From a literature review to a conceptual framework for affordable quality healthcare service using internet of things (IOT) network

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Abstract: There has been significant interest in integration of internet of things (IOT) and healthcare both in academic and the corporate world. This can be seen from the fact by the number of conferences held and number of special issues in journals that have been published. To establish further in this domain, the purpose of this research is two-fold. First it does literature review in healthcare and IOT from 151 papers published from 1998 to 2016. Second, it summarises findings from literature review in two parts. In the first part, it identifies the antecedents that impact both affordable quality healthcare and developing an enterprise network for IOT. In the second part, it integrates factors that affect both affordable healthcare with IOT. The results of this research will be useful for both practitioners and academicians as the paper discusses how to design a IOT based healthcare network that will reduce cost of healthcare while preventing chronic diseases. The paper also shows the limitations of the present research while describing stimuli for further research.

Keywords: internet of things; IOT; affordable healthcare; conceptual framework.


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Django framework based on Python for a pragmatic design of the website and MySQL for the back-end programming. She also has explored responsive-web development along with SEO optimisation using Google analytics and webmaster tools.

Ajit Kumar completed his Postdoctoral in Human Computer Interaction from the National Central University, Taiwan and PhD in Health Informatics from the Taipei Medical University, Taiwan. He has been involved in teaching, research and software industries for more than 13 years across four countries – Taiwan, Libya, India, Nigeria. He has worked with sophisticated healthcare information and communication technology that includes legacy mainframe to ubiquitous cloud computing. He is interested in learning, teaching and researching in areas, such as human-computer interaction, computer applications in healthcare, usability of healthcare software and software engineering. He has published 17 papers in peer-reviewed journals and presented 20 conference papers in various national and international conferences.

Sanjay Mohapatra completed his BE degree from the NIT Rourkela, MBA degree from the XIMB, MTech degree from the IIT Madras, India and PhD degree from the Utkal University. He has more than 27 years of combined industry and academic experience. He has consulted many organisations in different domains such as utilities, banking, insurance and healthcare sectors. His teaching interests are in IT strategy and management information systems and research interests are in the area of IT enabled processes. He has authored/co-authored 26 books, more than 62 papers in national and international refereed indexed journals besides publications in different conferences.

1 Introduction

‘Health’ as aptly defined by the World Health Organization’s constitution is a state of holistic physical, social and mental prosperity and not simply an absence of disease or impairment. Healthcare has been of much importance since the early man days. In order to reduce the mortality rate, treatment and therapeutic techniques have evolved drastically over the centuries from simple remedies derived from medicinal plants to hi-tech devices that can perform intricate and complicated surgeries and transplants. Research in the medical field was always directed towards providing the most optimal and immediate treatment to the ailing patients. But there is still a vast room for more innovation and progress for providing the best healthcare solutions for patients.

As per the definition stated above, Healthcare should also consider the mental and social well being of a patient along with their physical ailments. These aspects of patient welfare have become easy to tackle with an upcoming technology, internet of things (IOT), which has immense scope in providing healthcare solutions to a wide variety of people which would be both affordable as well effective. IOT is a networking framework, where various kinds of physical devices containing sensors, software, connectivity and other embedded devices are interconnected to each other via networks enabling them to exchange information among them. This technology is considered to be extremely beneficial for people who do not have access to immediate healthcare facilities and treatments. The main motivation for properly analysing the potential of IOT as a solution
to improve healthcare facilities is that this technology would aid in decentralising a wide variety of medical services. IOT technology allows medical devices and applications to be connected via online networks which would open up huge possibilities like remote long-term monitoring of patients, online medical prescription delivery, as well as quick exchange of patient information. Also, medical devices hooked up with IOT allow faster and accurate implementation of treatment procedures as well as better analytics regarding patient’s condition. The research here will strive to study healthcare services in conjunction with medical IOT devices. Based on the researched data from all the stakeholders, IOT Healthcare solutions will be scrutinised for factors responsible for its success and side-effects.

For progressing with innovative healthcare solutions, there is a dire need to go through all the existing standard literature on IOT healthcare solutions and analyse all the factors needed to be considered for cost effective and quality implementation. The parameters will be obtained from the technique of factor analysis from an expansive literature review. Using these parameters further modelling will be done using the framework of structural equation modelling (SEM). This method finds simultaneous relationships for every set of dependent variables and considers both independent as well as dependent variables to estimate their role in healthcare facilities and their impact on patients. The modelling will be done based on the information obtained from all the previously published literatures and feedback analysis of the interviews taken up with various stakeholders of the healthcare industry including patients, doctors, pharmacists, etc.

