Hajj Crowd Management via a Mobile Augmented Reality Application: A case of The Hajj event, Saudi Arabia.

Almoaid A. Owaidah

Submitted in fulfillment of the requirements of the Degree of MSc Computing Science at University of Glasgow

December 2014

Abstract

Hajj event is considered as one of the Islamic pillars that each Muslim, who could afford its' expenses and are well bodied, should perform its' rituals at least once in a lifetime. Therefore, they could travel to Mecca city, in the Kingdom of Saudi Arabia to perform Hajj rituals. This holy city hosts this event annually in the last month of the Arabic calendar, which is Dhul Hijjah, and it lasts for 6 days. In addition, those Muslim visitors or pilgrims are obligated to be accommodated at Hajj ritual places, which are Arafat, Mina and Muzdalifah. However, in the last ten years, it was noticed that the Hajj events are crowded every year. Therefore, Hajj crowd management is being a complex task, due to the huge number of the pilgrims as they are crowded at the Hajj ritual places. This huge number is causing many problems, and Hajj authorities are facing difficulties in managing those crowded pilgrims. As a result, this research focuses on three main problems that occur at Hajj events. First, difficulties in organizing the crowds' movements of the pilgrims, as Hajj events host enormous number of pilgrims in limited geographical spaces at the ritual places. This problem leads to overcrowdings, congestions and stampedes. Second, the pilgrims could get lost at Hajj ritual places, especially when they are moving between these places. Third, lack of directional information and guidance for those lost pilgrims. This problem leads to difficulties in finding their groups at the ritual sites, because the huge number of the pilgrims. Thus, this research proposes to deploy a technology, such as a Mobile Augmented Reality application. This application would assist the Hajj

authorities (staff and operators) in managing the pilgrims' movements between the ritual places, and to provide directions to the lost pilgrims. In addition, it would help those lost pilgrims by alerting, and sending their location information to their group guide.

On the other hand, the research literature review covers previous studies about the Hajj crowd management, as it is divided into two perspectives. The theoretical perspective, which explains the crowd management steps that should be followed and applied, as these steps would help the Hajj authorities to succeed in crowd management at Hajj events. The practical perspective presents some studies that are related to the Hajj events. Those studies offered some solutions to manage crowded pilgrims, to avoid overcrowdings and stampedes, and to identify, locate and guide lost pilgrims. The solutions were Radio Frequency Identification (RFID) systems, Global Positioning Systems (GPS) deceives and monitoring cameras.

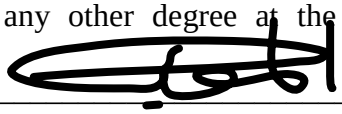
In addition, this research conducted and distributed questionnaires on 104 respondents. They were selected as they are related to Hajj events. The results of this research method confirmed that the Hajj events face problems. For example, overcrowdings, congestions and stampedes that occur at the ritual places, due to lack of pilgrims organization in limited spaces at these places. In addition, foreign pilgrims face difficulties in guidance, due to lack of directional information, and they could get lost from their groups at the Hajj events. In addition, the respondents suggested using technology to assist Hajj authorities in Hajj crowd management. Therefore, deploying MAR application is suggested, as a solution to solve or at least reduce the Hajj problems.

The proposed application could help the Hajj authorities to manage the crowded pilgrims at the Hajj ritual places as this research illustrates two scenarios in Hajj crowd management. In conclusion, this application is beneficial and significant in crowd management at Hajj events, as it could provide instant information using high-speed process in sending and receiving information. In addition, the information about the pilgrims' movements could be gathered, presented on smart devices and shared between applications' users. Those users will be the Hajj staff on the ground and the Hajj operators in the control room of Hajj operations.

Contents

Authors Declaration

“I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Signature 

Printed name Almoaid A. Owaidah”

Acknowledgment

I would like to express my special appreciation and thanks to my supervisor Professor “Christopher Johnson”, you have been a tremendous mentor for me. I would like to thank you for encouraging doing my research. Your advice on this research has been priceless. I would also like to thank all my colleagues at Computing Science School, especially “Stephan Raue”, who has always been a great inspiration for me. A special thanks to my family. Words cannot express how grateful I am to my, mother-in-law, father-in-law, my mother, father and my brothers for all of the sacrifices that you have made on my behalf. Your prayers for me was what sustained me this far. I would also like to thank my entire correspondents of this research; it would be useless without your contributions. At the end I would like express my appreciation to my beloved wife “Alaa” and my son “Muhammad” who spent sleepless nights and were always my support in the moments when there was no one to answer my queries.

Chapter1: The Research Introduction

1.1 Introduction

Memish et al. mentioned that mass gatherings "…represent large number of people attending an event that is focused at specific sites for a finite time" (2012, p. 56). Examples of these events would be rock concerts, religious and sporting events. Those events are different from each other depending on certain factors. These factors such as events' timing (annually, every 2, 4 years or more), organization and preparation, types of visitors (local, multi-culture, illiterate or well-educated…etc.) as well as the event's venue (indoors, outdoors or both). However, research in the crowd management field has been focused on the improvement of crowd management at those events, where high flows of crowds are estimated. The word "crowd" refers as a group of individuals who are gathered whatever their nationality, profession or sex, and whatever the chances that have brought them together (LaBon, 1982. P.2; Halabi, 2006, p.16).

One of these events that need this improvement is "Hajj" pilgrimage at the holy city of Mecca, Saudi Arabia. Thus, this study focuses on improving Hajj crowd management, especially at its' ritual places, which are Arafat, Muzdalifah and Mina city. Therefore, crowd management in Hajj operation is important, as it

helps to maintain the pilgrim's movement in unidirectional flows of crowd at most of the Hajj rituals. This method could break down the dynamic stop-and-go waves (Al-Salhie, Al-Zuhair & Al-Wabil, 2014, pp.383).

However, in the last decade, failure of managing crowds movements at Hajj events has resulted in many serious numbers of incidents and casualties. These incidents led to people could be lost, injured or dead. Therefore, this study argues Hajj staff, operators and other stakeholders could be assisted in Hajj crowd management, by deploying technologies (e.g. Mobile Augmented Reality Application). The usage of technologies could help Hajj crowd management to reduce crowds' problems, such as overcrowdings, stampedes and lost pilgrims at Hajj ritual locations.

