

# A SYSTEMATIC REVIEW OF TECHNOLOGICAL ISSUES IN MONITORING PILGRIMS' HEALTH DURING HAJJ: CURRENT STATE, CHALLENGES AND FUTURE DIRECTIONS

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## ABSTRACT

Hajj pilgrimage has been the focus of public health initiatives for centuries because it is one of the biggest and oldest annual mass gatherings in the world. But a little is done to objectively monitor pilgrims' health during Hajj who has been suffering from infectious and chronic diseases. The main objective of this study is to identify the technological issues in monitoring pilgrims' health in Hajj environment. We searched and reviewed articles from several scholarly databases along with relevant databases and web portals of the government of Saudi Arabia and World Health Organization (WHO) from the year 2012 to 2017 to identify the technologies and their limitations for pilgrims' health monitoring during Hajj. We explored the articles by using the search criteria "Hajj" AND "pilgrims' health monitoring" AND "technology" AND "medicine" OR "tracking" OR "infectious and chronic diseases". Only 15 research articles out of 134 articles fulfilled the selection criteria. During the study it is found that the common health problems during Hajj are mainly categorized into chronic or non-communicable diseases (62.5%) and infectious or communicable diseases (37.5%). Where, the major health burdens are respiratory disease, heat stroke or heat attack, cardiovascular or heart disease, Gastroenteritis infection, diabetes, and influenza with high fever. Literature review reveals that so far four different types of health facilities are proposed by the research community, among which health records and health guidelines are 40%, pilgrims' tracking to avoid risk is 27%, infectious diseases surveillance or prevention systems 20%, and monitoring of pilgrims' stress and health condition e.g. pulse and temperature monitoring is about 13%. However, not a single research has shown how to provide real-time health facilities to pilgrims who suffer from various chronic and infectious diseases at Hajj ritual sites. During Hajj it is urgent to ensure immediate healthcare facility and proper medication in order to secure pilgrims' lives. Our present study is limited to focus on the perspectives of deploying Wireless Body Area Networks (WBANs) which requires further investigation considering overcrowded and harsh environment at Hajj ritual sites. In this research, a future direction ensuring pilgrims' real-time health monitoring and providing adequate medical facilities during Hajj is also depicted.

**Keywords:** Hajj, Pilgrims, Technology, Health monitoring, Infectious and Chronic diseases, WBANs

## 1. INTRODUCTION

Every year during Hajj, the largest religious mass gathering, an amount of 2 to 3 million pilgrims from 184 countries congregate in Haram at Makkah in Saudi Arabia, and the number of pilgrims is

increasing every year at the rate of about 3.5 percent. During the Hajj period, the crowd density can increase to seven individual per m<sup>2</sup> which is an indicator of overcrowding and one of the leading causes of lost of pilgrims and injury. Moreover, during Hajj in Makkah, the temperature ranges

between 38°C and 50°C with a relative humidity of 25% to 50% thus favors heat stroke, heat exhaustion along with the development of various communicable or infectious diseases (37.5%) and chronic or non-communicable diseases (62.5%). The study revealed that respiratory diseases include pneumonia, influenza, and asthma (73.33%) were the main health burden encountered by the pilgrims during Hajj followed by heat stroke or heat attack, sunlight effects (16.67%), diabetes 13.32%, cardiovascular or heart disease (10%), and gastroenteritis 10.00% [1].

Researchers in [2] identified the respiratory disease as the most common cause (57%) of admission to hospital during Hajj, and cardiovascular or heart disease is the most common cause (43%) of death during the Hajj. It is also noticed in [2] that many patients have cardiac arrests, outside hospitals, at Hajj sites. Alzahrani et al. [3] mentioned that, one-fifth of the pilgrims suffer from multiple diseases where, respiratory infections are the most common (60.8%), followed by gastrointestinal (13.1%) diseases and diabetes, hypertension each constituted less than 3% of the total illnesses. According to the information from the Centre for Disease Control and Prevention (CDC), USA on 2015 and 2016 Hajj [4], around 46%–66% of deaths are caused by cardiovascular conditions among pilgrims during Hajj.

According to the Ministry of Health (MoH) of government of Saudi Arabia during Hajj in 2017, hospitals' emergency received 10,864 pilgrims, outpatient departments served 16,112 cases, and healthcare centers received 128,909 outpatients, and 1,158 cases admitted to hospitals. Hospitals conducted a total of 1300 surgeries in which 123 cardiac catheterization procedures, six open-heart surgeries. Common diseases during the Hajj season according to MoH are respiratory diseases, sun stroke and heat exhaustion, gastrointestinal diseases, cardiovascular diseases, diabetes, skin disease, food poisoning, and dry eye [5]. In addition, MoH of Saudi Arabia categorizes the chronic diseases and provides health tips to the pilgrims who are suffering from heart disease, hyper tension, diabetics, hypoglycaemia, asthma, kidney disease, and epilepsy [6].

The Government of the Kingdom of Saudi Arabia (KSA) in cooperation with MoH, World Health Organization (WHO), the international Centers for Diseases Control and Prevention (CDC) focus, as a top priority, on the preventive and protective aspect of pilgrims in Hajj and keeps abreast of the latest inventions, developments and

changes in medical and health status around the world. Relying on its vast accumulated experience in mass gathering medicine, and successful management of Hajj and Umrah seasons every year, the government of KSA in cooperation with MoH has taken several actions and provided pilgrims' guidelines and pocket guide for clinicians and health practitioners. During Hajj, MoH provides all human potential to serve pilgrims. In 2017 Hajj season, more than 29,000 health practitioners including various medical, technical and administrative groups are commissioned under Hajj manpower program [4].