2 Literature review

This study is dedicated to find the most optimum IOT solutions for making healthcare affordable. A sector of technologies, the information technology is also a class of IOT technologies. The current analysis of health information technology (HIT) implementations would help strategise effective technical solutions along with conceptualised models. To find the extent of impact of HIT on parameters like quality of healthcare delivery, easy accessibility to medical information, precision in medical diagnostic results and reduction of manual labour due to risks associated, a modular framework was proposed in a study by Rajagopal (2013). When assessed in terms of cost effectiveness in healthcare facilities, secure storage of medical records, accuracy and speed in diagnosis of diseases, accessibility to patients’ medical data, reduction in consultation time and treatment time, the variables that were most dependent with highest standardised coefficient values were quality healthcare delivery and precision and speed in medical test. The results from this study have imposed the fact that HIT has to be accompanied by other policy changes to strengthen the dependencies between it and other variables. For instance, user fees may be necessary to alleviate the negative relation between accessibility to medical information to patient and quality in administration due to the inconvenience caused to patients in accessing their medical data.

One of the recent HITs include electronic medical records (EMRs) which has shown effective results in cutting costs. As described by Jha et al. (2009), hospitals cited to be using basic EMRs have the minimum set of functionalities: demographic characteristics of patients, radiologic reports, laboratory reports, diagnostic test results, problem lists,
discharge summaries, medication lists and computerised prescriber order entry (CPOE) for medications. Implementation of this technology and its effects was researched using available data sets and revealed that once a medical event occurs, EMRs were shown to reduce death, readmissions and amount spent per patient. Hence there is a clear advantage of using EMR as an information system where it significantly reduces the chances of hospital acquired conditions (HACs), provides round the clock access to patient information and simultaneously aids in efficient clinical decision making. An overall optimised efficacy from HITs can be achieved by widening the scope of accessibility of the medical data. Walker et al. (2005) cites the advantages of the interchange of clinical and administrative data among medical organisations like hospitals, clinics, pharmacists, radiologists etc. While small scale implementation of the health care information exchange and interoperability (HIEI) technology might not promise any significant returns, holistic implementations of fully standardised HIEI can be estimated to yield about $77.8 billion per year. The one hindrance that can prevent hospitals from readily implementing HITs is its initial implementation costs. The one-time investment however can prove to be financially beneficial according to Bardhan and Thouin (2013). The installation of IT and scheduling systems after the inevitable implementation costs can reduce hospital operational costs and improve quality of healthcare delivery by elevating quality of patient scheduling, human resources management and finance management systems.

The medication distribution system whose efficient functioning is a key to the quality of healthcare delivery in a hospital. The workflow as pointed out in a study by Flynn et al. (2003) involves complexity and erroneous procedures like prescribing, ordering, transcribing and dispensing medications. They are in most hospitals carried out manually. This labour-intensive system has high risks of human error ranging from delay in medication delivery to wrongly perceived prescription order due to illegibility. Hence IT intervention in this sector has been a boon, proving advantageous in both order delivery time and accuracy. A case study presented by Shawahna et al. (2011) looks into a physician order entry system which is fully computerised and has immense benefits in reducing prescription errors. Also a keen study on effectiveness on medication distribution system by IT devices like digital scanning technology by Ker et al. (2014) depicts enhancement in medication delivery time and cost spent during the medication distribution process. This is a simple IOT device where prescription is to be scanned as soon as ordered by the physician and immediately transferred via a network to be displayed on a screen for the pharmacist. This would also help in keeping e-records of all prescription forms ordered along with other important details.

After admission into a hospital constant patient monitoring, medication management and after operation care is highly imperative. This task is currently carried out manually by nurses or periodically by doctors on duty. This leads to high chances of human error which might prove harmful for the patients. Hence as suggested in a product proposal by Catarinucci et al. (2015) connecting users over low powered wireless personal area network (6LoWPAN) or a REST framework to share patients information including patient vitals and environmental conditions which would be regulated by a monitoring application. This would essentially create a smart hospital system (SHS) for continuous and fast delivery of patient data which would in turn aid in quick and accurate delivery of necessary medical services. Such information collected could also be used for generating patient analytics and hence for anomaly detection. This is where big data would come into the picture, as it is highly necessary for storage of such volumes of patient data and
for analytical models to assess patient health further helping healthcare to shift from reactive to proactive healthcare. As cited by Patil and Sheshadri (2014) in their conference on big data, this collaboration of HIT from IOT network and big data would help in great reduction of costs involved with healthcare, with an annual profit of around $100 billion as estimated by The McKinsey Global Institute. This model however possesses various security and threat issues for which solutions are being researched to make patient data storage and transfer secure. To tackle this, a study by Islam et al. (2015) proposes IOT architecture solutions analysing various privacy issues including security, various possibilities of threat and attack systematics in the case of healthcare information breaching. Its solution recommends integration of big data, artificial intelligence and wearable to form an intelligent collaborative security model.

