

Automation Factors Influencing the Operation of IoT in Health Institutions: A Decision Support Methodology

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Abstract

Health institutions are adopting new technologies for their processes through automation by means of the concept of "Internet of Things" (IoT). Hence, offering innovative tools, applications and technology for the collection of key data and information, which is then integrated and consolidated, covering the different systems and their collaborators. The necessity of receiving quality medical services is essential in the public Policy of any country. The increasing demand for having an adequate number of medical specialists, pharmacies and medications stock, dental and mental health coverage and other, together with the minimization of the waiting list and patient care time have been a crucial concern. Under this context, it is valuable to redesign the processes planning and its coordination through the use of Information & Communications Technology (ICT) and IoT that unifies the systems. Based on previous research, the general purpose is to generate a system model to examine healthcare quality of service and corroborate its effectiveness in a real environment. The aim of this paper focus on the development of a decision support model to define key areas where the inclusion of IoT would sustain the efficiency in health care service. The research methodology is based on case study, integrating planning processes, data analysis, scoring method that interacts with multicriteria approach. A pilot case study is pursued in health institutions in Chile, determining critical factors and the current automation level system appraisal to generate actions of improvement in processes that show poor service quality. The results give rise to the development of an investment plan that can be converted into action plans for a health institution.

Keywords: automation, IoT, healthcare system.

1 Introduction

Today almost all organizations are digitized to a greater or lesser extent. The digitization requires a digital transformation that will force the organization to a great change to face this need. Health institutions are not unaware to this transformation since they feel pressure to improve the quality of service. Hospitals are focused on how to find new strategies to improve service, to allocate resources for the health professional and to meet the needs of citizens. It is essential to improve process. The contribution of the technological incorporation and ICT system with in hospital infrastructure, has played a great role in the health service, decreasing waiting times and others, thus much remains to be done. It is hoped that the implementation of IoT will improve the efficiency of processes in hospitals [6].

The fact that the Internet is present at the same time everywhere, allows the integration of sensors and devices into everyday objects, to be connected to the Internet through fixed and wireless networks. This leads to having the possibility of an innumerable applications such as small sensors that let to measure the temperature of a room or surveillance cameras, gaining communication capacity and to decrease the barriers that separate the real world from the virtual. Then more objects are being integrated with sensors, we can also find what's called smart health and automation. Therefore, there is interest in finding a method to determine the possible level of automation in health institutions and generate actions to make improvements in those processes that show poor quality of service. From previous author's research, this document focuses on developing a decision model by identifying levels and processes involved within a health institution, collecting, managing and interpreting the available information. The research methodology is based on case study, employing multi-criteria approach and by the use of the Analytical Hierarchy Process (AHP) [1, 15, 23, 25].

The output is a framework for defining priority areas for inclusion of the IoT, to improve and/or support the quality of health service according to user's requirements. Such as: improvement in the access of patient information by health professionals, in-corporation of medical devices, applications to improve the quality of life of chronic patients, improve efficiency in healthcare services, improve climate control infrastructure, and others.

A pilot study has been carried out at health institution in a region of Chile, with the aim of determining the desired degree of automation. These results lead to the development of an investment plan that can be turned into action plans for a health institution. Next section provides literature review, section 3 the system description, the following sections present the model development, its results and conclusions.

2 Literature review

Unique challenges have been faced, by the health area, to adapt to new technologies since the environment for health care organizations contains many forces that demand unprecedented levels of change such as demographic changes, higher user's expectations, greater competition and intensification of government pressure. In this perspective the decision support systems in the health sector has had a positive impact in the service provided.

Ciprin Candea et al. 2019 [5] emphasizes the importance of this systems and prepared an architecture for them. Also, the health care relationships and quality of service are important attributes of hospital performance that can be difficult to measure, interpret, and compare with other organizations. Several authors have contributed to emphasize the significance of the support provided by the management of ICT, Mobile technology (MT)&IoT [8] in the health and the need to improve the technological level.

Several mathematical aspects of IoT devices signals processing are presented in [20, 21]. The incorporation of IoT manages to improve efficiency in energy consumption we can see in the [3, 6, 7, 17].

