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Critical Success Factors to Control Nosocomial Infection by "Wireless Sensor Network" in Intensive Care Unit

Fahimeh Zerganipour[1], Sima Ajami[2]*, Saede Ketabi[3] and Ali Samimi[2]

[1]Health Information Technology, Medical Records Department, Golestan Hospital, Alley Golestan, Farvardin Street, Ahvaz, Iran
[2]Department of Management & Health Information Technology, School of Medical Management and Information Sciences, Isfahan University of Medical Sciences, Isfahan, Iran
[3]Associate Professor, Department of Management, Faculty of Administrative Sciences and Economics, University of Isfahan, Isfahan, Iran

Abstract

New information technologies (IT) can be effective in the prevention, identification, and reduction of transmission of nosocomial infection and consequently decreasing time and additional costs in the hospital. Among these technologies, wireless sensor network (WSN) is able to simultaneously cover the activities of data management, infection source identification and tracking, warning, and preventing infection transmission. For acceptance and successful implementation of WSN-based project in the hospital, identifying and paying attention to the indexes and critical success factors by IT managers and officials of care organization and the hospital is required that acceptance and implementation of the technology does not face failure and paying high costs. Hence, the aim of this study was to identify critical success factors of accepting infection diagnosis by wireless sensor network in the hospital that helps healthcare managers and staff to adopt and facilitate the WSN technology acceptance process at health care centers. This study was narrative review, which search was conducted with the help of libraries, books, conference proceedings, through databases of Science Direct, PubMed, Proquest, Springer, and SID (Scientific Information Database). We employed the following keywords and their combinations; Wireless Sensor Networks, Critical Success Factors, Nosocomial, and Hospital. The preliminary search resulted in 150 articles, which were published between 2003 and 2015. After a careful analysis of the content of each paper, a total of 43 sources was selected based on their relevancy.

Introduction

The word of "Nosocomial" has been derived from two Greek words "Nosos" meaning disease and "Komeion" meaning care; and refers to infections acquired in the hospital or other care centers that may occur inside the hospital or after hospital discharge. Infection means a phenomenon that due to invasion and growth and proliferation of infectious pathogen, the host is damaged; and meanwhile, nosocomial infection is an infection caused on a limited or released way and due to the pathogenic reactions related to the infectious agent or its toxins in the hospital provided:

1. Caused 48 to 72 hours after patient admission in the hospital;

2. At the time of admission, people shouldn't have obvious signs related to infection and the disease shouldn't be at its incubation period [1].

Investigations of World Health Organization around the world show that 5- 25% of hospitalized patients in the hospitals catch nosocomial infections that this rate in the intensive care unit (ICU) is 25% in developed countries and up to 50% in developing countries [2]. In Iran, the prevalence of nosocomial infections in special sections is high and up to 20%. The prevalence of these infections in intensive care infection (ICU) patients are 5 to 10 times general section patients [3]. Due to the nature of patients required hospitalization in ICU department and in terms of being weak, worsening the condition and being susceptible, they need more attention, monitoring and caring to prevent catching nosocomial infection.

Controlling nosocomial infection is necessary for patients and health care providers, both, that the planning needs use modern technology in health care. With further development of these technologies, the necessity of applying computers to meet the needs is felt more day after day in society. Recent development in reducing costs and miniaturizing the computing devices, and also using wireless communication technology and sensors simplifies human daily life. Sensor networks will be one of the critical technologies in future [4]. WSN is an appropriate option for places at which using wired receivers is expensive and difficult. These networks can be applied for the following purposes:

1- Controlling the region (for example existence of petrol or gas pipeline);

2- Controlling air pollution;

3- Forest fire detection;

4- Controlling greenhouse gases;

5- Landslide detection;

6- Controlling the health of the devices in the industrial sector;

7- Water and wastewater monitoring;

8- Microclimate assessment;

9- Monitoring animal populations;

10- Defense system;

11- Monitoring business and controlling work space;

*Corresponding author: Sima Ajami, Professor, Department of Management & Health Information Technology, School of Medical Management and Information Sciences, Isfahan University of Medical Sciences, Isfahan, Iran, Tel: +98-31-36684799; E-mail: ajami@mng.mui.ac.ir

12- Identifying explosives and toxic chemicals and microbial agents;

13- Agriculture (controlling reservoir water level and pumps;

14- Building control (control of movement in tunnels, bridges and embankments);

15- Controlling personal health;

16- Improving quality of life for elderly and patients with chronic diseases by creating smart environments;

17- Providing the possibility of smart home care;

18- Controlling the patient in real time in the hospital [4].