1.2 Motivation

Hajj is selected as the case study of this research, as it accommodates millions of pilgrims, who come from different places around the world, to perform this ritual at specific time and places. Those pilgrims create crowd congestions that could lead to chaos, panic, missing, injuries and even death. In addition, Al-Kodmany (2013, p.291) mentioned foreign pilgrims have a little awareness of the physical infrastructure of Hajj ritual places, locations of facilities and entrances and exits of these facilities. Therefore, those pilgrims are always seeking for help, because of this unfamiliar environment. Help could be provided by deploying emerging technologies, to serve those pilgrims at Hajj events as this task is the most

privilege of the Saudi government. Thus, the motivation of this research is to develop an application for Hajj crowd management that is only deployed by the Hajj staff and operators, to assist pilgrims at Hajj locations. In addition, this application would be used to manage the pilgrims' movements between the ritual places, and to prevent overcrowdings, stampedes, and them from getting lost from their groups.

1.3 Examples of Crowd incidents at Hajj events

Siddiqui & Gwynne (2012, p.478) argued that Hajj crowd management is a complex task at Hajj event. Firstly, Hajj events represent one of the largest annual events that gather pilgrims coming from all over the world, to perform this religious practice. They perform Hajj within specific areas and period of time (6 days). The aggregation of those pilgrims makes it more complex, because of their movement between the locations of Hajj ritual places (e.g. Arafat, Mina and Muzdalifah). Secondly, the Hajj has witnessed a number of serious crowd incidents. For example, between the years 1994 and 2006, there were five major incidents, which led to 1053 deaths and 1295 injuries (Ministry of Hajj, 2011; AlGadhi and Srill, 2003; Siddiqui & Gwynne, 2012, p.478). Thirdly, Hajj events are considered as multi-cultural events that bring more than 183 countries together in one place (the holy city of Mecca, Saudi Arabia). Examples of these countries include Indonesia, Pakistan, India, Turkey, Iran, Nigeria, Bangladesh,

Egypt, Europe countries, USA, Russia and China. This cultural and geographical diversity affects the management of the pilgrims as well as their behavior. At Hajj event in 2010, 2.8 million pilgrims have attended, of which 1.8 million pilgrims were foreigners. Fourthly, because of the diversity of the pilgrims, their main Hajj practices are the same, but some other practices are done differently depending on the individual's Islamic doctrine. Therefore, these differences indicate that although all pilgrims will perform Hajj by the same routes and in the same period, they will have different methods to perform it. Thus, these differences could complicate the management of pilgrims' movements at this event. For example, Khozium, Abuarafah and AbdRabou (2012, pp.278) illustrated groups of pilgrims are different in their movements from place to other, as for the pilgrims from the Arabic Gulf prefer to move by cars or buses. However, pilgrims from India, Pakistan and Bangladesh prefer to walk together in their movement. On the other hand, Shi'a or Iranian pilgrims prefer to stay together as well.

Al-Nuaim & Al-Masry (2012, p.50) summarized the main disasters that happened previously at Hajj events, due to dangerous overcrowding, stampedes and human bottlenecks (table 1).

Date	Accidents	Casualties	Place
1975	Fire	Death of 200 pilgrims	Camps for pilgrims near Makkah
1990	Suffocation	Death of 1,426 pilgrims	Inside a pedestrian tunnel
1994	Stampede	Death of 270 pilgrims	Al-Jamarat in Mina
1998		Death of 118 pilgrims, with another 180 injured	
2001		Death of 35 pilgrims.	
2003		Death of 14 pilgrims	
2004		Death of 251 pilgrims, with another 244 injured	
2006		Death of 346 pilgrims, with another 289 injured	

Table 1: Hajj disasters from 1975 to 2006

Halabi (2006, p.29) indicated that the causes of Hajj disasters over the years were the human behavior of the pilgrims, unsuccessful Hajj management, and physical building and surrounding environment of Hajj ritual places. Therefore, dangerous incidents occurred at previous Hajj events, when pilgrims were performing activities at Hajj ritual sites. The following incidents are the most serious crowds' disasters that occurred at Hajj events:

- According to GKStill (2013), in 2004, a crowd incident occurred at Mina Valley, specifically at Aljamarat Bridge, Mecca, Saudi Arabia. The results of this incident were that 251 died at that bridge. Those victims were from Indonesia, Pakistan and other Asian countries. They were crushed to death during the ritual of stoning the devil. In addition, this incident occurred after

some pilgrims have collapsed when 2 million pilgrims rushed towards the bridge to perform the ritual. Therefore, those pilgrims were pushing each other towards the directions of both the entrance and the exit on the bridge. Thus, this situation led those pilgrims to panic and collapse on each other at that bridge. Although The Saudi authorities tried to prevent the stampedes, by influencing the pilgrims to perform this ritual at another time, they did not follow the instructions.

- GKStill (2013) illustrated in 2006, 364 died at the same place, which is Aljamarat Bridge. This incident was different from the previous event (2004), as some of the pilgrims were carrying heavy bags and moving towards the bridge to perform the stoning ritual at noon. At that year, to avoid the 2004 incident to be repeated, the Saudi authorities consulted the Saudi Islamic scholars, to state a justification permitting pilgrims to perform the ritual at any time, as this ritual were performed at a specific time. This justification was approved. However, many pilgrims ignored it and insisted to perform this ritual as previous events. Therefore, nearly one million pilgrims were carrying their bags when they arrived at the bridge. The security forces tried to stop as many as they could, to enter the bridge without their bags, but they could not due to the large number of the arriving pilgrims. After the ritual, because the large numbers of them, pilgrims tried to leave the bridge, by rushing ahead and pushing each other to finish the ritual quickly, but this situation caused stampede. In addition, most of those pilgrims were lost and separated from their groups and relatives.

Helbing & Johansson (2011, p.710) analyzed the Hajj 2006 incident as the following:

- On January the 12th, 2006, the stop-and-go waves started on the entrance of the Al-Jamarat Bridge. Helbing et al. (2007, p.3) described these waves as irregular flows that cause people to be moved towards all directions, push them around and eventually caused them to stumble. While the crowd flows were smooth and continuous, at 11:53 am the stop-and-go waves started to appear. These waves were related to a significant drop of the flow. The duration of these waves were approximately 20 min.