Even though, Biet al. [4], proposes to incorporate technology gradually, since the incorporation of information technology (IT) infrastructure impacts performance.

Other applications that benefit from IoT are the identification of the status of the different sensors in the home by big data analysis pointed out by Jung et al. 2010 [11]. Also, Kashef et al. (2016) [12]

who mention the use of IoT to determine the lowest cost of hosting information in the cloud. However, is still pending to improve the data checking [16].

Another use of IoT systems is what Kovács & Csizmás (2018) [13] describes, stating that these systems, support decision-making at operational or tactical levels and increase flexibility and productivity [14, 24] mean that IoT is enabled by the latest developments in RFID, smart sensors, communication technologies and Internet protocols.

The basic premise is that smart sensors collaborate directly without human involvement to deliver a new class of applications. In the coming years, IoT is expected to connect various technologies to enable new applications by connecting physical objects in support of intelligent decision-making [29].

Giménez et al. (2019)[10] analyses the performance of 602 Colombian hospitals for the period 2009-2013. The analysis is performed from both static and temporal perspectives to assess the evolution of total factor productivity (change in hospital performance) and their components over the period. The results speak of improvements in efficiency through ICT. One particular case of application was the improvement in the rate of waiting for care in the area of traumatology noted in the study of Pinnarelli et al. (2012) [22], applying IoT, managing to increase the number of attentions by 46% and 34% respectively.

Meanwhile, the authors in [26], suggests that hospital evaluations create competition among health care providers. A multi criteria decision-making (MCDM) method is used to assess criteria that affect the quality of hospital service. AHP and other tools are applied are used for evaluating quality of service at hospitals. In Torkezad & Beheshtinia work (2019) [27] presents an IoT application, indicating that the automated health care system is the necessity and future of health care in India. In this regard, Wang et al.[28] will mention that improving technology generates a substantive impact in rural areas, as is the case with reality in China. This is how Zois [30] states that IoT technology and infrastructure have the potential to revolutionize the delivery of health services.

Networked body detection devices along with sensors in our living environment enable continuous, real-time collection of information related to an individual's physical and mental health and related behaviors. Captured continuously and aggregated, such information needs to be exploited effectively to enable real-time, continuous and personalized monitoring, treatment and interventions. But, medical decisions are often sequential and uncertain in nature.

Ajami & Ketabi[1] proposes in its study to evaluate the performance of the Medical Records Department (MRD) of selected hospitals in Iran through the use AHP. The results showed that the archive unit received the greatest importance with regard to information management. However, in respect to the user, the admission unit has received the greatest weight. This information allows managers to allocate and prioritize resources according to AHP's technique for classification in the MRDs.

3 System description

Considering the context expressed in previous section, this study concerns the development of a decision model with the aim to determine the degree of automation that would contribute to strengthen the service offered in hospitals, where the results will allow decision makers(DM)to develop an investment plan that can be turned into action plans for each health institution. Taking into account that health service users wishes to have different ICT and IoT applications to support operations and the health activities services and due to limited resources the health institution's ICT system applications do not always meet the user's requirements (quality level, performance, cost and others)there will be the omission of some with preference over others. In view of that, it is possible to distinguish critical representative users involved, as per, patients who demand fast medical assistance, with accurate, secure and confidential information about their health status. Doctors who require information about their patients, including that of other professionals, for complementary tests, instantly and at the site of care. The administrative staff who need information and tools that allows them to evaluate effectiveness and practice, to review and process data and costs and others. We put forward a multicriteria approach since it allows to face conflicting objectives through the use of AHP [2, 18, 19] that helps to establish criteria and classify user preferences. Then, for this study, potential and current ICT

and IoT users are classified into three groups: The patients, the doctors including clinical care staff (doctor, nurses, paramedics, etc.), and third group users performing administrative activities, billing, product distribution and inventory control. Empirical data is collected from three type of hospitals, public, private and regional to investigate infrastructure and needs. A pilot case study is developed involving a regional health institution.