According to the information provided by MoH [7], during 2012 Hajj season the ministry of health in Saudi Arabia launched "Eijad" system to secure health services to pilgrims. The objective of that system was to help the pilgrims and concerned bodies in reporting of missing pilgrims during Hajj performance and in searching for them in all clinics and hospitals located in the areas of Hajj performance in the cities of Makkah and Madinah. In addition, in 2017 Hajj season, the ministry of health of Saudi Arabia launched a healthcare guide app namely Hajj health campaign that enable Hajjis to get real time MoH advisories, healthcare tips along with emergency call for ambulance, police, and healthcare advice. It also facilitates to finding the nearest healthcare facility in Makkah and Madinah [8].

World Health Organization (WHO) in accordance with MoH of Saudi Arabia issued a guideline for entry visas for the Hajj season in 2017. The guideline consists of several requirements and recommendations for the pilgrims including yellow fever, meningococcal meningitis, poliomyelitis, seasonal influenza, zika and dengue, cholera, health education, food and international outbreaks response [9]. During the Hajj 2017, other than infectious diseases, MoH issued awareness guidelines for patients with chronic diseases and ask them to bring and keep a sufficient amount of medications. The MoH also requested the pilgrims with chronic diseases to visit the nearest clinic or hospital if needed [10]. The government of Saudi Arabia during the Hajj 2017 intensified its preparation for potential heat exhaustion and sunstrokes, since Hajj season coincides with high temperatures and low humidity. MoH provided guidelines to avoid direct sun heat exposure and overcrowding while performing rituals. According to MoH report, in 2017, almost 155 permanent and seasonal health centers across the Hajj rites have

been prepared to provide integrated and excellent health facilities and services [11].

Other than MoH, Ministry of Hajj and Umrah has launched several mobile apps to guide the pilgrims during pilgrimage namely 'Haj Services', 'Umrah Services', 'Hajj Bracelets Reader' [12]. Moreover, Institute for Hajj and Umrah at Umm Al-Qura University, Makkah in cooperation with GIS Technology Innovation Center of King Abdullah City of Science and Technology KACST, KSA launched 'Hajj Tag' app to collect and display spatial and temporal information. Two new research projects namely pilgrims Shuttle Buses Tracking project "Irshad" and Pilgrims Satisfaction Measurement project "Ridha" are also under development stage. Another project namely 'smarthajj' is also under development stage which will guide the pilgrims to find the nearest Masjid, shop, restroom and the way back to their residence in ritual sites easily [13-15].

It has been identified that during the pilgrimage, pilgrims suffer from various kinds of infectious and chronic diseases. Among the diseases, respiratory disease is the main health burden and the most common cause of admission to hospital followed by heat stroke, diabetes, cardiovascular disease, gastroenteritis, hypertension, skin disease and high fever [1-6]. We further prioritize the diseases according to the order of health burden and hospital admission as presented in Table 1.

*Table 1: Name of diseases and order of health burden and hospital admission during Hajj*

Name of Diseases	Order of Health Burden and Hospital Admission	Type of Diseases
Respiratory diseases including pneumonia, influenza, asthma,	1 <sup>st</sup>	Infectious
Heat stroke or heat attack	2 <sup>nd</sup>	Infectious
Diabetes	3 <sup>rd</sup>	Chronic
Cardiovascular or Heart disease	4 <sup>th</sup>	Chronic
Gastroenteritis	5 <sup>th</sup>	Infectious
Hypertension	6 <sup>th</sup>	Chronic
Skin disease and Dry eye	7 <sup>th</sup>	Infectious
High Fever	8 <sup>th</sup>	Infectious

It is observed that the government of KSA incorporation with MoH and ministry of Hajj and Umrah has taken several initiatives to provide healthcare facilities for pilgrims which are mainly health awareness guidelines, healthcare guidance apps, pre-Hajj healthcare and Hajj preparation guidelines. Though pilgrims' real-time health monitoring and providing healthcare facilities and services during Hajj is an important factor but, the initiatives that have been taken so far by the government of KSA and other organizations are not enough and cannot fulfill the pilgrims' demand on their instantaneous health monitoring in Hajj ritual sites. Hence, taking consideration of all these aforementioned pilgrims' health related factors the aim of this systematic literature review is to identify the technological issues in monitoring pilgrims' health in Hajj environment. In this research we also present the perspectives of deploying Wireless Body Area Networks (WBANs) for pilgrims health monitoring during Hajj. Deploying WBANs in overcrowded Hajj ritual sites and harsh environment is a critical research issues which requires further investigation and more exploration.

The paper is organized as follows. Section II presents detailed methods employed to conduct this review. Search results obtained from this study is also presented in this section. Section III presents the existing literature review. Section IV presents the discussions on several key challenges and provides future directions. Section IV concludes the paper.

## 2. METHODS

In this study, systematic literature review (SLR) method is used to identify and evaluate the existing literature in the scope of identification of technological issues in monitoring pilgrims' health during Hajj pilgrimage.

### 2.1 Formation of Research Question

First step in SLR is to form the research questions which need to be addressed. Three research questions have been defined to determine the technological issue in monitoring pilgrims' health at ritual sites.

Research question 1: What are the technologies available for pilgrims' health monitor and tracking in Hajj ritual sites?

Research question 2: What are the limitations found in existing technologies for pilgrims' health monitoring and tracking during Hajj?

Research question 3: What are the needs for deploying WBAN for pilgrims’ health monitoring during Hajj?

**2.2 Search Strategy and Selection Criteria**

Second step in SLR is to identify the relevant studies in the area of technological issue in monitoring pilgrims’ health. So we have following search strategy for the identification of studies.

Selection Period: Articles was selected from 2012 to 2017.

Terms used to search the relevant articles: “Hajj pilgrims” OR “ health monitoring” OR “ pilgrims’ health monitoring” OR “ pilgrims’ health problems” AND “Pilgrims’ tracking/monitoring technology” OR “Health monitoring technology” “Pilgrims’ health tracking/ monitoring technology” AND “Diseases during Hajj” OR “Infectious and chronic diseases in Hajj environment”

Scholarly databases searched: IEEE Xplore, PubMed, Scopus, Science Direct, The Elsevier, The Lancet and Springer Link,

Study Population: Saudi Arabia, Malaysia, USA, UK, Pakistan, France, Germany, and India.