Installing the sensors on patients' body for controlling their vital signs, when patients are required to be controlled for a long time, and guiding patients for medicine consumption by sensors embedded in the drug package that when a patient takes the drug by mistake, the sensors will create warning messages. Among these networks' applications for health care are systems of care for patients with disabilities who aren't taken care of, smart environment for the elderly, communication network between physicians with each other and other hospital staff, and patients' surveillance [5]. The ability of organizations for competition depends on their ability for applying smart technologies; therefore it is necessary that health system policy makers and managers are aware of issues relating to successful modern technology implementation so that they can equip their organizations to such technologies in this competitive world [6]. In order to prevent and control nosocomial infection, applying WSN can be helpful; since these networks are able to communicate with each other and with external networks via the internet or satellite, their application in health promotion like patient monitoring, diagnosis, prescribing and dispensing the drug in the hospitals, remote monitoring physiological data and particularly identifying and controlling nosocomial infection can be highly effective [7].

Health care providers should identify critical success factors (CSFs) of designing, implementing and developing these sensor networks in order to identify the same requirements of receiving and monitoring immediately. In order to manage sensor networks efficiently, several models have been presented and designed by organizations [8]. CSFs include necessary activities which should be formed well to achieve assignment and goals as well. There are significant issues that are considered at the time of implementing the projects with a focus on technology that while they center on real necessities, they cause to be possible members' coordination in maintaining direction toward defining goals [9]. Lack of attention to CSFs in WSN can lead to unsuccessful implementation of this technology, waste of money and time, users' resistance against acceptance and usage of this technology; therefore, the aim of this study was to identify critical success factors of accepting the technology of infection detection by wireless sensor network in the hospital that helps healthcare managers and staff to

adopt and facilitate the WSN technology acceptance process at health care centers.

Methodology

This study was narrative review, which was conducted with the help of libraries, books, conference proceedings, and databases of Science Direct, PubMed, Proquest, Springer, and SID (Scientific Information Database). In our searches, we employed the following keywords and their combinations; Wireless Sensor Networks, Critical Success Factors, Nosocomial, and Hospital. The preliminary search resulted in 150 articles, which were published between 2003 and 2015. After a careful analysis of the content of each paper, a total of 43 sources were selected based on their relevancy.

Results

Revolution of network concepts and unprecedented interlacement of technical challenges cause wireless sensor networks to be one of the largest research interests of 21st century. Anyway, only recently such systems have emerged as the product in the market [10]. Critical success factors in implementing this technology, particularly depend on the assignment and strategic purposes of the project. While the assignment and goals focus on the general purpose and what should ultimately be achieved, critical success factors focus on the most important areas and address what should be achieved and how to achieve. Also, although there is no certain limitation, but confirming the number of these limiting factors is helpful. This helps to maintain those factors' effectiveness and focus in providing the correct direction and prioritization than other components constituting project strategy [9]. Tables 1 and 2 compare the features of WSN technology with two other technologies of Radio Frequency Identification (RFID) and Mobile ad-hoc Network (MANET) [11,12]. Table 3 shows a summary of reports of different researches on critical success main factors and sub factors in the acceptance of WSN in the hospital [9,13-40].

Discussion

Effective criteria and sub criteria regarding prioritizing critical success factors of accepting WSN technology in hospitals in Iran into four main categories of organizational issues, technological factors, environmental factors and human factors along with 19 sub criteria of organizational process, needs assessment, top manager support, budget, cost-effectiveness, information volume and organization size, infrastructure, data, performance evaluation, cost, unique characters, stability, wearable, power management, vendors support, government support, competition, training, and technical knowledge were identified.

Ajami et al. in their study, identified effective criteria and sub criteria regarding prioritizing critical success factors of accepting RFID technology in hospitals in Iran into four main categories of

Technology	Purpose	Component	Protocols	Communication	Mobility	Programmability	Price	Deployment
WSN	Sense interested parameters in environments and attached objects	Sensor nodes, relay nodes, sinks	Zigbee,Wi-Fi	Multi-hub	Sensor nodes are usually static	Programmable	Sensor node — medium	Random or fixed
RFID	Detect presence and location of tagged objects	Tags, readers	RFID standard	Single-hub	Tags move with attached objects	Usually closed systems	Reader-expensive Tag-cheap	Fixed

Table 1: Comparison of WSN with RFID.

	Purpose	Component	Protocols	Communication	Mobility	Programmability	Price	Deployment
Attribute	Communicati on	Portability	Overhead	Network Congestion	Energy	Data Transportation Rate	Number of Sensors	Attribute
WSN	Multi-hub	Fixed	Yes	Commonly Yes	Limited	Low	Very High	WSN
MANET	Single-hub	Portable Router	Normally No	Normally No	Commonly Unlimited	It can be High	Low	MANET

Table 2: WSN compared with Mobile ad-hoc Networks (MANET).

