Internet Of Things Based Processes Improvement Of Indonesian Hospital

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Abstract

Indonesian's population is one of the highest in the world and create a potential market in the service industry especially healthcare. By the end of 2019, 85% of world business plans will implement Internet of Things (IoT). Implementation of IoT was driven by business innovation and business efficiency. This paper aims to establish a framework to integrate Internet of Things in healthcare industry especially hospital, in order to improve the overall quality of healthcare processes. Six experts' opinions are used to identify the relationship and select the factors and sub factors that supports the integration of Internet of Things in Indonesian hospital. Analytic Network Process (ANP) method is used to obtain the decision priority of healthcare practices supported by the implementation of Internet of Things. Zero-One Goal Programming (ZOGP) method is used to choose which healthcare practices will be implemented based on the optimal number of IT's employees, decision priority of ANP, procurement cost, installation cost, training cost, maintenance cost constraints. The case study was conducted to private and public hospitals in Jakarta.

Keywords
IoT, Healthcare Industry, Hospital, Analytic Network Process, Zero-One Goal Programming

1. Introduction

Indonesian's population has an average annual increase of more than 1%. By 2035 there will be more than 305 million people living in Indonesia (Badan Pusat Statistik, 2014). This relatively high number of population attracts service sector especially in healthcare industry. In 2018 there are 2776 hospitals all over Indonesia, where more than 63% of them are private hospitals. Once again this shows how much potential the healthcare industry in Indonesia has (Kementerian Kesehatan RI, 2018).

With such a great potential offered in healthcare industry, healthcare provider couldn't keep up with the customers' standards. As reported by the government, healthcare issues is the most discussed and complained topic. The report stated that healthcare issues become the number one most complained issues in 2017 and early 2018 (LAPOR!, 2017, 2018b, 2018a).

By the end of 2019 85% of business plans will implement IoT, this plan was driven by two main objective: Business innovation and Business efficiency. Report showed benefits of implementing IoT far exceeds the expectation, these will drive the business world to massively adopt IoT in 2019 (Aruba Networks, 2017).

About 60% of healthcare organizations in the world have adopted IoT, 80% of them clearly see the benefits of such adoption and 73% of them stated that one of the biggest benefit is cost saving (Aruba Networks, 2017). In this paper we, try to establish a framework to integrate Internet of Things in healthcare industry especially hospital, in order to improve the overall quality of healthcare processes Indonesia.

2. Literature Review

2.1. Healthcare Service Quality

Prior studies have concluded that quality service is one of the most important factors to be considered in order to improve patients' satisfaction. Healthcare processes improvement plays a significant role in improving and maintaining the desired level of quality service perceived by patients (Dachyar & Minar, 2018; Dachyar & Ti, 2018)

2.2. IoT Implementation in Healthcare Industry

Internet of Things (IoT) is an ecosystem that integrates hardware, devices, physical objects, software, and animals or humans in a specific network that enabled them to interact, communicate, record, obtain and share the data (Farahani et al., 2018).

Technology will play a significant role in monitoring patients in hospital and their home. Remote monitoring will offer significant benefits such as healthcare quality improvement and cost savings by identifying hazardous illnesses. Currently, the cost of healthcare is relatively high, since its mandatory for most of the patients to stay at the hospital for the entirety of the medication and healthcare process. With technology that can monitor patients remotely, we can easily addressed that problem. IoT technology collects real data in real-time and send those data to healthcare providers, thus reducing the healthcare cost and enabling early detection of disease (Ahmadi et al., 2018).

2.3. Analytic Network Process Method (ANP)

ANP method is a method utilized to solve decision-making problems without assuming the inter-dependence and inter-relation of factors within a different level or the same level of hierarchy (Saaty, 2004). To obtain the priority of each alternative in the decision-making model, pairwise comparison was used. Pairwise comparison matrices are constructed by comparing a pair of elements in regards to a specific component. ANP is used to generate the relative priority weight of healthcare practices supported by the implementation of Internet of Things (IoT).

2.4. Zero-One Goal Programming Method (ZOGP)

Goal Programming model does not optimize the objective directly. Instead, it tries to minimize the deviation of the desired goals and real achievement. The goals should be prioritized in the hierarchical priority. Deviation variables can be either positive or negative (Kim & Emery, 2000). ZOGP generates the decisions of which a healthcare practice should be implemented or not, based on the relative priority weight of healthcare practices obtained from ANP and other constraints concerned.

