. The following steps were performed when implementing the Kano model: (1) Identify the product or services requirement; (2) Develop the Kano questionnaire; and (3) Plot the Kano matrix by calculating the extent of satisfaction and dissatisfaction using Equations 1 and 2. (Hartono et al., 2017 ; Hartono, 2016)

$$\text{Extent of satisfaction} = \frac{A+O}{A+O+M+I} \quad (1)$$

$$\text{Extent of dissatisfaction} = \frac{O+M}{(A+O+M+I) \times (-1)} \quad (2)$$

Where A is the attractive criteria; O is the one-dimensional criteria; M is the must be criteria; and I is the indifference criteria

2.4. DEMATEL – ANP Integration

DEMATEL is a method that can be used to determine the links between various criteria. In addition to being able to capture the pattern of links between the criteria, the DEMATEL method is also able to capture and analyse the dominant criteria in a particular system (Yoserizal & Singgih, 2012). In Lee et al. (2011), an integration of the DEMATEL and ANP methods was used to analyse the corresponding relationships between the factors. If the relationships between the factors affecting an investment are known, the decision-making

process is expected to be more effective and efficient. The DEMATEL method can be used to investigate the relationship between the factors of a stock investment, followed by use of the ANP to evaluate the magnitude and links between the factors. The DEMATEL method is often applied to effectively arrange problems that contain links between the factors. The steps for implementing DEMATEL are as follows: (1) Construct an evaluation scale; (2) Develop the direct relationship matrix; (3) Develop the normalisation matrix; (4) Construct the total relationship matrix; (5) Calculate the importance and relationship values; and (6) Develop the network relationship matrix (NRM). ANP is designed to accommodate relationship and interdependence criteria, and can complement weaknesses in the Analytical Hierarchy Process (AHP). ANP can be seen as a generalisation of AHP. The fundamental difference between AHP and ANP is that the ANP is used in multi-criteria decision-making and is focused on the corresponding relationships between the criteria. AHP assumes that there is no link between the criteria and only explores hierarchical relationships. The ANP is able to represent the level of interest of various parties while taking into account the interdependence of any existing criteria and sub-criteria. A weighting calculation using the ANP can be performed using the Super Decision software package. The integration of the research methods can be illustrated in Figure 1.