In this review, we studied articles that are available in English. The outcome of the studies was subsequently based on technologies being used for pilgrims’ health monitoring; exploring the challenges and delineation the perspectives towards solving the existing challenges. Table 2 shows the search strategy used in this research.

*Table 2: Search conducted on different academic database*

Database s	Search criteria	Search fields
IEEE Xplore	“Hajj pilgrims” OR “ health monitoring” OR “ pilgrims’ health monitoring” OR “ pilgrims’ health problems” AND “Pilgrims’ tracking/monitoring technology” OR “Health monitoring technology” “Pilgrims’ health tracking/ monitoring technology” AND “Diseases during Hajj” OR “Infectious and chronic diseases in Hajj environment”	“abstract, title, keywords, body of the paper and conclusion”
Elsevier	“Hajj pilgrims” OR “ health monitoring” OR “	“abstract, title,

	pilgrims’ health monitoring” OR “ pilgrims’ health problems” AND “Pilgrims’ tracking/monitoring technology” OR “Health monitoring technology” “Pilgrims’ health tracking/ monitoring technology” AND “Diseases during Hajj” OR “Infectious and chronic diseases in Hajj environment”	keywords, body of the paper and conclusion”
Springer	“Hajj pilgrims” OR “ health monitoring” OR “ pilgrims’ health monitoring” OR “ pilgrims’ health problems” AND “Pilgrims’ tracking/monitoring technology” OR “Health monitoring technology” “Pilgrims’ health tracking/ monitoring technology” AND “Diseases during Hajj” OR “Infectious and chronic diseases in Hajj environment”	“abstract, title, keywords, body of the paper and conclusion”
Scopus	“Hajj pilgrims” OR “ health monitoring” OR “ pilgrims’ health monitoring” OR “ pilgrims’ health problems” AND “Pilgrims’ tracking/monitoring technology” OR “Health monitoring technology” “Pilgrims’ health tracking/ monitoring technology” AND “Diseases during Hajj” OR “Infectious and chronic diseases in Hajj environment”	“abstract, title, keywords, body of the paper and conclusion”
PubMed	“Hajj pilgrims” OR “ health monitoring” OR “ pilgrims’ health monitoring” OR “ pilgrims’ health problems” AND “Pilgrims’ tracking/monitoring technology” OR “Health monitoring technology” “Pilgrims’ health tracking/ monitoring	“abstract, title, keywords, body of the paper and conclusion”

	technology” AND “Diseases during Hajj” OR “Infectious and chronic diseases in Hajj environment”	
The Lancet	“Hajj pilgrims” OR “health monitoring” OR “pilgrims’ health monitoring” OR “pilgrims’ health problems” AND “Pilgrims’ tracking/monitoring technology” OR “Health monitoring technology” “Pilgrims’ health tracking/ monitoring technology” AND “Diseases during Hajj” OR “Infectious and chronic diseases in Hajj environment”	“abstract, title, keywords, body of the paper and conclusion”
Science Direct	“Hajj pilgrims” OR “health monitoring” OR “pilgrims’ health monitoring” OR “pilgrims’ health problems” AND “Pilgrims’ tracking/monitoring technology” OR “Health monitoring technology” “Pilgrims’ health tracking/ monitoring technology” AND “Diseases during Hajj” OR “Infectious and chronic diseases in Hajj environment”	“abstract, title, keywords, body of the paper and conclusion”

Among many problems during Hajj, providing real-time health monitoring and healthcare facilities to pilgrims are the most crucial and critical issues. During the pilgrimage, it is essential to identify people with health risk. Once defined, the system can easily monitor them, and an urgent and emergency medical assistant will provide for them. The healthcare sector during Hajj is looking for advanced information and communication technology, which will be able to give health care services to patient pilgrims in a wide-crowded area. It is increasing looking for technology that can automatically monitor and provide real-time healthcare facilities or treatments to the pilgrims, which can improve the quality of health services among pilgrims throughout the whole Hajj routine. This concise literature review is projected to provide a structured analysis of published articles on the availability of technologies for pilgrims monitoring and healthcare services over the past seven years with regards to Hajj pilgrimage around the world including Saudi Arabia as well. Pilgrims’ health problems, challenges, and suggestions for further improvement of the present healthcare situation in Hajj environment are highlighted in this study. Following research studies fulfilled the selection criteria which are completed since 2012 to explore the technological issue in monitoring pilgrims’ health during Hajj in Saudi Arabia.

Amar et al. in [17], proposed a procedure to maintaining electronic health records of pilgrims, quickly handle and retrieve pilgrims data profile using mobile cloud environment have been studied. A regular and syndromic infectious diseases surveillance system for pilgrims’ in Hajj has been proposed in [18]. Ahmed et al. [19] has proposed a routine health guideline and e-bracelet having pilgrims’ health record, GPS system, and telephonic system for handling emergency situation for pilgrims’ in Hajj. Authors in [20] described the factors in reducing health risks are discussed based on the Hajj guidelines provided by KSA, WHO, European, American and England centers for disease prevention and control. Pre-Hajj, during Hajj and post-Hajj health care risk factors are also identified based on the types of diseases and health guidelines accordingly provided. In [21], the pilgrim electronic health record-EHR management system in place at TabungHaji for Malaysian pilgrims has described. It emphasized on data integration to improve the current data sharing and updating process in pilgrims’ healthcare sector.

**2.3 Article Search Results**

For study selection we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines as presented in Figure 1 [16].

Initially, 134 records (112 articles +22 additional records) were identified through digital library searching. After removing duplicated records, 64 records were found suitable for screening. 36 records did not match our inclusion criteria at initial screening. A total 28 records were sought for full text reading and analysis. After excluding 13 records, 15 studies were finally selected for final review.