2.5. Research Gap

The prior studies have discussed healthcare practices that can be implemented in hospital with the support of Internet of Things (Catarinucci et al., 2015; Esteban-Cartelle, Gutierrez, & Fernandez-Ferreiro, 2017; Gharote, 2016; Kamalanathan, Eardley, Chibelushi, Collins, & Al, 2013; Rico, Cendón, Lanza, & Valiño, 2012; Sultan, 2010) and the aspects of quality that should be integrated in Internet of Things (White, Nallur, & Clarke, 2017). In this paper, we used the quality aspects as a consideration to select healthcare practices that should be implemented in Indonesian hospital. ZOGP method is incorporated to consider the constraints in the selection of healthcare practices.

3. Methods

Data Collection started by calculating the significance of factors and healthcare practices in implementing Internet of Things in Indonesian hospital by experts. The factors and healthcare practices that were previously acquired by literature review that has significance above a certain threshold will be used in this research. The ANP will be used to do pairwise-comparisons between factors and healthcare practices. The results of these pairwise-comparisons were priority vectors that represent each healthcare, that will be one of the corporate goals in ZOGP model.

3.1. Selection of Factors and Sub factors

Literature reviews obtained factors and healthcare practices that will support and can be supported by the implementation of Internet of Things technology in Indonesian hospital. Based on literature review we acquired 8 factors (31 sub factors) that support the implementation of IoT and 9 healthcare practices can be supported and further improved by the implementation of IoT. The selection of factors and subfactors that will be used further in this research would be made by seven hospitals' IT experts. The experts selected the factors and sub factors by filling in the questionnaire. The questionnaire contained Likert 5-scale measurement, where the value of 1 indicates "Very un-important," and the value of 5 indicates "Very important." The questionnaire was created to find the importance of factors that affect the implementation of IoT in hospital. The questionnaire was filled in by all six experts.

The result of the questionnaire was calculated to acquire geomean values for each factor and sub factor. Using a threshold of 3.5, every factor and sub factor that has geomean values less than 3.5 will be considered unimportant and insignificance. The final results obtained 8 factors and 29 sub factors that have geomean values higher than 3.5 which thus will be further processed in this research. The factors and sub factors are the shown in Table 1.

Table 1. The selected factors and sub factors

Factors	Functional Stability			Performance Efficiency			Compatibility		
Subfactors	Functional Completeness	Functional Correctness	Functional Appropriateness	Time-behaviour	Resource Utilization	Capacity	Co-existance	Interoperability	
Factors	Usability					Portability			
Subfactors	Learnability	Operability	User Error Protection	User Interface Aesthetics	Accessibility	Adaptability	Installability	Replaceability	
Factors	Reliability				Security				
Subfactors	Maturity	Availability	Fault Tolerance	Recoverability	Confidentiality	Integrity	Non-repudiation	Accountability	Authenticity
Factors	Maintainability								
Subfactors	Reuseability	Analysability	Modifiability	Testability	Effective production planning technique				

3.3 Relative Priority of Factors and Sub factors

The ANP model consists of factors, sub factors, and alternatives. the arrows that connect one factor to other factors and one sub factor to other subfactors represent the inter-relation between those elements. The ANP model is shown in Figure 1.

Six hospitals' IT experts were asked to fill in the questionnaire to do a pairwise-comparison. The questionnaire contained Likert 9-scale measurement. The scale represents the weight of importance of one factor to other factor. For example, we have two elements, a and b. In the questionnaire we filled in 2, this means that element a is two times more important than element b. If the questionnaire was filled in with the value of ½, then element b is two times more important than element a. All inconsistency ratio of each factor and sub factor are less than 0.1, meaning all experts inputs are validated and acceptable as shown in Table 2. The final result of the ANP is the normal values of each alternative. The higher their value the higher their priority to be implemented in healthcare practice. The final weight of each alternative in Table 3 is obtained by normalizing the Weighted Super matrix.