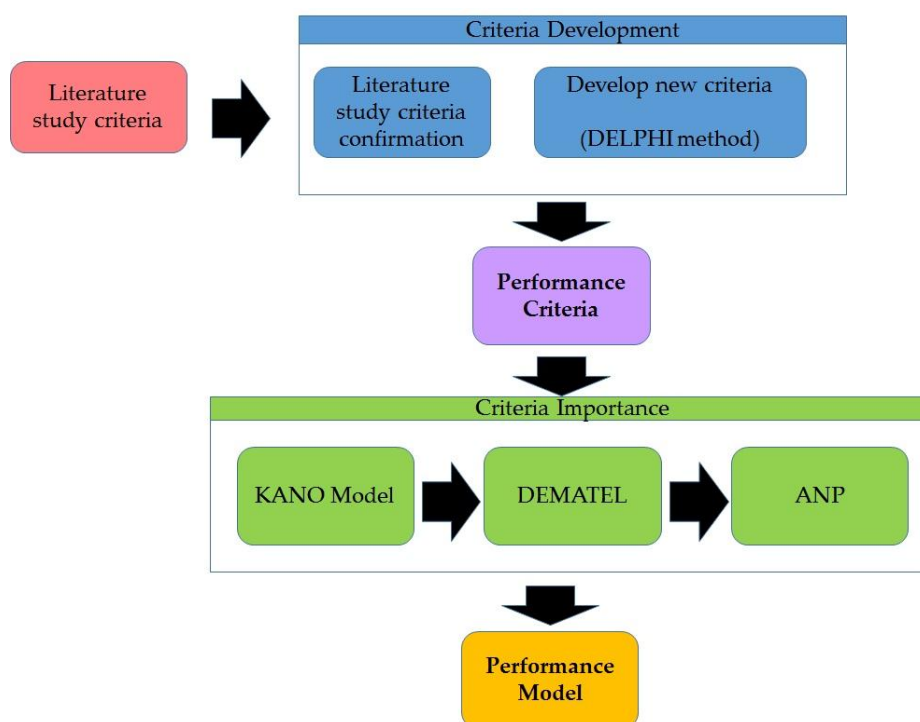


Figure 1 Method integration

2.5. Research Position

This study includes the concept of outsourcing maintenance activities and then monitoring selected performance measures using the criteria used in each phase of the outsourcing process. The resulting model can be used by the hospital when considering how best to measure the performance of outsourced maintenance functions. The idea of the study was obtained from the previous studies managed by Dewangan and Godse (2014) regarding their mapping review of research on outsourcing the maintenance of medical equipment. The healthcare industry is a service industry that is closely related to patient safety, and the characteristics of this industry are unique when compared to the manufacturing industry. In Indonesia, the performance measurement of outsourced maintenance activities is generally not managed by the hospital.

The performance criteria were obtained from a study with several references (Almeida, 2005; Almeida, 2007; Lee et al., 2011; Yildiz & Demirel, 2014, Singgih and Dalulia (2016)). However, Yildiz and Demirel, (2014) focused their research on the correlation of each criterion against the delivery of the service, and there was no stated preference level of interest in the form of the weighting of those criteria. The development of criteria can be managed by the method of case study analysis, which performs the collection, comparison and confirmation of the criteria used and is considered important by the users of outsourced maintenance. Case study analysis was used by (Angkiriwang, et al., 2014) by comparing the type of uncertainty in the demand characteristics of four different companies. The present study adopted the method of case study analysis to confirm the performance criteria of the new maintenance outsourcing providers obtained from the literature. The case study analysis was conducted in five class B hospitals in East Java. This study required the participation of the decision makers, or experts, in the field of maintenance at each hospital. These experts were asked to provide an assessment or to act as a resource throughout the study. The importance of the criteria that were obtained from literature was determined by each user. The criteria that were considered to be important to the users were then compared and selected using the principles of the Kano method, which separated the criteria into basic and additional attributes, and then weighted them against each criterion. There were some weighting methods proposed in the previous studies, including the Multi Attribute Utility Theory (MAUT) proposed by Almeida (2005) and Almeida (2007). Other weighting methods include an integration between the DEMATEL and ANP methods proposed by Wahjudi et al. (2016) and Liou and Chuang (2010), where these methods were used to consider the relationship between the criteria in contrast to the MAUT method, which does not consider the linkages between the criteria. Consequently, the method resulting from the integration of DEMATEL and ANP methods was used in the current study. Once the weighting criteria were obtained, a simple instrument was created that provided the maintenance performance measures in the form of a list of criteria and weights.

3. RESULTS AND DISCUSSION

The criteria that were selected from the literature were defined as the initial criteria. The criteria selected from the literature is shown in Table 1. The list of criteria included in the previous research has been consolidated by combining criteria with similar meanings. The results of this elaboration have been illustrated in Table 2.

Table 2 Literature study criteria

Criteria	Definition
Dependability	Response time achievement that has been stated in contract document.
Flexibility	Flexibility in handling abnormal conditions.
Service Quality	Customer satisfaction level due to provider services
Cost	Total cost that occurs from outsourcing activities in a certain period.
Turn Around Time	Total time required by the maintenance service provider begins with the request call until the equipment performed normally.
Contractual Relationship	Contract types offered by the provider.
Flexibility in billing	Flexibility in payment condition.
Knowledge sharing	Provider and customer relationship related to information and knowledge.
Equipment Types	Equipment types that the provider is capable of handling.
Firm Capacity & Human Resource	Provider capability on fulfill maintenance contract agreement.

The new criteria differed from one expert to another. However, there were some criteria that different experts defined similarly. The process of selecting the new criteria was based on the results of the scoring average and median. The scoring method used by each expert provided an assessment rate of the level of interest in each criterion. If the average value obtained from the results of the assessment indicated a value that was higher than 7.5, then the criterion could be used. A value of 10 was assigned if the criteria were considered to be very important, while a value of 1 was assigned if the criteria were considered to be unimportant. The scoring results have been shown in Table 3.