- On the same day, at 12:19, the density reached its' highest level, and video recordings showed another transition from stop-and-go waves to irregular flows or crowd turbulence. These flows were unintentional movements that changed into different directions. They caused many people to stumble. In addition, the pilgrims behind these flows were moved by the crowd and could not stop. The area of fallen pilgrims grew significantly, and they act as obstacles for other pilgrims.

Al-Gadhi (1996, p.100), argued that the causes of Al-Jamarat problem happens every year at Hajj events, because the movement of pilgrims at the bridge is in two opposite directions, where the movement inside the bridge is designed to be a one-way direction. In addition, Koshak (2005, p.13) mentioned that although the new construction of the bridge is multi-floors, the number of pilgrims is increasing every year (see Figure 1.1). This huge number could lead to more

overcrowdings at the bridge. Therefore, overcrowdings in the last ten years resulted panic in the crowd and pilgrims were trampled until some of them have lost their lives. Moreover, Shneider et al. (2011, pp.4) mentioned the pilgrim's numbers in 2009 was about 2.5 million pilgrims, as 154,000 were Saudis; 1,613,000 were foreigners. In addition, in 2010, the number of pilgrims increased to 2.8 million pilgrims (Royal Embassy of Saudi Arabia, 1996 – 2010).

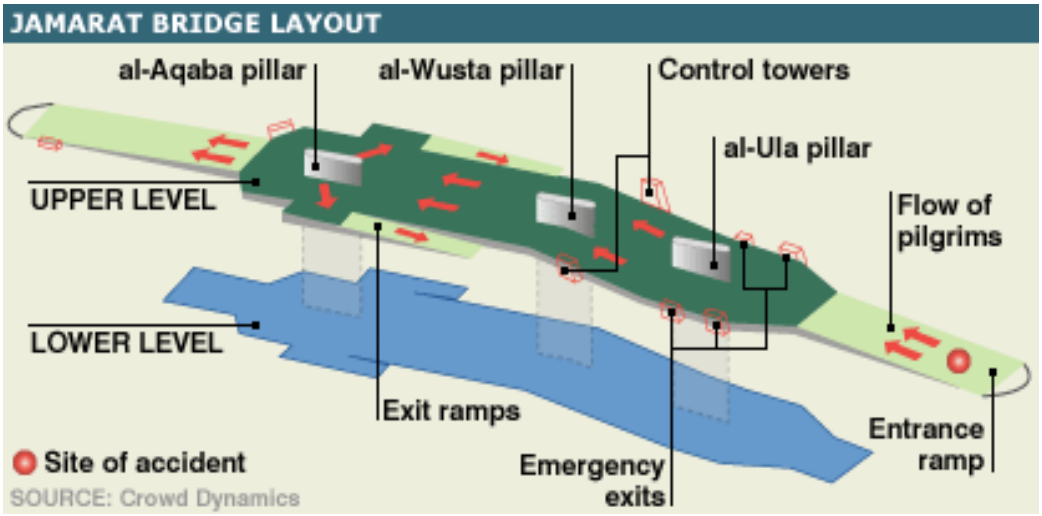


Figure 1: The new Aljamarat Bridge - http://hikm.wordpress.com/category/saudi-arabia/

1.4 The analysis of crowd incidents at Hajj events

Krausz and Bauckhage (2012, p.308) described that at any mass gatherings, such as religious events, crowd densities could be built up. These densities create a pattern of movement called "stop-and-go wave." This movement indicates a dangerous overcrowding that could be difficult to manage. In addition, if this pattern appears, the flow of pedestrians could last more than twenty minutes, and people at this wave move into all directions. Therefore, people will start to push each other, and some of them might fall. Thus, more people may join this wave, and others might die from suffocation.

Additionally, it was suggested that the concept of "panic" is a way of blaming the crowd that could result in a disaster (Sime, 1999; Cabinet Office, 2009 (B), p. 140). Moreover, Shiwakoti and Sarvi mentioned that panic "…refers to situations in which individuals have limited information and vision to high crowd density and short time of egress, and which result in physical competition and pushing behavior" (2013, p.12). Furthermore, Helbing & Johansson (2011, p.697) defined Panic as breakdown of order and individuals behavior start anxious reactions to a certain event. It is characterized by attempted escape of many individuals from a real threaten situations to struggle for survival that could end up in crushing of individuals in a crowd.

On the other hand, Al Bosta (2011, p.744) described the pilgrims' behaviors when they are in a crowd. For instance, when the crowds' movements go slow, the flow of this crowd will start to fall, which could cause the "stop-and-go

waves". These waves could result in a stampede, congestions and crowd disaster, such as pilgrims might be injured, dead or get lost. Because of this problem, some of them could panic in that crowd. This situation occurs when they are in stampedes or congestions; they cannot think clearly about the next reaction that they could do. Instead of that, some of them could create resistance to survive from that crowd. Moreover, because there is not any member of Hajj staff to help them, those pilgrims would collapse, trample and act as obstacles for others, which, therefore, cause fatal damages.

Panic has characteristics that could be shown in crowded places (Helbing et al., 2000a; Cabinet Office, 2009 (B), p.141):

- Individuals move faster than they do normally.
- Interaction between individuals could be physical, e.g. people start to push each other.
- Peoples' movements become uncoordinated, especially when they are moving towards a bottleneck.
- Jams could build up, which cause crowd pressure.
- Injured individuals are escaping slowly.
- Alternative routes or exits are unnoticed or are used inefficiently.

Halabi (2006, p.28) mentioned that overcrowding and bad management cause crowd disasters. Injuries and deaths were results of the panic that took place at previous Hajj events. In addition, Drury, Novelli and Stott stated "…panic could be preventable by effective crowd management as a part of emergency planning." In addition, they mentioned, "…clear credible and timely information during and

after the incident will aid order and an efficient response" (2013, p.27). Therefore, "…these disasters are characterised by poor communications prior to, during and in the aftermath of an incident, which it is very often the victims, rather than the designers and managers of crowd settings who are blamed" (Sime, 1995, p.2; Cabinet Office, 2009 (B), p.165).