Criterion	Sub criteria	Definition	References
Technology	**Infrastructure**	Including "related and necessary software and hardware platforms" for implementation of WSN technology such as received signal, battery life, coverage area, sensor network physical security, network configuration, immediate communication, scalability, and error rate.	[9,13-18]
	Cost	Cost is an amount that has to be paid or spent to design, purchase, implement, and maintain the network and also overhead costs resulted from processing, connecting and storing the data in WSN and its accessories.	[13-23]
	Data	It is data quality, optimal amount of data, data transmission security, and compressing available data (to save network traffic consumption and sensors battery) in sensor network.	[9,14,18,20-26]
	Performance evaluation	Testing and assessing WSN and its performance after implementation.	[14-16,18,20,27]
	Unique Characteristics	The unique characteristics of each technology is called unique characteristics that includes sensor networks ability to interact with surroundings or with other technologies like RFID, HIS, and information dashboard, network coverage, WSN lifetime, prediction of troubleshooter systems, flexibility, fault tolerance, tolerance of environmental conditions such as temperature changes, tolerance of wrong information processing, reliability, efficient smart system, the number of adjacent nodes, and mean distance to adjacent nodes.	[14,17,19-20,22-33]
	Stability	Long-term accuracy and stability of WSN.	[14,25,27]
	Wearable	The possibility of wearing or locating the sensors in the clothes or in other equipments related to doctors, nurses and patients.	[14,24-25,33]
	Power Management	Checking network energy consumption such as checking the energy of low-power sensor nodes existing in the network and reinforcing them in order to send minimum essential data and also considering warning system and backup patterns in cases of difficulty or disruption in the network.	[14,23,27,30,33]
Environmental	**Vendors Support**	Assurance of the provision of services (approved by buyer) after selling to the buyer.	[9,13-18]
	Government Support	The government can affect positively in technology implementation by financial support in implementing pilot projects or even issuance of the order of exemption from tax.	[13-17,34-35]
	Competition	Equipping the organization by new technologies is considered among organization advantages in better provision of healthcare services that leads to the organization competition with other similar organizations.	[13-16,26]
Human Resources	**Training**	Training the users through different ways (workshop, sessions, media, and leaflets) regarding advantages and disadvantages and how to use WSN.	[13,15-18,24,33,36]
	Technical Knowledge	Users' knowledge of how to install WSN labels to doctors, nurses and patients' body and equipments.	[13,15-16,36-38]
Organizational	**Organizational Processes**	Total activities necessary to be done to reach the organization special goals are called organizational processes. These processes should be matched with the organization rules and instructions.	[14-15,18,24,36]
	Top manager support	Top managers support and ongoing monitoring in formulating and implementing each new activity or plan such as WSN.	[9,13-18, 39]
	Needs Assessment	Evaluating outcomes, benefits and challenges of changes in human financial resources and deploying new methods in each unit.	[13-14,39]
	Information Volume and Organization size	The amount of information created in an organization for production or providing services is called Information Volume and Organization size. Hospitals have different information needs in various sectors, and IT acceptance takes place faster and easier in organizations with high concentration than ones with low concentration.	[13-17,24,37,39- 40]
	Budget	Budget is the capital that is offered the organization by which the organization can provide necessary facilities in order to reach the goals.	[13-15,17,22,39]
	Cost-Effectiveness	The ratio of obtained results (reducing the risk of patients with nosocomial infection, reducing the duration of hospitalization of patients, less employment of manpower, reducing the health cost and improving the quality of services) after deploying WSN technology to the amount of initial capital of setting up the technology.	[13-15,21,41]

Table 3: Critical success main factors and sub factors of acceptance of WSN in the hospital.

organizational issues, technological factors, environmental factors and human factors along with 17 sub criteria of needs assessment, top manager support, budget, cost- effectiveness, information volume, infrastructure, comparative advantage, compatibility, cost, vendors support, government support, competition, state rules and standards, technical knowledge, training, readiness and acceptance, and trust that

is consistent with critical factors of this study [13].

Hussain- M in his study, obtained four main criteria like systematic field, organizational fields, individual field, and behavioral purpose of application with ten critical and sub criteria such as perceived usefulness, perceived ease of use, attitude, self-efficacy, training, management support, organized conditions, system reliability, information quality, and quality of providing services [24].

Ajami et al. in their study, stated that government support and staff readiness and acceptance can lead to acceptance of RFID technology, which are similar to the criteria identified in this study. Yan et al. in a study, considered a strategy to solve ETBG problems that this strategy has proposed a combination of factors to select an analytic hierarchy process-based cluster head. This method not only uses the general weight of four criteria, including remaining energy, the number of adjacent nodes, mean distance to adjacent nodes, and distance to line slop center, but also optimizes mathematical method of determination of weight coefficients to reduce the effect of human factors, and causes that selected nodes are adequately optimized to be applied as cluster head. The results of simulation, in this study, have shown that selected cluster heads have scattered more correctly, so that the network lifetime becomes longer and the proposed pattern is more suitable for larger scale of sensor networks [28].