**3. EXISTING LITERATURE STUDY ON TECHNOLOGICAL ISSUES IN PILGRIMS’ HEALTH MONITORING**



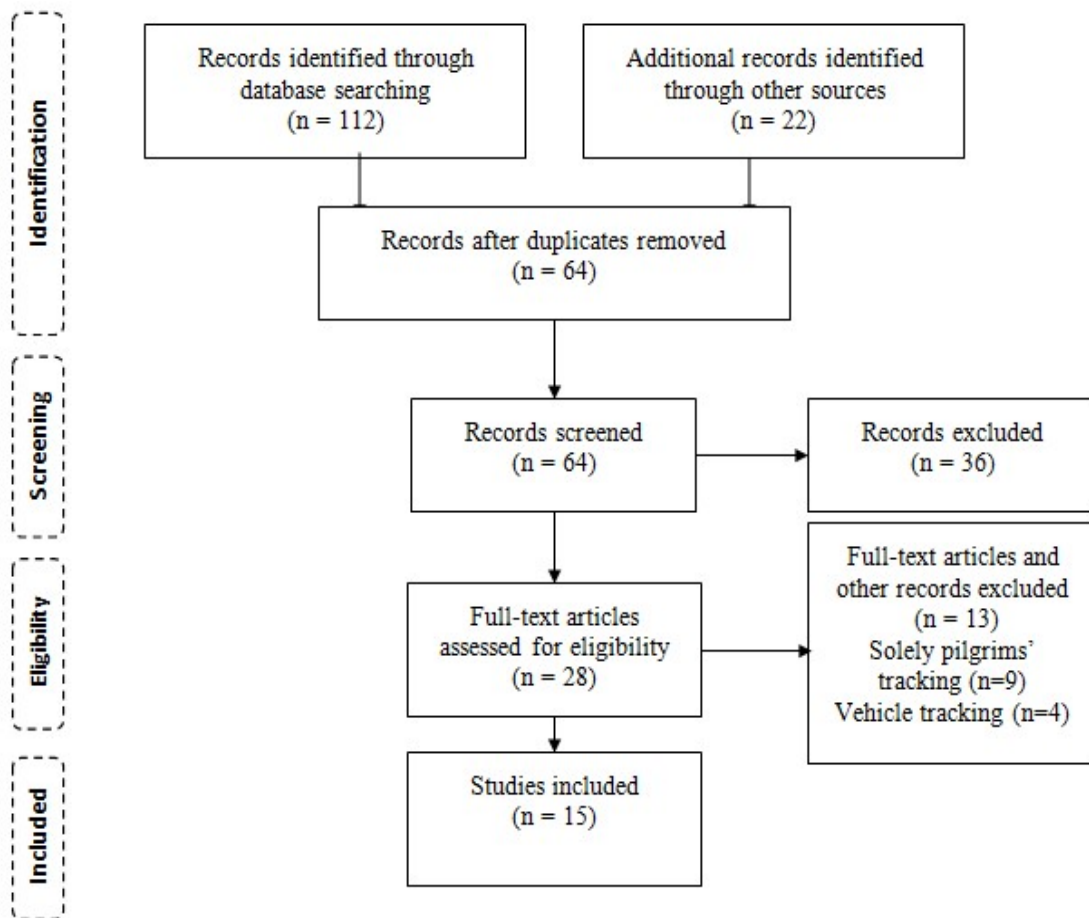


Figure 1: The study selection process

In [22] an app AlHajj, an interactive Hajj guide, described an interactive map allowing pilgrims to walk through the process of the Hajj. It allows a better understanding of obligations, locations, dates and Hajj activities with the sequence. Sizes of gathering, diversity of population, climate and health facilities around Hajj site those influence the health issues of pilgrims have been discussed in [23]. Both infectious and non-infectious related illness and their prevention methods are also demonstrated. Elaine et al. [24] has proposed that, utilizing various information and communication technologies including the Internet, mobile phone applications, and wireless sensor networks infectious diseases can be promptly and early detected in mass gatherings.

Nafea et al. [25] proposed pilgrims' health records using a mobile application and electronic health record-EHR systems. It further proposed a patient locator framework while performing Hajj by monitoring and tracking patients. Geabel et al. [26] proposed to develop pilgrims' smart identification-

PSI system to improve the current identification method using RFID technology.

In [27], Amir et al. proposed smart-phone and wearable devices based systems for identification of activities and stages, analysis of group behavior, recognition of stressful situations and health monitoring of pilgrims in general. Boudhir et al. [28] proposed a system that will control the health of patients and locate the lost pilgrims to intervene in time to save lives and guide the lost pilgrims to their camps. Currently, for pilgrims' identification, authors have proposed using of RFID technology and their aim to use of BSN and WSN technologies to control and identify the localization of pilgrims and healthcare issue. Still, there is no further progress of the system. The system has not been tested and implemented in a real-world scenario. Network and communication issues were not adequately analyzed. In [29], authors have proposed a pilgrim tracking and identification system using WSNs and GPS on a mobile phone.

Authors in [30] proposed GPS/GIS enabled mobile-based infectious diseases namely H1N1 Influenza and influenza like diseases surveillance systems. Authors emphasized utilizing mobile computing technology to provide rapid and accurate data collection for public health decision-making during the mass gatherings in Hajj. In [31], Noor et al. proposed a technology based on GSM, GPS, microcontroller, pulse rate and temperature sensor, and graphical LCD. It is mainly focused on transmitting the data information of the pilgrims (Health condition, tracking) using GSM and shown

a comparison why GSM is better than RFID in case of larger pilgrimage area. The proposed bracelet is due to replace the existing bracelet worn by pilgrims as identification tag. Table 3 below presents the summary of all reviewed article on technological issues in pilgrims' healthcare, and health monitoring conducted globally. Providing proper healthcare facilities during pilgrimage is an important factor especially for the pilgrims who are aged and suffer from various infectious diseases and chronic diseases.