On the other hand, Illiyas et al. (2013, p.11) pointed out human stampedes are the most common hazard could be seen at mass gathering events. They are characterized by massive flow of individuals in a crowd in response to a danger. They could additionally result in death, due to suffocation under the high pressure that is caused by the push in that crowd. For example, it reviewed that human stampede at mass gathering events occurred between the years 1980 and 2007, which caused 7069 death and 14,000 injuries (Hsieh et al., 2009; Illiyas et al., 2013, p.11). In addition, an example of one of the most dangerous human stampedes occurred at Hajj event 2006, specifically at Aljamarat Bridge. This stampede resulted in 364 deaths (Hsu EB, 2011; Illiyas et al., 2013, p.11). Figure 2 shows the stages of crowd incidents at Hajj events from the crowd incident analysis.

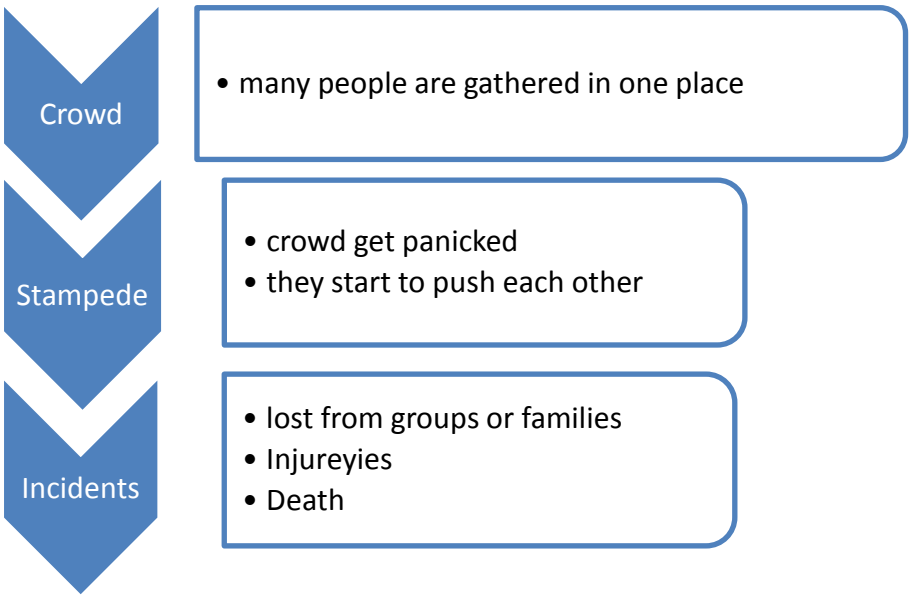


Figure 2: The stages of crowd incidents

In addition, the following diagram (Figure 3) presents the key factors that can be found at the majority of crowd disasters, as Hajj events is one of them:

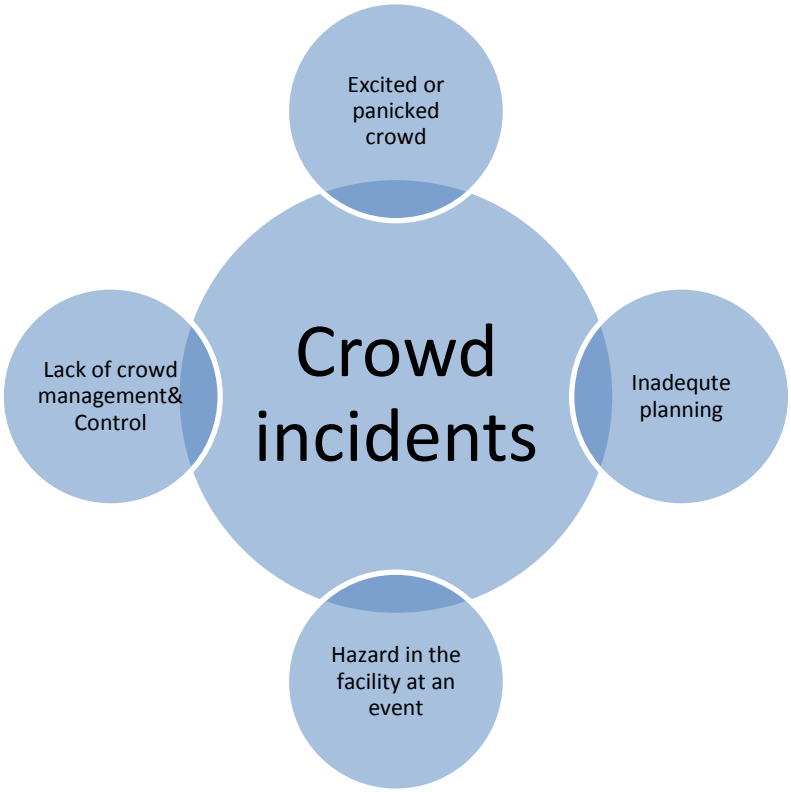


Figure 3: Crowd disasters reasons by Dickie 1995 (Cabinet Office, 2009 (B), p.165)

1.5 Research problems

This study focuses on problems that face both the pilgrims and Hajj staff at Hajj events. These problems are the following:

1.5.1 Organizational problems at Hajj ritual places

Pilgrims arrive in Saudi Arabia and perform Hajj at the same time and places. They come to perform this duty at least once in their lifetime. There is problem regarding organizing pilgrims' movements. For example, the complexity of Hajj management is not only that the technology is unused, but it is also due to the pilgrim's huge number at geographical limited areas of Hajj ritual places (Al-Hashedi et al., 2011, p.1).

1.5.2 The problem of lost pilgrims at Hajj ritual places

Besides the problem of stampedes and congestions, crowds could cause another significant problem, which is lost or missing pilgrim. This problem occurs when they are gathered at the Hajj holy locations, as they might easily get lost from their groups, friends or families.

Yamin and Albugami (2014, pp.191) illustrated that Hajj is about practicing rituals at different places, which could include massive movement between these places by large number of pilgrims. Therefore, many problems could occur from this movement, and one of these problems is pilgrims could be separated from their groups and families, and they could go missing for long hours or even days. In addition, Amro & Nijem (2012, pp.439) illustrated the statistics of Hajj 2011, as around 30,000 pilgrims were lost during Hajj various activities. This figure included situations where pilgrims were lost from more than 24 hours and eventually found.

In addition, Osman and Shaout (2014, pp.29) explained that pilgrims could get lost because of the lack of cooperation between Hajj authorities. For example, the Hajj managers of foreign campaigns (the group guide from Tawafa Establishments) provide every pilgrim with an identification number in wristbands. These numbers are only linked with their databases. Therefore, pilgrim's details are not accessible by any other Hajj authorities such police force. Thus, this lack of a comprehensive database could be connected to all Hajj authorities and sectors.