A very important need of the hour to make healthcare delivery fast paced and effective requires discharged or chronically ill patients to be constantly monitored outside the hospital environment and tantamount preventive medication and measures provided to them. Recent technological advancement which currently occupies a large market are the wearable devices like smart watches, health monitors etc has a lot of scope in the medical field. Currently they include stress monitors, blood pressure measurement, calorie counter and such fitness monitoring features. As aptly defined in a research study by Gao et al. (2016) wearable electronics are “devices that can be attached to human skin to unceasingly monitor an individual’s body conditions and activities, without interfering in the user’s motions”. Hence this device, constantly connected to the patient’s body would provide real time data about the patient’s vital and in case of anomaly initiate immediate medical care. According to a study by Mustafa et al. in 2017 the technicalities that are vital for a successfully operating wearable device are secure connectivity among devices and applications in three levels of data collection, data transmission to a hub and permanent storage and observation in a medical station, low power consumption, wearability, reduced risks of data loss, multi-functionality of a single device, sensor accuracy, etc. IOT is the key factor which ensures connectivity among various such embedded systems or sensors via a network and works on the information collected from them. In association with IOT wearable devices have a lot of scope to not only ameliorate the quality and swiftness of healthcare delivery but also make it cost effective.

2.1 Gaps in research

The profound scope of IOT technology in revolutionising healthcare has been predicted and articulated by many case studies and research papers. But practical evidence to analyse the large scale overall implication of IOT on healthcare is sparse due to the reluctance of a majority of hospitals/clinics to install such devices in their facilities. This disinclination has been attributed to high investment costs. This factor hinders the implementation and testing of big data analytics in the field of healthcare to analyse large amounts of medical data belonging to a wide population of patients. Extensive data from widespread usage of IOT healthcare devices is crucial to further evaluate security threats, limits of interoperability and overall degree of improvement in the quality and affordability of healthcare.

In the technical research front although wearable have been considered to be an propitious solution to long distance continuous monitoring, there are many limitations yet to conquer. Current capabilities of the wearable devices are limited to motion, location
and activity sensing, with still a long way to go for their complete independence in health surveillance. Existing remote health monitoring devices for recording certain body vitals do exist, nonetheless compromising the wearability and connectivity of the device. Constructive research towards IOT devices with features encompassing all of continual monitoring, precision, interoperability as well as wearability is imperative.

2.2 Research question

The main query driving this research is ‘What are the factors and their interdependent relations, that are crucial to the successful implementation of IOT technology in Healthcare sectors in order to make its services affordable all the while maintaining its quality’.

2.3 Research objective

With increasing population especially of old aged individuals, healthcare needs have dramatically increased over the years. Hence investing research and innovation has become necessary. Novel technologies are being integrated with healthcare services to make the workflow more productive. Keeping two important sectors in mind, Healthcare and IOT technology, this study aims to do an invasive literature review to probe situations where IOT has been implemented in medical practices/workflows.

The objective is to find the factors that come into picture for advantageous integration to make healthcare services efficient, cost and time effective all the while maintaining or improving quality of services. The factors are crucial to study the necessary parameters around which further advancements and inventiveness can be planned and appropriate guidelines generated. The factors found from the literature review are used to form a model to highlight the importance and hierarchy of each of them and analyse their interdependent relations. The emphasised gaps in the literature target to draw attention to scenarios yet to be worked upon. The overall objective of this paper is to form a comprehensive study to assess implementation of IOT technology in the sphere of healthcare and draw out parameters affecting quality and affordability.

3 Research methodology

For literature review, it is important that we define clear boundaries to specify the scope of review. We made four important criteria for selecting articles.

First the journals were selected from peer reviewed scientific journals with focus on management and written in English. This excluded journals in other languages and focus in technology alone.

Publications with focus on healthcare were considered to get literature related to the domain. This second criteria helped us to find factors related to the healthcare domain.

As a third criteria, we excluded publications which had a focus on policies related to healthcare as review of such literature would have diluted focus on affordable healthcare in private sector.