Table 3: Summary of Existing Research Studies on Technological Issues in Pilgrims' Healthcare, and Health Monitoring during Hajj

Author/Year	Theory/ Standpoint	Domain and Method	Significant Findings
Amar et al. (2017) [17]	Providing proper and accurate healthcare services to pilgrims is a big challenge especially for elder people who suffer from various infectious and chronic diseases. Due to pilgrims' mobility in different religious sites, maintain proper healthcare procedures become a major concern where many pilgrims do not know how to convey their medical history or even their current medication. Hence it is important to ensure real time pilgrims health monitoring during pilgrimage.	Healthcare mobile cloud application for pilgrims during Hajj has been proposed.  Feasibility Study.	Procedure to maintaining electronic health records of pilgrims, quickly handle and retrieve pilgrims data profile using mobile cloud environment have been studied.
Badriah et al. (2017) [18]	Although during Hajj pilgrims are suffering from both infectious and chronic diseases, but there is no health security considering non-infectious diseases are discussed.	Strengthening health security at the Hajj mass gatherings taking consideration of infectious disease has been proposed.  Literature review.	A regular indicator-based infectious disease surveillance system is available in public health sectors in Saudi Arabia. But during Hajj there is a need for integration of regular and syndromic infectious diseases surveillance system to ensure timely reporting of events information. Hence an integrated infectious diseases surveillance system has been proposed.
Ahmed et al. (2016) [19]	Basic health requirements and how to access health needs at Hajj are discussed, but real time pilgrims health monitoring is still remaining as a research issue.	Routine health guidelines for pilgrims and novel wearable technology e-bracelet have been studied.  Literature review.	A prototype of e-bracelet has been designed and proposed for Hajj 2016 and upon acceptance of pilgrims a full version of e-bracelet to be rolled out likely in Hajj 2017. The proposed e-bracelet will be an intelligent system having pilgrims health record, GPS system, telephonic system for handling emergency situation.

<p>Shafi et al. (2016) [20]</p>	<p>Health risks during Hajj including communicable diseases or infectious diseases, gastrointestinal disorders, and non-communicable diseases including diabetes, hypertension, arthritis, epilepsy, liver and kidney disease are the major causes of pilgrims' burden and mortality during Hajj. Many pilgrims both elderly and young have existing chronic or non-communicable diseases which need to be monitored during Hajj using modern technology which is not properly mentioned in this study.</p>	<p>Health issues during Hajj in reducing the risks to pilgrims and to wider global health security is discussed.  Literature review.</p>	<p>Factors in reducing health risks are discussed based on the Hajj guidelines provided by KSA, WHO, European, American and England centers for disease prevention and control. Pre-Hajj, during Hajj and post-Hajj health care risk factors are also identified based on the types of diseases and health guidelines accordingly provided.</p>
<p>Ali et al. (2016) [21]</p>	<p>Restricted to store and sharing pilgrims' health related data management system. Not emphasized on pilgrims real time healthcare services and monitoring systems.</p>	<p>To improve healthcare facilities for Malaysian pilgrims at Hajj. Case study.</p>	<p>It emphasized on information technology-IT based data integration systems in order to improve the current data sharing and updating process in pilgrims' healthcare sector.</p>
<p>Shaout et al. (2016) [22]</p>	<p>Although, providing real-time pilgrims healthcare services during Hajj are an urgent issue, but the app is restricted to Hajj guidelines only.</p>	<p>Described an interactive map allowing pilgrims to walk through the process of the Hajj. Experimental study</p>	<p>This mobile application allows better understanding of obligations, locations, dates and Hajj activities with the sequence.</p>
<p>Asaad et al. (2015) [23]</p>	<p>Respiratory infections, meningococcal disease, and gastrointestinal illness among the infectious diseases are considered as most causes of hospital admission at Hajj in different years. Vaccination and healthcare regulations are considered the only preventive measure to reduce the risks of infectious diseases. In Hajj non-infectious illness including stampede, fire, injury, heatstroke, severe acute cardiovascular disease, intense emotional stress, and dehydration are considered the main reasons of mortality and morbidity and the rate is more than that of infectious diseases. Old age and pre-existing illnesses increase the risk of heat related illness. Crowd management and control, grouping and scheduling pilgrims along with the usage of sun protection equipment are proposed to prevent non-infectious diseases. But, real-time health monitoring technology specially for pilgrims suffering from chronic diseases have not been discussed.</p>	<p>Issues influence the health in Hajj ritual sites and their prevention methods have reviewed.  Literature review.</p>	<p>Sizes of gathering, diversity of population, climate and health facilities around Hajj site those influence the health issues of pilgrims have been discussed. Both infectious and non-infectious related illness and their prevention methods are also demonstrated.</p>
<p>Elaine et al. (2015) [24]</p>	<p>Although during Hajj pilgrims are suffering from both infectious and chronic diseases, but there is no novel approach has been proposed for chronic or non-infectious diseases.</p>	<p>Presented novel approaches to disease surveillance can result in prompt detection of infectious diseases.</p>	<p>It has been proposed that, utilizing various information and communication technologies including the Internet, mobile phone applications, and wireless</p>