Table 3 New criteria

No	Criteria	H I	H II	H III	H IV	H V	Average	Median
1	Technician Skill	10	8.5	9	10	8	9.1	9
2	Administration	10	8	8	8	10	8.8	8
3	Diagnosis Accuracy	10	8.5	9	10	8	9.1	9
4	Part Availability	10	8	9	10	8	9	9
5	SOP Clarity	10	8	8	10	9	9	9
6	Routine reporting	10	9	8	8	9	8.8	9
7	Attitude	8	8.5	7	8	8	7.9	8

Based on the calculation of the average value of each user, the average value increased by more than 7.5, and the median value approached the average value of each criterion. This may imply that the user reached the level of agreement for the new criteria, and that the new criteria that have been captured may be used as performance criteria.

The criteria collected were used to construct the performance model. Before assigning suitable weights, the criteria were evaluated using the Kano Model and separated into the five dimensions mentioned previously. The criteria developed from the Kano model are illustrated in Table 4.

Table 4 Kano dimension

Criteria	Dimension
Dependability	one dimensional
Flexibility	must be
Service Quality	one dimensional
Cost	attractive
Turn Around Time	indifferent
Contractual Relationship	indifferent
Flexibility in billing	indifferent
Knowledge sharing	one dimensional
Equipment Types	must be
Firm Capacity	one dimensional
Technician Skill	one dimensional
Adminstration	one dimensional
Diagnosis Accuracy	one dimensional
Part Availability	attractive
SOP Clarity	one dimensional
Routine Reporting	attractive
Attitude	one dimensional

The indifferent criteria, such as the turn-around time, flexibility in billing, and contractual relationship, should be eliminated because they have no impact on performance. The gathered

criteria should be weighted based on the importance definition by integrating the results from DEMATEL and ANP. The significance matrix is illustrated in Table 5.

Table 5 Significance matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1		2.015	2.013		2.013		2.013	2.013	2.004	2.015	2.009		2.009	2.009
C2			2.034		2.034		2.034	2.034	2.025	2.036	2.030		2.030	2.030
C3		2.039			2.038		2.038	2.038	2.028	2.039	2.034		2.034	2.034
C4		2.085	2.083		2.083	1.992	2.083	2.083	2.093	2.085	2.080	1.976	2.080	2.080
C5		2.030	2.028				2.028	2.028	2.038	2.030	2.043		2.043	2.043
C6														
C7		2.099	2.097		2.097	2.006	2.026	2.097	2.107	2.099	2.113	2.008	2.113	2.113
C8		2.065	2.063		2.063		2.063	1.992	2.073	2.065	2.079		2.079	2.079
C9		2.082	2.080		2.080	1.990	2.080	2.080	2.011	2.082	2.095		2.095	2.095
C10		2.096	2.094		2.094	2.003	2.094	2.094	2.104	2.023	2.109	1.986	2.109	2.109
C11		2.113	2.112		2.112	2.037	2.112	2.112	2.119	2.113	2.050	2.002	2.127	2.127
C12		2.044	2.042		2.042		2.042	2.042	2.052	2.044	2.058		2.058	2.058
C13		2.017	2.015		2.015		2.015	2.015	2.025	2.017	2.030			2.030
C14		2.016	2.014		2.014		2.014	2.014	2.024	2.016	2.030		2.030	

As the significance matrix has been defined, the ANP operation can be performed using the Super Decision software. The significance matrix is used in the development of the criteria relationship model, and the output of the ANP operation is the weight of each criterion. The criteria weights are illustrated in Table 6.

Table 6 Criteria description and weighting

Notation	Criteria	Definition	Description	Weight
C1	Dependability	Response time achievement that has been stated in contract document.	When the damage occurs and the provider immediately responds in a short time to deal with the damage, the provider has a good performance and the equipment can be immediately available when needed by patients.	0.0
C2	Flexibility	Flexibility in handling abnormal conditions.	Flexibility is a support level of availability criteria. The availability level of medical equipment can affect patient safety.	0.175684
C3	Service Quality	Customer satisfaction level due to provider services.	Service quality is measured from the error rate of damage handling. If the provider handling the damage is not appropriate, when the equipment is needed by the patient, then the equipment cannot function properly, influencing patient safety.	0.053293
C4	Cost	Total cost that occurs from outsourcing activities in a certain period.	If the total cost of using the provider is low, the hospital may immediately call the provider if there is damage to medical equipment, so the availability of the medical equipment is maintained.	0.0
C5	Knowledge sharing	Provider and customer relationship related with information and knowledge.	If the provider is transparent about equipment damage information, when others time minor damage occurs, the hospital can handle it on their own, thus reducing the Mean Time To Repair. Reduced MTTR can reduce the waiting time of patients who need the equipment.	0.005496
C6	Equipment	Equipment types that	More equipment that can be handled by	0.018238