As a result of lost pilgrim's problem, Mantoro et al. (2011, pp.1) explained that nowadays, the Hajj authorities are dealing with lost or missing pilgrims, usually by distributing multilingual guards and mobilized volunteers by directing them and finding their ways. However, this problem still occurs not only because of the language barriers, but also because of those guards and volunteers are not placed everywhere in Mecca city and the ritual sites of Hajj.

In addition, there are a couple of factors that could cause a person to get lost at the Hajj event. Mantoro et al. (2011, p.1) explained some of these factors as the following:

- Exhaustion and weariness: at religious events, people or pilgrims could get exhausted and tired after performing certain activities. Therefore, they will not be fully aware of their locations.
- The events' environment: people, who are participating at an the Hajj event, could get confused because of the environment, especially those who are participating at this event for their first time.

1.5.3 The problem of lack of directional information and guidance at Hajj ritual places

Lack of signage at Hajj event venues is a significant problem. Mantoro, Ayu and Mahmud (2012, p.12) mentioned that when pilgrims get lost, they could face some difficulties in obtaining directions of a location at Hajj event. These defficulties are due to lack of signings, maps, or street names, as some countries use landmarks or symbols to get to the required location. In addition, One of the interviewees of Hamhoum and Kray (2012, pp.1014) mentioned from his experience at Hajj that he had been lost and couldn't remember his hotel for 3 days. The interviewee added that there were human guides (volunteers) and a number of static signs, but they were limited and written in Arabic language. In addition, some pilgrims do not speak or understand the Arabic language, which is the official language of Saudi Arabia. As a result, they get confused or misunderstand the directions to the Hajj ritual places. In addition, it is not easy to find a translator that speaks the pilgrims' language, or a native speaker (Mohandes, 2008, p.3). Pilgrims without guidance by the Hajj authorities often become lost; they cannot find their groups or campaigns (Khan, 2011, p.5).

Therefore, Taileb et al. (2014, pp.134) mentioned that foreign pilgrims, especially those whose come to Hajj for the first time, need the necessary information about the Hajj ritual sites and how they could be directed or guided to these places. In addition, pilgrims can gain this information in many ways. For example, from their campaign guide, volunteers, conventional printed maps or following the signs. However, pilgrims could face some problems when using these methods. For instants, volunteers are not available all the time; foreign pilgrims are forced

to stick with their campaign without moving freely. In addition, street signs are inadequat, printed maps could not be trusted if these maps are not distributed by Hajj authorities, foreign pilgrims could not read maps that are printed in Arabic language, which is the main language of Saudi Arabia.

In conclusion, Hameed (2010, pp.2) summarized Hajj management problems into: Managerial, organizational, guidance problems, such as misleading places, misunderstanding the static signs, difficulties in communicating between foreign pilgrims and Hajj authorities' employees (language barberries), and most importantly inefficiently in using the "powerful facilities" of information and communication technologies ICT. As a result of not deploying ICT at Hajj events, there are many problems that weaken the management of Hajj. For example, lack of comprehensive databases that could link all Hajj organizers together, manual and not computerized activities that are done by Hajj authorities. In addition, lack of geographical and guidance system that could provide information and maps of Mecca city and Hajj ritual places, and lack of a smart system for monitoring. However, if an ICT system is deployed in Hajj management, it will overcome many problems current problems. For example, it will offer high capacity of data storage, processing and retrieval, represent data in different methods such as texts, pictures, audio and videos, high capacity of for communication and data transmission and designing and development tools such as multimedia, virtual and augmented reality.

1.6 Research questions

- What is the importance of deploying technologies (e.g. Mobile Augmented Reality) in Hajj crowd management, which would help to reduce some of the main Hajj problems (identifying and tracking lost pilgrims, language barriers and organizing pilgrims' movements between Hajj ritual places)?
- How deploying technologies (e.g. MAR) would help Hajj staff, who's working on the ground, and Hajj operators, who's working in control room, to manage the pilgrims' movements, and reduce Hajj problems especially at rituals peak times?
- What are the technical resources that might be reliable in Hajj crowd management?
- What could be the expected outcomes of deploying technologies (e.g. MAR) in Hajj crowd management?

1.7 Research objectives

- Present an ICT system, which could help the Hajj authorities, to manage and control crowds, and avoid overcrowdings and stampedes.
- Present an ICT system that provides directions to lost pilgrims.
- Present an ICT system that monitors and estimates the size of the crowds, at a specific area, which could help Hajj staff and operators to manage them efficiently.

1.8 Research Methodology

This study conducted qualitative method, which was questionnaires, were distributed to 104 correspondents. These questionnaires contained closed-end questions, which use Likert scale, and open-end questions, as each correspondent could freely answer the questions and write down any suggested ideas in each question.

1.9 Conclusion

This research focuses on developing a Mobile Augmented Reality application, to assist Hajj staff and operators in Hajj crowd management. This application would help them to manage crowds' movements between Hajj ritual places, and provide information and directions to lost pilgrims, to reunite them with their groups or be guided to their destinations. In addition, previous Hajj events witnessed crowds' incidents such as overcrowdings, stampedes and lost pilgrims. These problems occur every year, because of the limited spaces of Hajj ritual locations and lack of directional information and pilgrims' guidance. Therefore, implementing MAR application would be a beneficial method, to reduce Hajj problems as much as it can.

1.10 Dissertation description

Chapter 2 covers topics of Literature Review that are related to the Hajj crowd management. Chapter 3 discusses about the Hajj event, as it is the case study of this research. This chapter covers Hajj dates and activities, Hajj authorities and their tasks. Chapter 4 discusses the research methodology, which is the quantitative study. In addition, it reviews the results of these and the discussions. Chapter 5 presents the proposed system that could be used in Hajj crowd management. Finally, Chapter 6 covers the conclusion and recommendations of the research.

Chapter 2: The Literature Review

2.1 Introduction

After describing Hajj main problems and illustrating its' previous crowd incidents, the literature review covers additional information regarding Hajj crowd management. It analyzes previous studies on deploying technologies to manage crowds at Hajj events. Because this area of research has much information regarding the topic of this dissertation, the literature is divided into three main themes. Firstly, crowd management theory. Secondly, practical studies on deploying technologies at Hajj events, and thirdly, the technology of Augmented Reality.