		Literature review.	sensor networks infectious diseases can be promptly and early detected in mass gatherings.
Nafea (2014) [70] [25]	System was not deployed yet. Communication and health monitoring challenges for pilgrims during Hajj were not discussed.	To keep pilgrims health records. It also proposes a patient locator framework during performing Hajj by monitoring and tracking patients. Analytical study.	To keep pilgrims health records using mobile application and electronic health record-EHR systems.
Geabel (2014) [26]	Although, providing proper healthcare facilities for pilgrims' during Hajj is an important issue but, the matter has not been addressed.	Pilgrims' identification during Hajj. Experimental study	This paper describes radio frequency identifier (RFID) based pilgrims identification system.
Amir et al. (2013) [27]	Since most of the Hajj pilgrims are of very old age and may suffer from various chronic and communicable diseases so early-detection of health issues can provide feedback to individuals and inform the medical team for fast interventions. This is particularly important to ensure all sorts of medical facilities so that pilgrims can be shown the completeness of their pilgrimage journey in terms of performed rituals. Although health monitoring is a vital factor, but the issue is not investigated properly.	Monitoring and understanding pilgrims during pilgrimage.  Experimental study.	Smartphone and wearable devices have been deployed for identification of activities and stages, analysis of group behavior, recognition of stressful situations and health monitoring of pilgrims in general.
Boudhir et al. (2013) [28]	Still there is no further progress of the system. The system has not been tested and implemented in a real world scenario. Network and communication issues were not properly analyzed.	Control the health of patients and locate the lost pilgrims in order to intervene in time to save lives and guide the lost pilgrims to their camps.  Analytical study.	Currently, for pilgrims' identification, authors have proposed using of RFID technology and their aim to use of BSN and WSN technologies to control and identify the localization of pilgrims and healthcare issue.
Mohandes et al. (2013) [29]	There is a need for monitoring pilgrims' health conditions during pilgrimage at Hajj ritual sites. Because, during Hajj many pilgrims suffer from both communicable and non-communicable diseases along with some other emergency issues and these topics have not been discussed.	Pilgrims' tracking and identification during Hajj.  Experimental study.	Wireless sensor networks (WSNs) and GPS in a mobile phone based pilgrims tracking and identification systems is presented in this paper.
Wei Li, (2013) [30]	During Hajj, both chronic and infectious diseases are considered as highest priority and require proper monitoring and treatment. But, in this research infectious disease like H1N1 Influenza A and Influenza-like illnesses were under surveillance.	This study aims to develop and implement a mobile-based disease surveillance system during Hajj.  Case study.	GPS/GIS enabled Mobile-based disease surveillance system has been proposed as a feasible and effective way to support and strengthen preparedness for H1N1 Influenza and influenza like diseases.

			Author emphasized utilizing mobile computing technology to provide rapid and accurate data collection for public health decision-making during the mass gatherings.
Noor et al. (2012) [31]	Although, providing proper healthcare facilities for pilgrims' during Hajj is an important issue but, the issue was not demonstrated clearly taking consideration of both infectious and chronic diseases.	Medical identifier system for pilgrims has been proposed.  Case study	A technology has been proposed based on GSM, GPS, microcontroller, pulse rate and temperature sensor, and graphical LCD. It was mainly focus on transmitting the data information of the pilgrims (Health condition, tracking) using GSM and shown a comparison why GSM is better than RFID in case of larger pilgrimage area. The proposed bracelet is due to replace the existing bracelet worn by pilgrims as identification tag.

### 3.1 Results and Key Findings

Table 4 presents the specific facilities and relevant technologies that have so far been proposed by the

research communities for monitoring pilgrims' health during Hajj. Data presented in Table 4 has been extracted from the studies presented in Table 3.

*Table 4: Precise technologies, suggestions, and key findings in healthcare issues for pilgrims*

Key Findings	Proposed Technologies or Suggestions	Methods. Reference
Health record	Mobile applications.	Feasibility study. [17]
Regular and syndromic infectious diseases surveillance system during Hajj	Need for infectious diseases surveillance system	Literature review. [18]
Health record, routine health guidelines, handling emergency situation using e-bracelet.	e-bracelet having GPS system, and telephonic system	Literature review. [19]
Health guidelines in reducing pre-Hajj, during Hajj and post-Hajj health care risk factors.	Pilgrims' health guidelines in accordance with KSA Hajj guidelines	Literature review. [20]
Data sharing and data updating process for pilgrims' healthcare sector	IT based data integrating systems	Case study. [21]
An interactive map allowing pilgrims to walk through the process of the Hajj.	Mobile applications.	Experimental study. [22]
Influenza health issues and risks during Hajj and their methods of prevention.	Health risks preventive measure considering vaccination and healthcare regulations	Literature review. [23]
Proposed infectious disease surveillance systems during mass gathering in Hajj environment.	Internet, mobile phone applications, and wireless sensor networks	Literature review. [24]
Electronic health record-EHR systems	Mobile applications.	Analytical study. [25]
Pilgrims' automatic identification system.	Radio frequency identifier (RFID)	Experimental study. [26]
Monitoring and understanding of pilgrims and recognition of stressful situations during pilgrimage.	Smartphone and wearable devices	Experimental study. [27]

Identify the localization of pilgrims and healthcare issue.	RFID, BSN and WSN technology	Analytical study. [28]
Pilgrims’ tracking and identification during Hajj.	Wireless sensor networks (WSNs) and GPS in a mobile phone.	Experimental study. [29]
Infectious disease like H1N1 Influenza A and Influenza-like illnesses surveillance system	GPS/GIS enabled mobile-based disease surveillance system	Case study. [30]
Medical identifier systems for pilgrims or tracking of health conditions using GSM instead of RFID.	A bracelet based technology has been proposed based on GSM, GPS, microcontroller, pulse rate and temperature sensor, and graphical LCD.	Case study. [31]

Key health issues as defined in Table 4 are further categorized into four major types of healthcare facilities based on the current literature review. These four types are categorized on the basis of objectives and technologies deployed or proposed in relevant studies as presented in Table 5 and in Figure 2.

According to the studies that have been selected, reviewed and illustrated in Figure 3, it has been identified that 33% of the reviewed articles used literature review method followed by 27% experimental study, 20% case study, 13% analytical study and 7% feasibility study.

During the review of literature, we found that various types of technologies have been proposed or deployed for healthcare facilities for pilgrims as described before. Table 6 shows the deployment of different technologies with respect to the four major types of health facilities during Hajj.