Nejad et al. in the study, have classified smart network advantages resulting from development in 6 critical areas such as: technical (with sub criteria of variable heterogeneous spectral characteristics in time and place, reliability and latency requirements, harsh environmental conditions and limitation of low power sensor nodes energy), economy (low cost, rapid deployment, flexibility, intelligence of collecting), efficiency, environment, security and safety [19].

Otero et al. in a research have provided the possibility of selecting the best kind of wireless sensor networks for decision makers through paired comparative matrix between selected criteria like: deployment cost, network connectivity, network coverage and network lifetime [22].

AL-Hawari et al. in their research have made a purposive selection of the best temperature sensor among alternative sensors in special industrial supplies. The underlying pattern of decision making has been based on AHP method that has graded temperature sensors in terms of various features, according to various levels obtained from independent assessment of four main criteria: static criteria (along with sub criteria : maximum operating temperature, minimum operating temperature, temperature curve, maximum sensitivity area, self- heating factors, long- term accuracy and stability, local temperature coefficient, wires development, setting up long wiring from the sensors, measurement factor and measuring the temperature), dynamic characteristics (along with sub criteria: electronic simulation requirement, local output levels in centigrade and quick time stability of local temperature), environmental criteria (along with sub criteria: small local size, sound safety, features of fragility- durability, environment with high temperature dip and resistance to erosion) and other criteria (along with sub criteria: measurement point or area, industrial variance, standards of Network Information Security and Technology(NIST) news, and cost). Paired comparisons were done based on specialized reviews in each area [27].

Na et al. in the research have prioritized WSN models presented by the different designers that among presents models, the model presented by Escenauer et al. about which the criteria of scalability, key connectivity, flexibility, excess storage, excess processing, and excess communication have been weighed, has had the highest priority [30].

Jang et al. in a study titled have stated issues and practical challenges which should be got noticed in designing and implementing WSNs in the building; these factors include: 1- cost, 2- reliability which is composed of elements such as accuracy, signal coverage throughout the building, user interface, secrecy, fault tolerance, Received Signal Strength Indication (RSSI), Link Quality Indication (LQI), and Packet Error Rate., 3- power management, 4- interoperability, 5- ease of use and maintenance, and 6- network security [23].

Christine et al. in a study have stated security, quality of service (QoS) and network configuration as challenges facing sensor nodes [17].

In the study conducted by Azimi et al. with the title of "A New Model to Identify and Evaluate Critical Success Factors in the IT Projects; Case Study: Using RFID Technology in Iranian Fuel Distribution System" in 2008 – 2009, critical success factors have been prioritized by the help of the AHP in 6 classes that the most important priority of these factors are in order: Support from senior management, Hardware infrastructure, Technology sanction, Pilot projects, beneficiary's participation, and data management [9].

Neves et al. in their study have considered different matrices for WSNs evaluation like: network lifetime, coverage, cost and ease of deployment, response time, time precision, security, and effective sample rate, that many of these matrices are linked together [32].

Generally, criteria identified in mentioned studies have many similarities with the criteria identified in the present study, but criteria prioritization is significantly different in various studies, that in each country, in hospitals, these factors should be getting noticed based on priority importance in order to facilitate acceptance and implementation of the technology.

In various studies, different criteria were identified as critical success factors of WSN technology acceptance in the hospital. These criteria are generally subjective factors; in different studies, obvious differences are observed between prioritization and mentioned criteria weight that this makes clear the necessity of utilizing systematic and multi-criteria decision making patterns more than ever; methods by which decision makers can identify certain prioritization of factors by weighting various criteria [41]. AHP is one of multi- criteria the decision making processes which lead to consideration of subjective factors in the decision making process as objective factors [42].

Conclusion

Hospitals could reduce nosocomial infections by using new technology, such as WSN which alarms for patient's wound or bed infected, schedules filter changes, reports observing in front of hand-washing areas to make sure employees spend enough time at the sink, monitors and warns staff to observe healthcare regulations. The technology can serve as an extra reminder, especially because even the most thorough infection-prevention guidelines are only as good as the people who are supposed to follow them. Successful acceptance and implementation of WSN technology- based projects in hospital, requires identification and paying attention to indicators and critical factors especially at the time of formulating relevant strategies by IT managers and officials of the care organization and target hospital so that deployment and acceptance of the technology do not face failure and high cost because the criteria, which have been considered as critical success factors in various studies, have obvious differences, that result from organizational, environmental and economic conditions.

Support and Source of Funds

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