Notation	Criteria	Definition	Description	Weight
	Types	provider capable to handle.	provider is better. If there are some devices that are damaged at once can be repaired simultaneously by the same provider. when medical equipment is needed by the patient, the equipment is available and reliable.	
C7	Firm Capacity	Provider capability to fulfill the maintenace contract agreement.	If the whole provider company has the ability to handle medical equipment both technically and in management, then the medical equipment is certain to be available and reliable when needed by the patient. .	0.132503
C8	Technician Skill	Technician ability to solve medical device problems or damage.	If the technician of the provider has the good ability to handle medical equipment, the medical equipment can be used properly when needed by the patient.	0.256881
C9	Administration	Quality and administration accuracy performed by maintenance service provider.	Providers with a good administrative system with a simple bureaucracy can cut the waiting time for medical equipment repairs that affect the availability of medical equipment.	0.041585
C10	Diagnosis Accuracy	Provider ability to diagnose problems on the medical devices, as well as provide diagnosis-related information to users of the service maintenance service provider.	The accuracy of diagnosis is a criterion for reliability and availability, so an accuate diagnosis can lead to better reliability and availability.	0.222181
C11	Part Availability	Availability of damaged parts replacement.	Replacement parts for the medical equipment should be available because it will shorten the repair time, so the availability of medical equipment is maintained	0.01998
C12	SOP Clarity	Clarity of standard operating procedures in performing maintenance activities and transparency to users.	Providers who have SPO clarity can perform medical equipment repairs properly, effective and efficient. When medical equipment is needed, the medical equipment is available.	0.00914
C13	Routine Reporting	Report providing after maintenance activities.	In addition to reporting after the completion of medical equipment repair activities, consumers generally expect routine reporting over a period of time. This is so then the medical equipment maintenance activities can be well documented as an experience for further improvement.	0.045708
C14	Attitude	Attitude of maintenance service provider.	Attitude of human resources at the provider end may affect the performance of the provider. Good attitude from providers is proven by technicians who work well to improve the medical equipment, so the availability and reliability of equipment is also good.	0.019312

The flexibility criterion in the must-be category had the third highest weighting among the 14 proposed criteria. The first and second rank criteria, namely technician skill and diagnostic accuracy, were the criteria proposed by expert 1 according to the weighting assigned by expert 1. The criterion for technician skill, which was proposed by some experts as a new criterion, was considered to be a uniform criterion, the highest weight of which was considered to be a representation of the real conditions in the field. The criteria of cost and dependability did not contribute to the performance assessment. In addition, the cost criterion was not preferred because it was not a major consideration as it was unlikely to change due to the fact that it is a quantity that has precise numbers. Frequently, cost is correlated with the quality of the available facilities. In medical equipment, quality is important because it is related to the safety of the patient, but cost is not the emphasis. The criterion of dependability was not considered to be an important criterion when compared to flexibility. Therefore, in the pair-wise comparison of ANP, the rate of the criterion of flexibility was 9, which means that it was more important than the criterion of dependability.

4. CONCLUSION

By integrating several methods, namely case study analysis, Delphi, Kano, DEMATEL, and ANP, a performance model was developed which can be used by the healthcare industry to assess the performance of their maintenance outsourcing providers. The resulting performance criteria can be used as a reference when assessing the performance of general outsourcing. Case study analysis and Delphi was used to determine new criteria based on the needs of the user, Kano was used to identify criteria for the basic and special dimension requirements, DEMATEL was used to determine linkages between the criteria, and ANP was used to weight the criteria. The results obtained from the Kano method indicated that the criteria that must be fulfilled (basic requirements) must also provide flexibility in terms of abnormal situations and the type of equipment that can be handled by the provider (equipment types). The three criteria that had the highest weighting were the criterion of technician skill at 0.256881, the criterion for diagnostic accuracy at 0.222181, and the criterion of flexibility at 0.175684. The two criteria that were assigned a weight of 0 (meaning that they did not contribute to performance) were the criteria of cost and dependability.

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