Table 5: Different types of health facilities has been proposed in current literature and percentage of research conducted

Major types of health facilities	Percentage of research conducted	References
Health record. Health guidelines.	40%	[17] [19] [20] [21] [24] [25]
Pilgrims’ tracking to avoid risks, crowd and accidents.	27%	[22] [26] [28] [29]
Infectious diseases surveillance or prevention systems	20%	[18] [23] [30]
Pilgrims’ stress monitoring. Pilgrims health condition e.g. pulse and temperature monitoring.	13%	[27] [31]

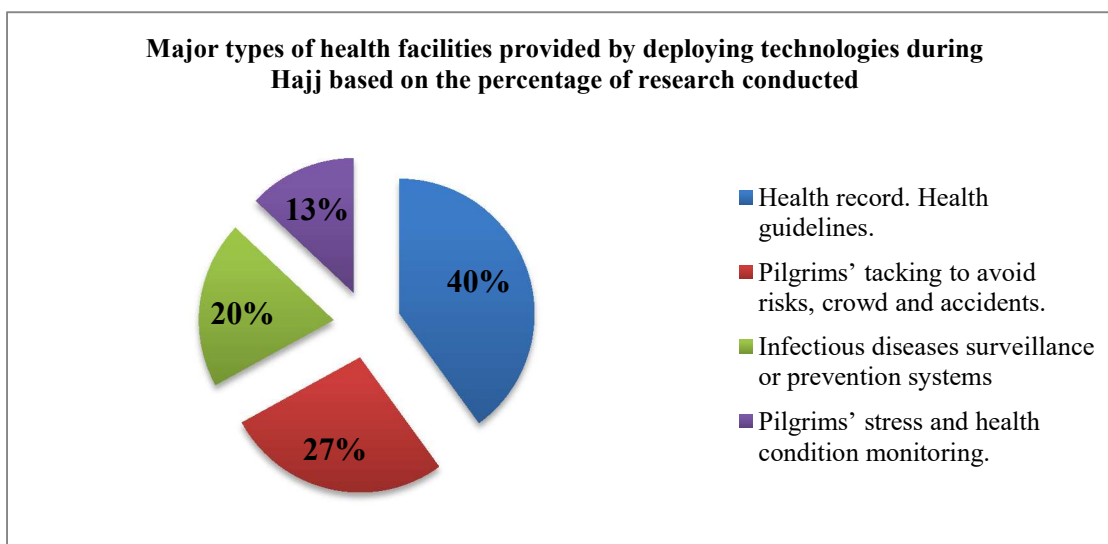


Figure 2: Types of health facilities provided by deploying technologies during Hajj based on the percentage of research conducted

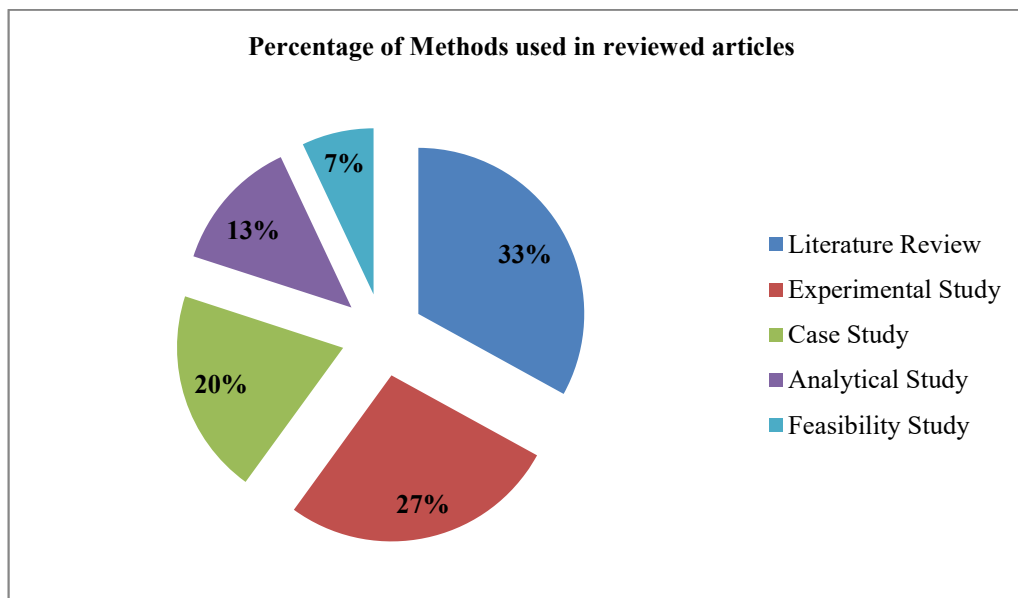


Figure 3: Percentage of Methods used in reviewed articles by the authors

Table 6: Different technologies have been proposed in respect to the four major types of health facilities during Hajj in current literature

Major types of health facilities provided by deploying technologies during Hajj	Name of Technologies deployed
Health record. Health guidelines.	Mobile phone, GPS, IT, WSN
Pilgrims’ tracking to avoid risks, crowd and accidents.	RFID, BSN, WSN
Infectious diseases surveillance or prevention systems	Mobile phone, GPS, GIS
Pilgrims’ stress monitoring. Pilgrims health condition e.g. pulse and temperature monitoring.	Mobile phone, Wearable device, GPS, GSM, Pulse and Temperatures sensors

#### 4. CHALLENGES AND FUTURE DIRECTIONS

During Hajj, the main challenge is to monitor a large number of pilgrims’ health conditions and provide adequate healthcare facilities. Conventional or traditional concepts of disease control in overcrowded Hajj ritual sites is not enough and do not adequately address the complexity of the health-related problems. According to our study, during pilgrimage 62.5% pilgrims suffer from

chronic or non-communicable diseases and 37.5% pilgrims suffer from various communicable or infectious diseases. Among different types of diseases, respiratory disease is the most common cause (57%) of admission to hospital during Hajj, and cardiovascular or heart disease is the most common cause (43%) of death during the Hajj. Hajj poses complex medical and healthcare challenges that require a broad expertise to handle diseases real-time.

