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The Alternative Selection for Internet of Things (IoT) Implementation in Medical Rehabilitation

Rayi Adila Paramita[1] and Muhammad Dachyar[2]
[1]*Department of Industrial Engineering, Universitas Indonesia, Depok 16424, Indonesia*
[2]*Department of Industrial Engineering, Universitas Indonesia, Depok 16424, Indonesia*
[1]rayiadila@gmail.com, [2]mdachyar@yahoo.com

Abstract

Medical rehabilitation services face problems in terms of limited duration and intensity of therapy. The implementation of the Internet of Things (IoT) in medical rehabilitation helps doctors and nurses to provide accurate care and faster recovery which could improve the service quality. This study aims to choose the best alternative IoT that can be implemented in medical rehabilitation units in hospitals by taking into account the factors of IoT implementation and hospital financial capability. The alternative options for implementation of IoT: Motion Gaming Rehabilitation, Virtual reality-based rehabilitation, Robot Therapy, Brain Computer Interfaces. The opinions of experts were used to identify and select factors and sub-factors that support the process of applying IoT in medical rehabilitation in hospitals. The Best Worst Method (BWM) method is used to obtain priority weighting from the criteria and sub-criteria for applying IoT. The Additive Ratio Assessment (ARAS) method is used to obtain the utility level of each alternative IoT. The Zero One Goal Programming method is used to decide whether the implementation of IoT is chosen based on limitations such as the ARAS utility level of each alternative, procurement and installation costs, training costs, and maintenance costs. The final result, virtual reality-based rehabilitation is chosen based on the factors of IoT implementation and the hospital financial capability.

Keywords: *Internet of Things (IoT), Medical Rehabilitation, Best Worst Method (BWM), Additive Ratio Assessment (ARAS), Zero One Goal Programming (ZOGP)*

1. Introduction

More than one billion people worldwide are affected by damage to the neurological system which cause disability [1]. This damage as a result of illness or injury. Medical rehabilitation is seen as a way to improve the quality of life of people with disabilities. Reducing recovery time after a stroke is a real challenge for therapists, thus intensive training is needed to exploit the full potential of recovery. The technology known as the Internet of Things (IoT) has helped practitioners and researchers to design innovative solutions in different contexts, especially in health care [2]. IoT has been proven to help provide more intensive training which provides better rehabilitation outcomes, for example in individuals with stroke and reducing hospital admission rates. IoT-based rehabilitation provides comfort, effective care, adequate interaction, and rapid reconfiguration to make maximum use of medical resources according to the specific needs of the patient [3]

Benefit of implementing IoT make the business world will move towards massive adoption. The opportunity to implement IoT is high, but the implementation of IoT still has obstacles. High cost is one of the leading obstacle in implementing an IoT solution [4–7]. Organizational factors, security, low trust in the IoT, the availability of human resources who understand IoT technology also determines the decision in organizations to implement the IoT [8, 9]. Hospital need to determine the priorities of the IoT in increasing the effectiveness of health services in medical rehabilitation.

This study aims to choose the best alternative of IoT in medical rehabilitation by taking into account the factors of IoT application and the financial capability of the hospital from experts judgment. The IT expert role as manager and coordinator. The medical rehabilitation unit expert role as doctors, physiotherapists, and nurses.

Medical rehabilitation is a health service for patients who experience physical and body functions, due to illness or injury [1]. Medical rehabilitation services together with physiotherapy services, help patients for developing, maintaining and restoring bodily movements and functions using manual treatment, increased motion, equipment (physical, electrotherapeutic and mechanical), functional and communication training.

Two main functions in the implementation of IoT-based rehabilitation: 1) prompt and accurate diagnosis for patients; and 2) develop rehabilitation strategies based on diagnosis. Compared to traditional hospital rehabilitation, IoT-based rehabilitation provides comfort, effective care, adequate interaction, and rapid reconfiguration to make use of medical resources suitable to the specific needs of patients [3]. The application of IoT in medical rehabilitation that required according to the expert's description that can be provide by particular IoT technology; Motion Gaming Rehabilitation, Virtual Reality-Based Rehabilitation System, Robot Therapy, and Brain Computer Interfaces (BCI).

Best Worst Method (BWM), Additive Ratio Assessment (ARAS), and Zero-one Goal Programming (ZOGP) were used in this study. This study complement the gap from previous studies by integrating the three methods in a hospital unit that has never been previously studied, namely in the medical rehabilitation unit.

2. Methodology

A new unique method integrating BWM, ARAS and ZOGP is suggested to solve IoT technology selection in this study which consists of five stages. First stage was obtain IoT implementation factors from previous studies. Second stage was to validate IoT factors with experts. Third stage was calculate the relative weight of each criterion based on the experts judgment by BWM. Fourth stage was obtain a utility function of each alternative IoT technology by ARAS method. Fifth stage was decide whether the application of the IoT is chosen based on quantitative constraints by ZOGP method.