The theoretical theme describes and defines the importance of events' crowd management and its' main steps. In addition, the practical theme describes the use of technologies at Hajj events to assist crowd management. Finally, the theme of

Augmented Reality technology defines and presents how this technology could be built and deployed in different applications.

2.2 Theatrical theme: Crowd Management theory

Crowd management is a systematic planning and supervising the movement of the crowd at an event (Erin, 2002; Earl, 2006, p.74). In addition, crowd management covers risk assessment, anticipating crowd behavior, observing entry and exit points, emergency assistance, first aid, public safety and security of the event (Wetheimer, 2000b:4; Earl, 2006, p.75). Moreover, Health Safety Executive (HSE) (2000, p.31) mentioned events' management should provide enough number of staff, to make sure that crowd management is carried out effectively. That staff has the following duties:

- Knowing the design of the events' venue, assisting the public by giving them information about the available facilities and remembering those with special needs.
- Being aware of the locations of entrances and exits.
- Make sure that overcrowding does not occur in any part of the venue, by managing and directing the crowd, especially the visitors who is entering or leaving the venue.
- Keeping passageways and exits clear all times.

- Controlling unruly behavior and immediate investigation of any disturbances or incidents.
- Instant communications with supervisors.
- Knowing the procedures of evacuating the venue.
- Monitoring the crowds at any points where overcrowding may occur.

The Cabinet Office (2009 (B), p.255) presented crowd management steps, which were findings of interviewing experts in the field of crowd and control management. These steps are the following:

2.2.1 Planning and preparation

- At this stage, there are some factors that should be considered such as:
  - Event's type.
  - Event's timing and location(s).
  - Event's entry is free or paid.
  - Techniques for directing the crowds at the event.
  - Which stakeholders that are needed to be involved?
  - Aims and objectives of the event.
  - Problems that could arise at the event.
  - The Procedures that must be followed to deal with any event's problems.

Planning and preparing for the upcoming annual event, (e.g. Hajj) is significant, even if the planning and preparing for provirus events were successful. For an

event that hosts different locations, Planning and preparing will have different requirements from one location to another. For example, at Hajj, pilgrims at Arafat location spend only one day, while, at Aljamarat Bridge, pilgrims spend three days to complete their duties. Therefore, every location of the event should be planned equally and separately depending on the nature of each location. In addition, "What if…?" scenarios are useful during the planning stage, as they could be used to test the plan at events' sites, to think what are the possible problems that could occur at these sites, and to develop an adequate plans that could help to manage these events problems. In addition, how information of these problems could be shared among the stakeholders of the event. Therefore, all stakeholders should participate at planning these scenarios as useful information could be gathered from different perspectives.

2.2.2 Assessing Risks

Health & Safety Executive (HSE) (2000, p.17) mentioned risk assessment is an important step in managing the crowd safely. It helps event's organizers or staff to plan for any expected and unexpected risks that could occur at the event and to manage these risks. On the other hand, if something goes wrong and things started to harm people, who are involved at the event, this situation is called "Hazard." Therefore, risk assessment is required to assess at what precautions they need to take to prevent harm. This assessment should examine and evaluate all parts of the events' venues. In addition, event's organizers

should think about incidents that could occur, such as visitors collapsing or large-scale emergency such as escaping from the fire.

At the planning stage, event's organizers should associate with experts and experienced people, who have the right capability and knowledge, to take part in the risk assessment process. HSE (2000, p.17) developed a five-step approach to risk assessment as the following:

1- Look for the hazards:

Hazards presented by a crowd	Hazards presented by avenue
Jostling between people	Moving vehicles share the same route as pedestrians
Jostling against fixed structures, such as barriers	Trapped people, such as wheelchair users in the crowds
Trampling under foot	Objects, e.g. stalls, could obstruct movement and cause congestions at busy periods.

Surging, swaying and rushing	Failure of equipment, e.g. turnstiles
Aggressive behavior (principally between groups of rival supporters)	Sources of fire, e.g. cooking equipment
Dangerous behavior, such as climbing on equipment, running down steep slopes…etc.	Crowd movements obstructed by people queuing

Table 2: Hazards types – HSE (2000, p.18)

2- Decide who might be harmed and how:

This step aims to find out what are the causes of the hazards identified in step 1. By knowing the causes, this could help to decide later in the assessment process what actions are needed to discard the hazards. In addition, thinking about the consequences and who might be harmed could help to decide how to protect people from the harm.

3- Evaluate the risk and decide whether the existing precautions are adequate or more should be done:

This step aims to decide for each significant hazard how much risk remains after the existing precautions have been taken into account. The findings will enable event's organizers to know the importance of hazards and priorities actions that need to be taken to control them.

4- Record the findings:

It is good to keep a written record of what have been done. Significant findings include:

- Identified significant hazards in the assessment
- The remaining risks
- The conclusion of the assessment including the actions that have been identified to reduce the risks.

5- Review the assessment and revise it if necessary:

Event's organizers should review and revise the assessment if it is developed, which suggest that the assessment may no longer be valid, such as:

- Major changes to the events venue
- Previous incidents that have injured members of the public
- Serious incidents at other events venue from which could learn and take preventive actions in the future.

2.2.3 Multi-Agencies Teamwork

Multi-agencies or events stakeholders could include fire and ambulance service, local authorities and event's organizers. All of those agencies should be well placed at the events sites. If the event is successful, it is better that all the multi-agencies still work together through whole event, from the begging of the planning stage until the last person of the event is gone. In addition, it is significant that roles and responsibilities of each agency are identified, to make sure that these roles are integrated successfully.

2.2.4 Understanding the crowds

There is a scheme that could be used to understand and categories the crowds at different events. Factors to categories crowds types are the following (Cabinet Office, 2009 (A), p.133):

- Purpose of the crowd.
- Duration of the crowd.
- Start time of the event.
- Individuals' location at the event.
- Event atmosphere and level of conflict.
- Level of interaction between event's organizers and the crowds.
- Heterogeneity of crowd membership.
- Size of group units within a large crowd.
- Amount of luggage.