The efforts so far have been taken by the government of KSA, other healthcare organization including MoH, Ministry of Hajj and Umrah, WHO, and research community do not reflect the needs of pilgrims’ real-time health monitoring. According to our study, it is found that major healthcare facilities that have been proposed so far are mainly related to health guidelines, health records database, pilgrims’ tracking to avoid crowds and risks, infectious diseases surveillance systems; pilgrims’ stress and health conditions monitoring, e.g., pulse and body temperature monitoring. Though several chronic and infectious diseases are the main causes of health burden during Hajj, a little initiative has been taken to improve the situation. Thus, the need for adequate planning for pilgrims’ health monitoring and the prevention and control of disease outbreaks show the importance of academic and scientific research discipline.

The propagation of an infectious agent and health burden due to chronic diseases during a mass gathering like Hajj can strain the health system of the host region and pose a threat to local and global health. The lessons learned from the study and healthcare challenges that were faced during Hajj gave us insights on how to improve the present health care situation, and to provide the best medical facilities and health monitoring of pilgrims.

In order to ensure real-time medical facilities during the pilgrimage in Hajj ritual sites, it is significant to deploy an efficient medical information and communication technology (ICT) that will be able to monitor pilgrims' physiological conditions and to deliver health-related information to the healthcare stations. As can be seen, the medical ICT is multidiscipline research area and wireless body area network (WBAN) is considered as a modern way to monitor human's health-related parameters remotely and seamlessly. This new prominent technology which is under IEEE 802.15.6 TG6 is a subset of wireless personal area network (WPAN) which was formed in November 2007 offered the quick monitoring and evolution in patients' medical and life-critical data and thus providing proper healthcare services [32]. WBAN has potential to provide many advantages to patients, medical staff, and society at large through continuous monitoring of various physiological vital signs and provide real-time feedback to the user and the medical staff. To fully exploit wireless technology for healthcare, telemedicine, and m-health, Van Dam et al. first introduced the concept of WBAN in 2001. Original motivation and advanced development of body sensor networks (BSNs) for healthcare were coined by Prof Guang Zhong Yang of Imperial College in the early 2000s and then illustrated in his book 'body sensor networks' in 2006.

The major advantages what WBAN and associated suitable communication network can provide are location independent patients' real-time monitoring facility [33-38]. Modern information and communication technology (ICT) systems have the ability to make it possible for WBAN to connect itself to the Internet to transmit data and efficiently administer the proper delivery of healthcare services among the pilgrims during Hajj. Therefore, integration of the medical technology and ICT in the healthcare sector is a prominent research direction, especially for the one involving WBAN. Our present study is limited to focus on the perspectives of deploying WBANs which requires

further investigation considering overcrowded and harsh environment at Hajj ritual sites.

## 5. CONCLUSION

According to our study, during pilgrimage 62.5% pilgrims suffer from chronic or non-communicable diseases and 37.5% pilgrims suffer from various communicable or infectious diseases. Among different types of diseases, respiratory disease is the most common cause (57%) of admission to hospital during Hajj, and cardiovascular or heart disease is the most common cause (43%) of death during the Hajj. Hajj poses complex medical and healthcare challenges that require a broad expertise to handle diseases real-time. But, a little initiative has been taken and a few researches have been done to overcome such medical challenges.

In this study, a systematic literature review is conducted on selected research studies to explore the technological issues for pilgrims monitoring and healthcare services over the past seven years with regards to Hajj pilgrimage around the world including Saudi Arabia as well. Pilgrims' health problems, challenges, and suggestions for further improvement of the present healthcare situation in Hajj environment are highlighted in this study. It is found that, there are four different types of medical facilities so far have been proposed or somehow implemented in Hajj pilgrimage. As can be seen, among these four major types of health facilities, health records and health guidelines are 40%, pilgrims' tracking to avoid risk is 27%, infectious diseases surveillance or prevention systems 20%, and monitoring of pilgrims' stress and health condition e.g. pulse and temperature monitoring is about 13%. However, during the Hajj, the main challenge is to monitor a large number of pilgrims' health conditions and provide adequate healthcare facilities. Unfortunately, this issue has not been adequately addressed so far in the research community and not a single research has shown how to provide real-time health facilities to pilgrims who suffer from various chronic and infectious diseases during various Hajj ritual sites.

Only, the conventional or traditional concepts of disease control in overcrowded Hajj ritual sites is not enough and do not adequately address the complexity of the health-related problems. In order to ensure real-time medical facilities during the pilgrimage in Hajj ritual sites, it is significant to deploy an efficient medical information and communication technology (ICT) that will be able



to monitor pilgrims' physiological conditions and to deliver health-related information to the healthcare stations. As can be seen, the medical ICT is multidiscipline research area and wireless body area networks (WBANs) have been seen as a modern way to monitor human's health-related parameters remotely and seamlessly

Therefore, in this research paper, we have proposed to deploy WBAN technology to efficiently monitoring pilgrims' health. However, proficiently and efficiently monitoring pilgrims health status during Hajj at overcrowded Hajj ritual sites using WBANs is a challenging and critical research issue which requires further investigation and more exploration.

WBANs bring out a new set of requirements and specifications, which are necessary for developing a WBANs assisted healthcare system for pilgrims health monitoring during Hajj. This paper provides a strong foundation for future work ensuring real-time monitoring of pilgrims health and providing medical facilities by giving highest priority to emergency traffic followed by normal traffic and on-demand traffic.

#### Conflict of Interest

The authors declare that they have no competing interests.

#### Ethical Approval

This article does not contain any studies with human participants performed by any of the authors.

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