3. Result and Discussion

3.1 Validation of IoT Technology Adoption Factors and Subfactors

Based on the review of the literature, there are 6 factors and 30 subfactors. Validation of these factors will be conducted by hospitals' experts through a Likert 1-5 scale questionnaire where 1 represents very unrelated and 5 represents very related. The threshold for the factors and subfactors are 3,44 [10]. After this step, the results shows that there will be 6 factors and 29 subfactors as shown in Table 1.

Table 1. The Selected Factors and Subfactors of IoT Technology Adoption

Factors	Subfactors	Ref.	Factors	Subfactors	Ref.
Technology	Reliability	[11]; [12]; [13]		Compatibility	[14]; [15]; [16]
	Complexity	[14]; [15]; [16]		Availability	[17]; [18]; [19]

Factors	Subfactors	Ref.	Factors	Subfactors	Ref.
Organization	Corporate Strategy	[20]; [21]; [22]	Security	Confidentiality	[17]; [18]; [19]
	Management Support	[20]; [23]; [24]		Non Repudiation	[17]; [18]; [19]
	Technology Competence	[20]; [25]; [26]		Privacy	[17]; [18]; [19]
	Cost Effectiveness	[27]; [28]; [29]	Perceived of Usefulness	Sharing	[27]; [38]; [28]
	Budget Availability	[20]; [30]; [31]		Medical History	[27]; [39]; [28]
Environment	Regulation	[32]; [25]; [23]		Time Saving	[27]; [40]; [41]
	Convenience of Use	[33]; [34]; [35]		Error Identification	[38]; [15]; [42]
	Pressure from External	[25]; [23]; [14]		Quality of Care	[27]; [38]; [43]
	Consumer Expectations	[36] ;[31]; [37]	Perceived Ease of Use	Usability	[32]; [44]; [45]
Security	Authentication	[17]; [18]; [19]		Customization	[33]; [44]; [46]
	Authorization	[17]; [18]; [19]		Accessibility	[32]; [47]; [44]
	Integrity	[17]; [18]; [19]		Responsiveness	[47]; [40]; [15]
				User Interface	[27]; [32]; [44]

3.2 Validation of IoT Technology Adoption Factors and Subfactors

Weighting factors and subfactors for implementing IoT is done by using the Best-Worst Method (BWM). The weighting of factors and subfactors is based on expert judgment by filling in questionnaire. In accordance with the stages of the BWM method, each expert will be asked to select the best (most important) factors and subfactors, as well as the worst (least important) factors and subfactors for each criterion. The results of data processing using the BWM method are local weights for each factors and subfactors [48]. To get the global weighting of each subfactor, the value of the factor weight is multiplied by the local weight value of the subfactor. The priority weight obtained will be an input to assess internet of things technology alternatives.

3.3 IoT Technology Assessment

IoT Technology Assessment is carried out using the Additive Ratio Assessment (ARAS) method. The ARAS method is used to compare utility functions from alternatives with optimal utility function values. In accordance with the ARAS method stage, each expert will be asked to assess the technology of the IoT subfactors that have been identified. The utility level (Qi) of each alternative can be seen in Table 2. The utility level will be an input for the ZOGP model.

Table 2. Utility Level of Each Alternative

Technology Alternative	Qi
Virtual reality	0,9093
Robot Therapy	0,9125
Motion Gaming Rehabilitation	0,8844
Brain computer interfaces	0,9054

3.4 Construction of ZOGP Model

In this study, the outcome of ZOGP was the decision to implement or not implement IOT technology for medical rehabilitation in hospitals. The construction of objective functions is carried out by using questionnaire to determine the preference level based on stakeholders' goal in making the decision. The priority weights of the objectives are shown in Table 3. Next, to construct the constraints, input from previous processes is needed and using questionnaire to determine financial capability of the hospital.

Table 3. Weight of Goals

	Goal	Weight
1	Utility Level	10
2	Installation Cost	10
3	Training Cost	1
4	Maintenance Cost	5

$$Min = \sum_{i=1}^{n} w_{iARAS}\left(g_i {d_i}^- + g_i {d_i}^+\right) = w_1\left(g_1 {d_1}^- + g_1 {d_1}^+\right) + w_2\left(g_2 {d_2}^- + g_2 {d_2}^+\right) + \cdots + w_n\left(g_i {d_i}^- + g_i {d_i}^+\right) \quad (1)$$

Subject to:

$$\sum_{j=1}^{4} Q_{jARAS}\, x_j + {d_1}^- - {d_1}^+ = 4$$

$$\sum_{j=1}^{4} i_J\ x_j + {d_2}^- - {d_2}^{\ +} = I$$

$$\sum_{j=1}^{4} t_J \; x_j + {d_3}^- - {d_3}^+ = T$$

$$\sum_{j=1}^{4} m_J \; x_j + {d_4}^- - {d_4}^+ = M$$

$$x_j \in \{0,1\}$$

$$j \in (element\ of\ alternative)$$

$${d_1}^-, {d_1}^+, {d_2}^-, {d_2}^+, {d_3}^-, {d_3}^+, {d_4}^-, {d_4}^+ \geq 0$$