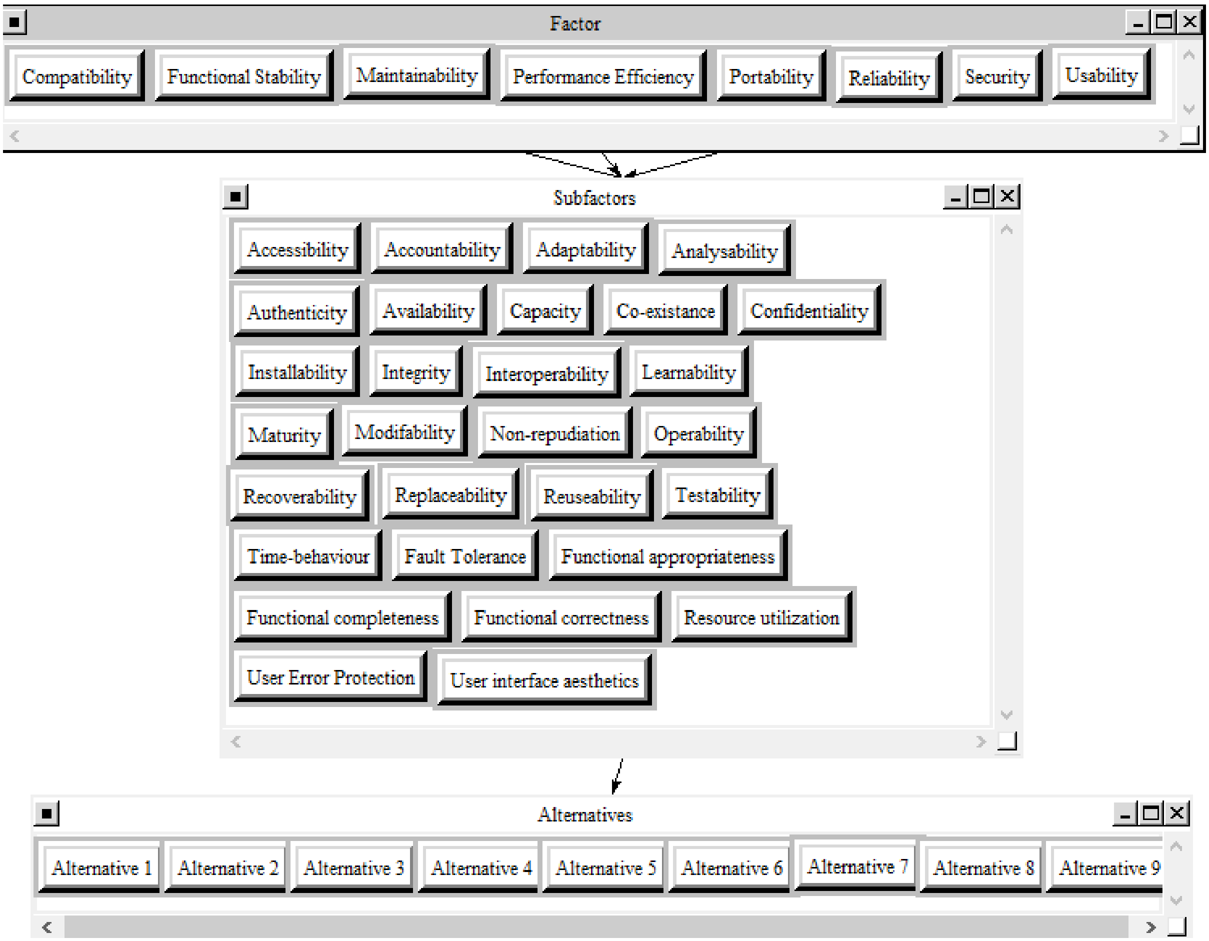

Figure 1. ANP Model

Table 2. Inconsistency Ratio related to decision priority of each factors, sub factors and alternatives

Name	Inconsistency Ratio
Compatibility	0.089
Functional Stability	0.059
Maintainability	0.075
Performance Efficiency	0.050
Portability	0.065
Reliability	0.080
Security	0.091
Usability	0.045
Accessibility	0.098
Accountability	0.097
Adaptability	0.097
Analyzability	0.099
Authenticity	0.099
Availability	0.099
Capacity	0.099
Co-existence	0.098
Confidentiality	0.099
Fault Tolerance	0.099
Functional Appropriateness	0.099
Functional Completeness	0.098