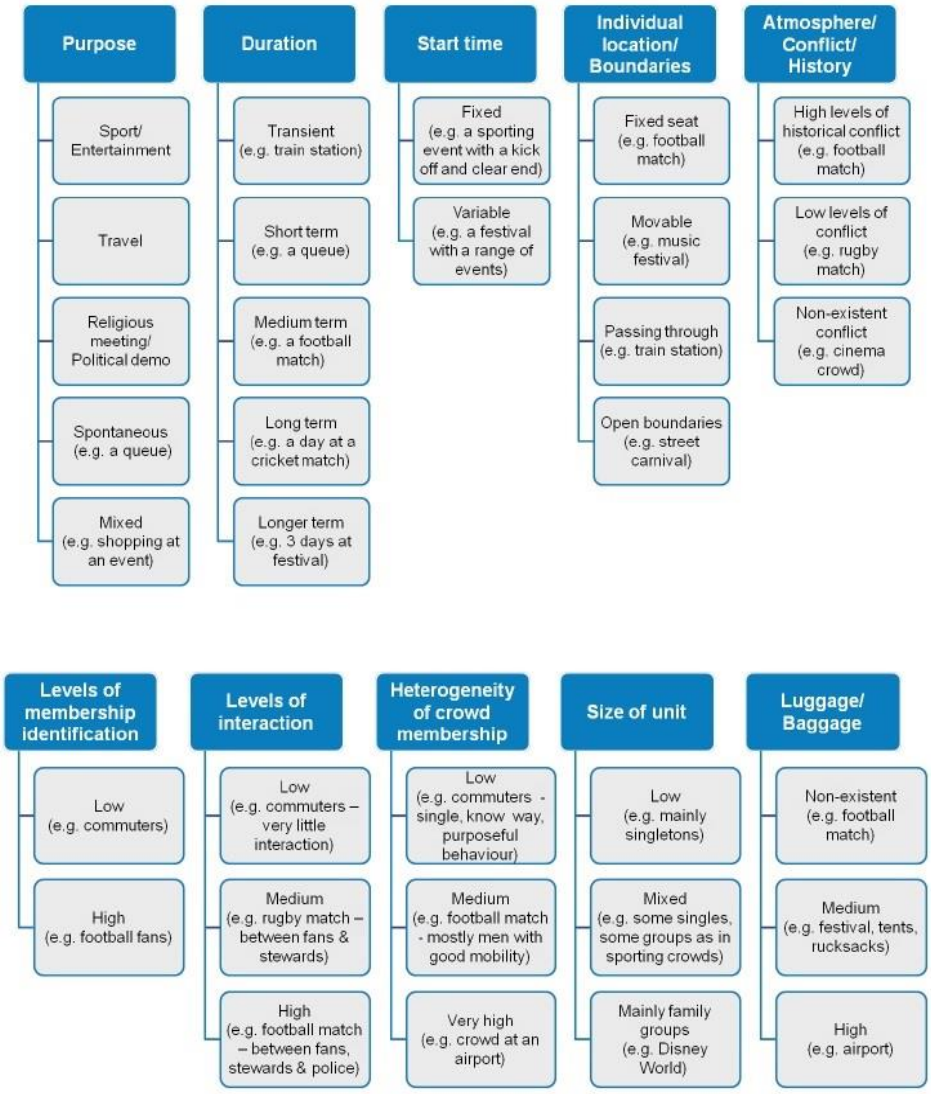


Figure 4: Scheme of crowds at events – Cabinet Office (2009 (A), p.133)

Figure 4 demonstrates various types of crowds that could cover all these factors and which crowd could be categorized. For example, in the planning step, to understand the Hajj crowds by using this category, Hajj crowds would be as the following:

- Purpose: Religious meeting. Hajj is one of the main pillars of the Islamic religion, and every adult Muslim must perform Hajj once in a lifetime (Amro & Nijem, 2012, p.438).
- Duration: Long term (6 days at event). Hajj is performed from 8^{th} until 13^{th} of the last month according to the Hijri calendar, which is the month of Dul-Alhijjah (Amro & Nijem, 2012, p.438).
- Start time: Variable (specific time and dates of the event). As mentioned in "Duration."
- Individuals' location/boundaries: Movable (and outdoors). Hajj duties must be completed at the Grand Mosque and Hajj ritual places (Mina, Muzdalefah and Arafat). In addition, pilgrims move between these places as they camp in Mina, walk about 10 miles to Arafat and pray then they return to Mina to stone the devil at Aljamarat Bridge by stone where were collected from Arafat (Al-Nuaim & Al-Masry, 2012, p.48).
- Atmosphere/conflict: High level. The Hajj has witness's number of serious crowd incidents between 1994 – 2006 there were five major incidents. These incidents led to 1053 death and 1295 injuries (Ministry of Hajj, 2011; AlGadhi and Srill, 2003; Siddiqui & Gwynne, 2012, p.478).
- Levels of interaction: High. People could get lost at Hajj, guided and found by the authorities (Amro & Nijem, 2012, p.439).

- Heterogeneity of crowd membership: Very high. Hajj event is considered one of the multi-cultural events that bring more than 183 countries together in one place (the holy city of Mecca, Saudi Arabia). Example of these countries includes Indonesia, Pakistan, India, Turkey, Iran, Nigeria, Bangladesh, Egypt, Europe, USA, Russia and China. Therefore, this cultural and geographical diversity in one place could effect on the management of those pilgrims as well as on their behavior (Siddiqui & Gwynne, 2012, p.479).
- Size of unit: mainly family and friend groups. Pilgrims at Hajj move in relatively huge groups with one or more guides (Amro & Nijem, 2012, p.439).

2.2.5 Communication and information

Communicating with the events' crowd and providing information to them is important for the successful of the event.in addition, information should be used to the whole crowd, accurate, comprehensive, timely, updated and presented as visual and audio. Moreover, information that is presented to the crowd should be clear. For example, describing how to arrive at the event by public transportation, describing the events locations (avenues, toilets...etc.) and how to get their directions. However, in providing signs, the native language of the events host is not suitable for international nationalities. Therefore, these signs should use multi-languages or event use pictograms, which are symbols that are used to represent an object or an idea, as a universal language. In addition, all kinds of information should be gathered and shared to all multiple agencies that are involved, to organize the crowds.

2.2.6 Experienced Personnel

Utilizing experience in planning and managing crowds is a significant part of crowd management. This experience that is developed from years of managing, dealing, working with crowds presents a good knowledge about crowds and their behavior.