Where *w*aras is the priority weight of ARAS in the objective function, *w*i the priority weight of the installation cost on the objective function, wt is the priority weight of the training costs on the objective function, wm is the priority weight of the maintenance cost on the objective function, and QjARAS is the ARAS utility function from Alternative j. xj is an alternative to j, ij is the cost incurred to procure and install alternative j, I is the budget limitation of the procurement and installation process, tj is the costs incurred for training employees to learn alternative technologies j, T is the budget limitation of the process employee training, mj is the cost incurred to maintenance for alternatives j, M is the budget limitation of the perform maintenance process. Therefore, based on the data obtained, the mathematical model is as follows:

- Objective function

  $Min.Z = 10\ d_1^- + 10\ d_2^+ + d_3^+ + 5\ d_4^+$ (2)

- 1st constraint. Utility level of IoT implementation alternative is equal to 4

  $0{,}9093X1 + 0{,}9125X2 + 0{,}8844X3 + 0{,}9054X4 + d_1^- - d_1^+ = 4$ (3)

- 2nd constraint. Minimizing procurement and installation cost to $15000

  $11250X1 + 26250X2 + 5625X3 + 9000X4 + d_2^- - d_2^+ = 15000$ (4)

- 3rd constraint. Minimizing training cost to $1500

  $750X1 + 2625X2 + 750X3 + 750X4 + d_3^- - d_3^+ = 1500$ (5)

- 4th constraint. Minimizing maintenance cost to $2200

  $1650X1 + 6424X2 + 880X3 + 1474X4 + d_3^- - d_3^+ = 2200$ (6)

The results of selection model of IoT implementation in medical rehabilitation hospitals are shown in Table 4.

Table 4. Result of ZOGP

Variable	Value
X_1	1
X_2	0
X_3	0
X_4	0

The results shown in Lingo 17, X1 (Virtual reality-based rehabilitation), X2 (Robot therapy), X3 (Motion gaming rehabilitation) and X4 (Brain computer interfaces) represent the first to fourth alternative IoT. In the Lingo results obtained, in the "value" section there are numbers 0 and 1, where the number 0 indicates that the application of IoT was not selected while number 1 indicates the application of the IoT was chosen.

3.5 Analysis of ZOGP Scenarios

From the previous data processing, the results of the selection of IoT implementation in medical rehabilitation is virtual reality-based rehabilitation system. The author wants to find out whether there will be a change in technology priority after making scenarios in the use of the ZOGP model for the implementation of IoT in medical rehabilitation.

There are 2 ZOGP scenarios in the selection of alternatives to the application of IoT technology in medical rehabilitation to improve the health care process, each scenario shows a change in the limits of resources owned by the company. The first scenario, the hospital budget is increased to 1,5 times the current budget. The second scenario, when the budget of the hospital is increased to double the current budget. The comparation between the scenarios are shown in Table 5.

Table 5. Result of ZOGP

Scenario	I	T	M	Selected Alternative	Min Z
Current	15000	1500	2200	*Virtual reality*	31
1	22500	2250	3300	*Virtual reality*, *Brain computer interfaces*	22.1
2	30000	3000	4400	*Virtual reality*, *Brain computer interfaces*, *Motion Gaming Rehabilitation*	13.3

The greater the hospital's resources, the more IoT alternatives will be chosen. With an increase in the number of IoT alternatives implemented, the objective function is also increasingly optimal (minimization of the objective function). It is necessary to compare the changes in the resources owned with the changes in the objective function produced. The percentage change in the use of the amount of resources used in scenario 1 to current scenario is 50% resulting in a change in objective function of 29%. If the two values are used as a basis for determining productivity in alternative implementations, it can be said that scenario 2 is expected to provide a change in objective function of 58%, but the change obtained in objective function of scenario 2 is only 57%.

4. Conclusion

The integration of MCDM method: BWM, ARAS, and ZOGP, and utilizing internet of things to support the technology selection in the medical rehabilitation is

proven can achieve the research goal that is to choose the best alternative of IoT in medical rehabilitation by taking into account the factors of IoT application and the financial capability of the hospital.

In this study 6 criteria and 29 sub-criteria were used in the selection of IoT technology in medical rehabilitation. There are two analyzes obtained in the selection of IoT technology in hospital medical rehabilitation. Based on ARAS analysis, the best technology is robot therapy. According to the experts, robot therapy is the most needed in their workplace, while based on ZOGP analysis, the best technology is Virtual reality-based rehabilitation technology, which is the most financially feasible technology according to IT procurement.

Further conclusion is using the rising budget scenario. Scenario 1 when the budget is increased to 1.5 times the hospital budget and scenario 2 when costs are increased to double the hospital budget. Based on 2 ZOGP scenarios calculated by adding the hospital's resources. Scenario 1 that implements virtual reality-based rehabilitation and brain computer interfaces provides the highest increase in productivity with the addition of smaller resources.

5. References

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