Finally websites, papers and conference proceedings that related IOT in healthcare were considered which helped us to integrate antecedents from healthcare domain and IOT applications.
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The search for such articles was made through keywords. The databases that were used for this search were Elsevier (http://www.sciencedirect.com), Emerald (http://www.emeraldinsight.com), Springer (http://www.springerlink.com), Wiley (http://www.wiley.com), or library services (e.g., Ebsco: http://www.ebsco.com; Scopus: http://www.scopus.com, Metapress: http://www.metapress.com, or Subito: http://www.subito-doc.de). After doing the search, we filtered the articles as per the criteria given above. The selected articles were reviewed among the authors independently so that mistakes and biases can be removed. Reading the papers, cited references were used as a secondary source. However, it did not result in additional papers. This implies that the search made by authors were valid. Using these criteria, a total of 151 papers were selected.

3.1 Content analysis

In a first step of the evaluation, descriptive dimensions were used to classify the papers. The content of the papers were further assessed by means of a descriptive analysis:

1. How is the distribution of publications across the time period?
2. In which journals are such articles published?
3. What research methodologies were applied?
4. Which dimensions of healthcare were addressed?

4 Conceptual framework

The information that has been obtained in the literature review forms the basis of a theoretical framework in order to closely analyse all the various variables and parameters that are vital to affordable and quality healthcare delivery in health centres and hospitals.

Upon careful assessment 31 parameters were found to be crucial for the deteminations of quality in healthcare services, while simultaneously making it affordable and accessible to the general population. The variables found were segregated according to their relevance to the issue at hand. The relation among the variables formed the foundation for the theoretical framework that analyses the impact on healthcare services.

5 Discussions

Based on the literature review, a framework was arrived which show 31 parameters that influence research question. The research question has several dependent variable which are impacted by these 31 parameters. These parameters can be divided into:

a. infrastructure related
b. information technology
c. type of service provided by the hospital or healthcare centre
d. operations management (also known as quality of administration).
These parameters will be further influenced by other factors and have been detailed out in this section. Please refer Figure 1 for a representative conceptual framework that details all the parameters discussed in this section.

5.1 Dependent variables

1. affordability of healthcare services
2. accuracy of diagnostic technologies
3. speed in delivery of medical test results
4. easy storage and accessibility of medical records of patients
5. privacy and degree of threat to patient medical data
6. quick delivery of precise medical consultation (Mohapatra, 2015c)
7. efficient workflow of prescription ordering and delivery (Mohapatra, 2015b, 2015d).

5.2 Independent variables

a. Health centre/hospital infrastructure
   1. operational area covered by the hospital premise
   2. time duration for traversing between various sections of hospital
   3. number and density of hospital beds
   4. nursing staff per department
   5. total monitoring time per patient
   6. physician and surgeon density
   7. quantity and quality of diagnostic equipment (CRs, MRAs, PETs) (Mohapatra and Mohanty, 2001)
   8. medication supply of hospital pharmacy
   9. promptness of pharmacists in prescription delivery
   10. post discharge monitoring of patients of old age or having chronic diseases.

b. Healthcare information technology
   1. medical record of patient data in cloud
   2. easy connectivity of medical data for authorised personals
   3. persistent long distant monitoring systems (Wearable IOTs)
   4. electronic medication delivery system
   5. security algorithms to tackle privacy threats (Mohapatra, 2011; Mohapatra and Murarka, 2017)
   6. electronic management of patients post admission
   7. healthcare data analytics.
c Quality of healthcare service
1 sanitation
2 healthcare delivery by qualified physicians
3 decision systems for accurate clinical analysis
4 daily, round the clock care by for admitted patients
5 professional/ethical/technical competency (Mohapatra, 2015a).

d Quality of administration
1 patient scheduling
2 finance resource management (Mohapatra, 2010).

Figure 1 Theoretical construct (see online version for colours)
6 Conclusions

This study has taken a broad look at affordable and quality healthcare using IOT technology (Mohapatra, 2009). It offers a conceptual framework in Figure 1 based on literature review. The network (Anbuudayasankar et al., 2014) to be designed by healthcare service providers can use the parameters so that patients are satisfied while the network designed is inexpensive and is sustainable. In future research, researchers may improve the framework and can apply to different geographies by customising the same. This might lead to identifying new parameters or giving higher weightages to specific parameter.

7 Further study

The present literature review excluded publications in languages other than English. This could have led to omission of several religions, regional and cultural specific parameters in our findings. Since religion and culture plays a vital role in implementing healthcare services in certain geographies, a further study on these aspects might lead to specific parameters that are related to specific region. Further study on government policies that govern healthcare services can lead to findings that could help influence policy making. The present study does not delve into healthcare policies as these were excluded from the ambit of the present research. In future, detailed studies into stakeholder requirements can lead to interesting conceptual framework. Role of stakeholders and their involvement in design and implementation of healthcare services cannot be denied and by researching in future studies into this aspect can provide a roadmap for sustainable healthcare.

References