Name	Inconsistency Ratio
Functional Correctness	0.099
Installability	0.099
Integrity	0.099
Interoperability	0.099
Learnability	0.097
Maturity	0.098
Modifiability	0.099
Non-repudiation	0.095
Operability	0.096
Recoverability	0.099
Replaceability	0.092
Resource Utilization	0.089
Reusability	0.069
Testability	0.098
Tame-behavior	0.098
User Error Protection	0.083
User Interface Aesthetics	0.098

Table 3. Final weight of each alternatives

Alternative		Normals
1	Hospital Logistics System	0.079
2	Patient Discharge Planning System	0.104
3	Drug Dispenser System	0.166
4	Pharmaceutical Compounding System	0.122
5	Drug Storage and Distribution System	0.097
6	Smart Hospital System	0.139
7	Medical Equipment Locator System	0.098
8	Medical Safety System	0.094
9	Intelligent arm wrist	0.101

3.3. Construction of ZOGP Model

We use five constraints, which are the relative priority of ANP that have inconsistency ratio less than 0.1, procurement and installation cost, training cost, maintenance cost, and the number of IT staffs.

$$\min = w_{anp} d_1^- + w_p d_2^+ + w_t d_3^+ + w_m d_4^+ + w_s d_5^+$$

$$subject\ to:$$

$$\sum_{j=1}^{n} w_{jANP}\, x_j + d_1^- - d_1^+ = 1 \qquad \sum m_{j\,x_j} + d_4^- - d_4^+ = M$$

$$\sum t_{j\,x_j} + d_3^- - d_3^+ = T \qquad \sum s_{j\,x_j} + d_4^- - d_4^+ = S$$

$$x_j \in \{0,1\}, \qquad j \in (element\ of\ alternatives) \qquad d_1^-, d_1^+, d_2^-, d_2^+, d_3^-, d_3^+, d_4^-, d_4^+ \geq 0$$

Where w_{anp} is the priority weight of ANP in the objective function, w_p is the priority weight of procurement cost in the objective function, w_t is the priority weight of the training cost in the objective function, w_m is the priority weight of the maintenance cost in the objective function, w_s is the priority weight of the number of IT staff in the objective function, w_{jANP} is the ANP decision priority of Alternative j, x_j is j^{th} alternative, p_j is the cost spent to procure and install Alternative j, P is the procurement and installation budget limitation, tj is the cost spent to train health-workforce for alternative j, T is the number of training budget limitation. mj is the cost spent to maintain alternative j, M is the maintenance cost limitation. sj is the number of IT employees available to be responsible for alternative j, S is the number of IT staff limitation.

To determine the resource needed to implement every alternative, we created a questionnaire. This questionnaire contained how many or how much resources would be needed to implement every alternative. The result of the questionnaire is shown in Table 4.

Table 4. Resource needed to implement each alternative

Alternative	H	Procurement Cost (Rupiah)	Training Cost (Rupiah)	Maintenance Cost (Rupiah)	Number of IT Staff
1	Hospital Logistics System	120,000,000	12,000,000	24,000,000	8
2	Patient Discharge Planning System	150,000,000	15,000,000	30,000,000	8
3	Drug Dispenser System	80,000,000	8,000,000	16,000,000	4
4	Pharmaceutical Compounding System	200,000,000	20,000,000	40,000,000	4
5	Drug Storage and Distribution System	80,000,000	8,000,000	16,000,000	4
6	Smart Hospital System	1,500,000,000	20,000,000	150,000,000	12
7	Medical Equipment Locator System	200,000,000	20,000,000	40,000,000	8
8	Medical Safety System	200,000,000	20,000,000	40,000,000	8
9	Intelligent arm wrist	200,000,000	20,000,000	40,000,000	8

Six hospitals' IT experts decided that all deviations in the objective function are as follow:
$w_{anp} = 12, w_p = 12, w_t = 1, w_m = 6, w_s = 5$

Based on the data obtained, we showed mathematical model of scenario 1, as follows:

Priority 1. Vector priority of ANP, with the sum of 1.
$0{,}079X_1 + 0{,}104X_2 + 0{,}122X_3 + 0{,}16X_4 + 0{,}097X_5 + 0{,}139X_6 + 0{,}098X_7 + 0{,}094X_8 + 0{,}101X_9 + d_1^- - d_1^+ = 1$