4 Research methodology

The key research is related to the effect of the incorporation of new ICT and Hospital 4.0 in the health sector to strengthen service. The study is conducted in three parts. Initially it seeks to identify the critical factors and attributes that the user of health sys-tem considers important in meeting a service requirement and to define a set of criteria that will help DMs to evaluate the support of ICT and/or IoT alternatives. Through questionnaires, interviews and field observation, data and statistics is collected from hospital representatives and patients .Thus, many factors emerge and the critical effects of the implementation of some service activities need to be recognized. This practice allows for the next step to be taken, to structure the problem situation, integrating the main elements and generating a hierarchy structure that have to be validated by an expert group. Then, representatives from each type of user in the hospital form a team of experts. The last stage involves an assessment procedure through a pair comparison process.

Through the AHP method the different factors and elements considered in the hierarchy are clas-sified and evaluated. The experts' judgment is based on their own experience and knowledge. The weighting of the measured attributes of each activity is then recorded to obtain a rating on the value of the IoT support for each activity that would lead to an improvement of the service.

5 Case study

The case study takes place in a regional public hospital of high complexity in Chile. Following the methodology, with the information obtained previously, it was possible to design a hierarchy structure that was validated by an expert panel made up of representatives of each considered cluster named as Doctors group (Physician, nurse, para-medics etc.), Patients and Administrative Staff. This group totals 24 experts.

5.1 AHP hierarchy model

The hierarchy structure model is displayed in Figure 1. The overall goal states the importance of IoT and ICT support in healthcare-related activities. Clusters at level 1, refers to user crite-

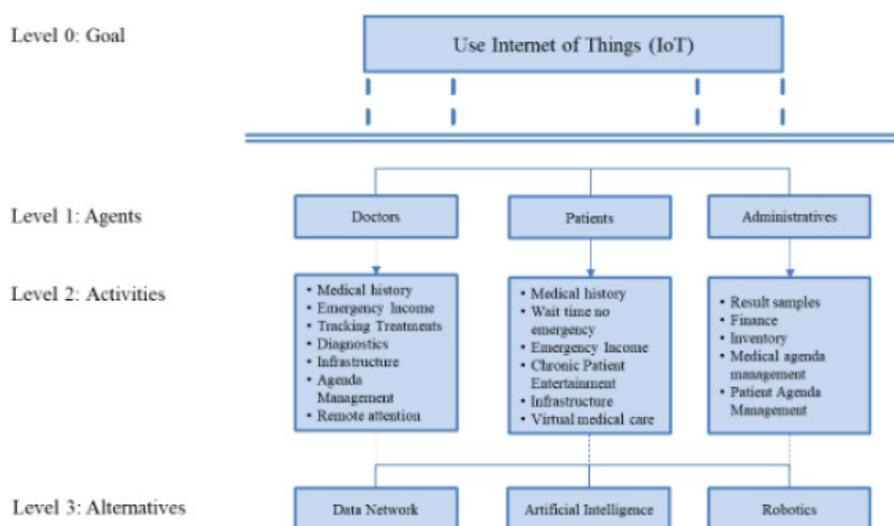


Figure 1: Initial hierarchy model

ria/perspective, named agents. Level 2 to the activities/applications, where users are involved in and would need ICT and /or IoT support. The third level represent the alternatives to provide these requirement.

AHP utilizes pairwise comparison procedure, to estimate the importance or priority of the factors involved. To put into action the model, we use the software Expert Choice TM.

5.2 Pairwise evaluation

Considering the current situation, applying AHP, the expert panel followed the pairwise evaluation process, along the hierarchy, based on their judgment and experience.

A first result is shown in Figure 2 indicating the relative importance of the alternative support for agents. Additionally, it can be seen that in relative terms the greatest importance is for the group of Doctors to have ICT and/or IoT support to develop their tasks.