Priority 2. Minimize the procurement and installation cost to 500 (in million rupiah)
$120X_1 + 150X_2 + 80X_3 + 200X_4 + 200X_5 + 1500X_6 + 200X_7 + 200X_8 + 200X_9 + d_2^- - d_2^+ = 500$

Priority 3. Minimize the training cost to 40 (in million rupiah)
$12X_1 + 15X_2 + 8X_3 + 20X_4 + 20X_5 + 20X_6 + 20X_7 + 200X_8 + 20X_9 + d_3^- - d_3^+ = 40$

Priority 4. Minimize the maintenance cost to 50 (in million rupiah)
$24X_1 + 30X_2 + 16X_3 + 40X_4 + 16X_5 + 150X_6 + 40X_7 + 40X_8 + 40X_9 + d_4^- - d_4^+ = 50$

Priority 5. Minimize the number of IT staffs needed to 10
$8X_1 + 8X_2 + 4X_3 + 4X_4 + 4X_5 + 12X_6 + 8X_7 + 8X_8 + 8X_9 + d_5^- - d_5^+ = 10$

Binary model
$X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9 = 0, 1$

Non-negativity
$X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, d_1^-, d_1^+, d_2^-, d_2^+, d_3^- - d_3^+, d_4^-, d_4^+, d_5^-, d_5^+ > 0$

Objective function
min $12d_1^- + 12d_2^+ + d_3^+ + 6d_4^+ + 5d_5^+$

The results of scenario 1 ZOGP is shown in Table 5.

Table 5. Results of ZOGP - first scenario

Variable	x_j
d_1^-	0,718
d_2^+	0
d_3^+	0
d_4^+	0
d_5^+	0
X_1	0
X_2	0
X_3	1
X_4	0
X_5	1
X_6	0
X_7	0
X_8	0
X_9	0
d_1^+	0
d_2^-	0
d_3^-	0
d_4^-	0
d_5^-	0

Value of $x_j = 1$ indicates that certain healthcare practice is implemented and the value of $x_j = 0$ indicates that certain healthcare practice is not implemented in that particular scenario.

4. Results and Discussion

4.1. The results of Healthcare Practice selection based on ZOGP Model

Apart from, the original ZOGP calculation (Scenario 1), we also calculate the Model when the hospital has a higher budget limitation - two times higher than the current value (Scenario 2) and when the hospital has a lower budget limitation – half of the current value (Scenario 3). It can be seen in Table 6. that different scenario resulted in a different decision, but 1 healthcare practice can be implemented in any scenario. That healthcare practice is X_3.

Table 6. Results of ZOGP - all scenarios

Variable	Scenario 1	Scenario 2	Scenario 3
	Value	Value	Value
d_1^-	0.718	0.542	0.878
d_2^+	0	0	0
d_3^+	0	0	0
d_4^+	0	0	0

Variable	Scenario 1	Scenario 2	Scenario 3
	Value	Value	Value
d_5^+	0	0	0
X_1	0	1	0
X_2	0	0	0
X_3	**1**	**1**	**1**
X_4	1	1	0
X_5	0	1	0
X_6	0	0	0
X_7	0	0	0
X_8	0	0	0
X_9	0	0	0
d_1^+	0	0	0
d_2^-	0	0	0
d_3^-	0	0	0
d_4^-	0	0	0
d_5^-	0	0	0

4.2. Analysis of ZOGP scenarios

The result objective function from each scenario can be seen at Table 7.

Table 7. Objective function comparison of each scenario

Scenario	Budget-constraint multiplier	Objective function	Objective function percentage difference from normal scenario
1	1	9.372	0%
2	2	6.504	30.6%
3	0.5	10.536	12.41%

Based on the result obtained from scenario 1 through 3, it can be seen that budget constraint is inelastic to the objective function. In scenario 2 when the budget multiplier is increased by 100%, it only improves the objective function by 30.6%, whereas decreasing the budget multiplier by 50% in scenario 3 only worsen the objective function by 12.41%. This difference in objective function is solely affected by the first constraint (weight of ANP).

5. Conclusion

This research found 8 factors and 29 sub factors that can support the implementation of IoT in healthcare practice, Those factors are functional stability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. Drug dispenser System, Smart Hospital System, and Pharmaceutical Compounding System are IoT supported-healthcare practices with the highest value based on qualitative parameters. One healthcare practice can be implemented in any scenario based on the results of ZOGP. That healthcare practice is Drug Dispenser System.

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