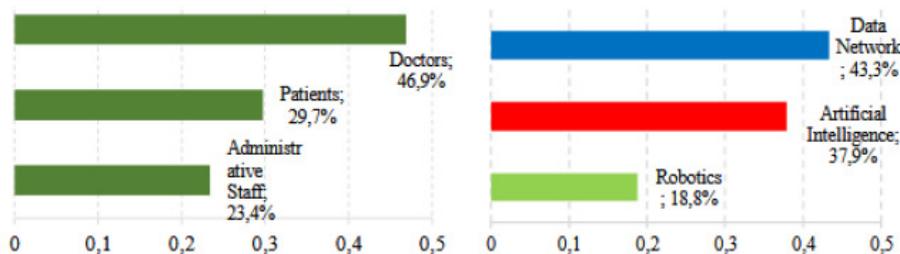


Figure 2: Experts panel overall relative priorities

Where, the clusters representing the use of Data Network and the use of Artificial Intelligence, tell to have more importance to support activities to all participants, with a priority of 43.3% and 37.9% respectively.

6 Result discussion

With regard to the requirements of IoT applications, from the Doctors group perspective, the results point out a slight preference for Artificial Intelligence over the Data Network to develop their healthcare service activities. As seen in Figure 3.

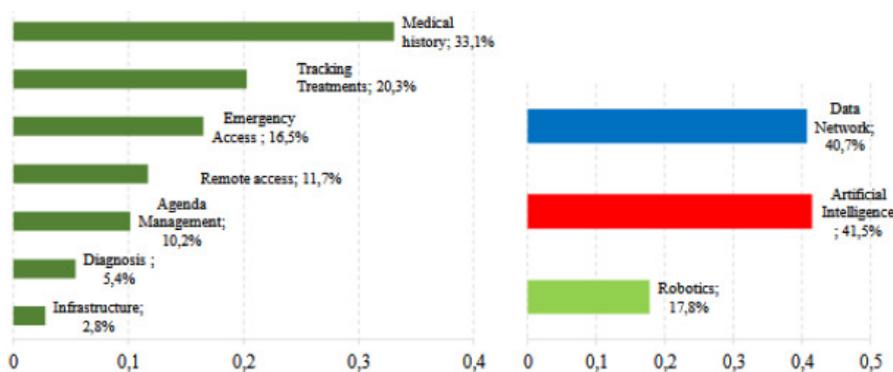


Figure 3: Priority results from doctor's perspective

This relative importance lies in the usefulness of having access to the patient's Medical History. (33,1%).

On the other hand , in the comparison between Data Network versus Artificial Intelligence to meet Doctors support necessities, in this case, Artificial Intelligence has priority to support the provision for Emergency Access and disease Diagnosis follow by Tracking Treatments according to the initial results.

From Patients perspective, the results indicated that the importance of Data Network for patient health-related activities is mainly related to an Emergency Service requirement as shown in Figure 4.

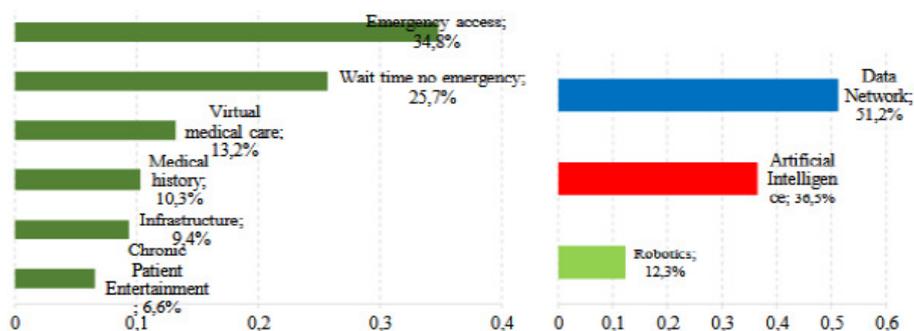


Figure 4: Priority results from patients' perspective

However, in the comparison between Data Network versus Artificial Intelligence to meet Patients necessities, Artificial Intelligence has priority to support the provision of Virtual Medical Care, Medical History and/or Waiting Time, according to the results.

From Administrative Staff perspective, managerial activities such as to generate doctors agenda and patients schedule, the tests delivery and test results within institution or externally, the Data Network is a higher priority supporting their activities.(Figure 5)

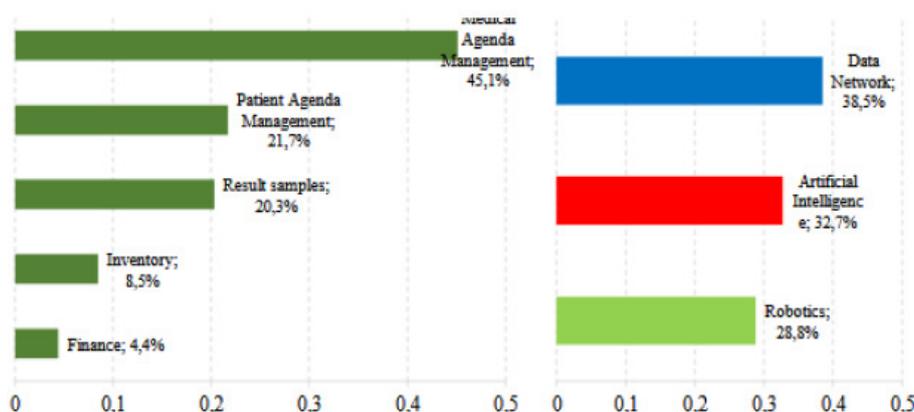


Figure 5: Priority results from Administrative perspective

Summing up, Table 1; gives an outline of the main results. These outcomes provide information regarding the priority requirements for ICT and/or IoT support for each user group.

For the case studied, it was possible to define the most influential factors in the use of IoT, which are related to the requirements of the user group and to the ICT system infrastructure provision available, in order to carry out its main activity. The results allow elaborating actions plan and generating an investment plan.

To apply the results, it is necessary to create an Information System (IS) that considers the main influence factors, following the recommendations suggested by Filip (2012) [9], to design and implement a decision support system (DSS).

The people involved in the process are:

- i) the users, identified in Table 1, who will be the beneficiaries,
- ii) the senior managers from the health institution, who will have to make the implementation decision, and
- iii) the designers, who will have to create the system.

Table 1: Local and Global priority results

Users clusters	Rank	Priority Activities	Local %	IoT Alternatives	Global %
Doctors	46,9	Medical history	33,1	Data Network	43,3
		Tracking Treatments	20,3		
		Emergency access	16,5		
		Remote assistance	10,2		
		Agenda Management	11,7		
		Diagnosis	5,4		
		Infrastructure	2,8		
Patients	29,7	Emergency access	34,8	Artificial Intelligence	37,9
		Waiting time, no emergency	25,7		
		Virtual medical care	13,2		
		Medical history	10,3		
		Infrastructure	9,4		
		Chronic Patient Entertain	6,6		
Administrative Staff	23,4	Medical agenda management	45,1	Rebotics	18,8
		Patient agenda management	21,7		
		Result samples	20,3		
		Inventory	8,5		
		Finance	4,4		

7 Conclusions

This document proposes a methodology using multi-criteria approach applying AHP, to develop a decision model based on a real case study. The AHP model helps to understand the selection process in a conflictive environment and to know the main technological requirements to adapt to the changing needs of healthcare provision.

The ranking obtained helps to recognize activities that need to reach technological standard and to contribute to improve the quality of service and adapt to healthcare necessities change. This will allow to initiate implementation actions, and to generate investment plans.

The support of incorporating new ICT and IoT plays an important potential role. Since, population growth requiring health services, especially in rural areas increases every day. Remotely located patients are patients who are far from the doctor and need constant monitoring and support. The problem also lies in updating doctors on monitoring parameters and patient history. Health system challenges in developing countries include technology, infrastructure, trained physicians and connectivity among all stake-holders.

Author contributions

The authors contributed equally to this work.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgment

Special thanks from the authors of the “Direccion de Investigacion Cientifica y Tecnologica” (DI-CYT) N°061817OH and the Department of Industrial Engineering of the University of Santiago de Chile for support during the development of the study.

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Cite this paper as:

Oddershede, A.; Macuada, C.; Quezada, L.; Montt, C. (2020). Automation Factors Influencing the Operation of IoT in Health Institutions: A Decision Support Methodology, *International Journal of Computers Communications & Control*, 15(4), 3878, 2020.

<https://doi.org/10.15837/ijccc.2020.4.3878>