2.2.7 Observing and monitoring

One of the important steps in crowd management is to observe continually and monitor the crowds because it would help to identify any sign of problems, danger or any possible of crowd disorder. It is significant to use various types of crowd monitoring during the event. For example, officers on the ground, uncover officers in the crowd, Closed Circuit Televisions (CCTVs), helicopters for an overall view…etc. If using CCTVs, using alternative monitoring tools would be ideal, as sometimes CCTVs could give false images. For example, some CCTV pictures could show crowds density is high at a specific area, whereas in reality the crowd density is normal. HSE (2000, p.47) mentioned jostling, trampling and suffocating are all potential hazards that could appear at crowded events. Therefore, to avoid these harms, crowd management should ensure that crowd behavior and movements are monitored efficiently such as, placing stewards and

CCTV's at suitable points. In addition, all events' staff should know their roles in crowd monitoring, and to take actions immediately if the people are at risk. In addition, HSE (2000, p.49) stated CCTV's could provide information on the distribution in many areas. They are useful for directing and monitoring crowd management operations. However, it is useful to use a selection of systems to monitor the events. For example, CCTV's could be used at key locations supported by staff watching the crowd from vantage points at these locations. Moreover, HSE (2000, p.47) illustrated some areas that event's staff should closely monitor them, such as the following:

- Entrances and exits
- Standing areas where crowd surges or pushing could occur
- Popular stalls, attractions and refreshments
- Bottlenecks (e.g. stairs and escalators)
- Areas where people queue and Enclosed areas

HSE (2000, p.47) mentioned that counting systems could be helpful in estimating the number of people within the venue areas. These systems are helpful, as they provide information to event's staff know to how people are entering and when and if an area are expected to become full. For example, turnstiles that are linked to automatic counting systems, computerized systems linked to sensors at entry points…etc. in addition, HSE (2000, p.48) pointed out using event's staffs within the crowds is essential to experience crowding conditions. They observe people's faces and identify signs of distress.

Cabinet Office (2009 (B), p.76) mentioned the following factors that are important to be considered in enhancing the efficiency of crowd management and crowd control:

- Crowd management is about facilitating the crowd's movement and activities, to ensure that the crowd can safely enjoy the event that they come to be part of. E.g., ticket sales, seating, parking, public announcement and communication between the crowd management members. However, crowd control is about the actions taken to control the crowd on their behavior become undesirable.
- Insufficient in the planning stage of crowd management could result in the lack of awareness, unclear information of how to deal with a problem, and how the crowds could be managed.
- The events venue should be visited before the start of the event and on the day of the event. These visits are to assess the geography of the location and to determine where the potential hazards areas, such as crowds' bottlenecks, could be.
- Crowd facilities such as toilets should be given extra attention, to make these places more accessible.
- It is a vital to use personal experience in the planning phase of the crowd management.
- All stakeholders, who are participating in organizing the event, must be aware of their roles and responsibilities before, during and after the event under both normal and emergency situations.
- Crowd management training and evacuation training are important for event organizers.

- Family and friend groups prefer to move together as a unit. If they arrive together at the event, they move around together and leave together (Pan, Han, Dauber & Law, 2006; Cabinet Office, 2009 (A), p.50).

2.3. Crowd Management in practical: Implementing technologies in Hajj Crowd Management

Weiss & Craiger (2002, p.44) described the main idea of using technology is to surround users with computers and softwares that assist them in their work and personal lives. Technologies have main types. For example, nanotechnology, which is minimizing the computer components down to the atomic scale, and wireless computing, which is the use of wireless technologies, to connect the computers to each other's by a network. In addition, the technology of context awareness. It has the ability of computers to understand the user's current situation, to offer services or relevant information to a particular context.

2.3.1 Implementing RFID technology in Hajj Crowd Management

Khan (2011) described implementing RFID system at King Abdul-Aziz International Airport (KAIA) in Jeddah city, Saudi Arabia. The Hajj terminal is

based at this airport, which is the main portal for foreigners, receives millions of pilgrims every year. Because of the huge number of the arrival pilgrims, KAIA officials face many difficulties in managing those pilgrims. For example, guiding and directing the pilgrims to their correct areas and language barriers between those pilgrims, who come from different countries, and KAIA officials. Therefore, the author proposed an RFID system, which is Radio Frequency ID, to help the arrival pilgrims to be guided, grouped and manage at KAIA. This proposed system could help KAIA officials to solve many of the arrival pilgrims' problems. For example, identifying and counting those pilgrims according to their nationalities, counting them in a specific area and guiding them using their language.

The proposed RFID system has requirements to deploy:

- Each foreign pilgrim will be given an RFID card or tag in his/her country before the arrival or after passing the immigration at Hajj terminal at KAIA.
- After the pilgrim passes the immigration checkpoints and enters the plazas gate, a monitor will reveal a welcoming message written in his/her language.
- The pilgrim will be guided into the specific area to his/her Tawafa Establishment office. Each office has a unique color and number.

- KAIA officials can collect a report from the system indicating the numbers of pilgrims at the plaza area, and which Tawafa Establishment office is collecting his pilgrims.

Implementation of the proposed RFID system:

- Tools of the systems:

  The Hardware components are:

  - RFID cards or tags.
  - RFID readers.
  - Data server, where pilgrims' information is stored in the system.
  - Access points, which allowing the KAIA officials to access the system to retrieve data, register new pilgrims and collect reports.
  - Monitors, which displays the guidance and welcoming message for pilgrims.

  The software tools are:

  - Visual basic.NET, which is the programming language for the system.
  - ATID AT-570 RFID reader software development
  - Oracle SQL developer, the tool that is used to build the systems' database.

This study aimed to provide a system that could help KAIA officials to manage the arrival foreign pilgrims. This system could rapidly identify, greet and direct them by their language to their Tawafa Establishments officials to transport them to Mecca city. The proposed system is about deploying RFID system at KAIA. The tags are distributed to pilgrims and contain their information. In addition, the readers are used to scan the tags and identify each pilgrim. However, the author focused on implementing this system only at the KAIA, while he did not mention how this system could be deployed at Hajj events in general. Therefore, the RFID tags are useless in Hajj crowd management if they could not be deployed in other places, such as the Hajj holy places. The RFID system would be implemented efficiently if it were used in sequence at KAIA and Hajj places together. Because Hajj rituals are done in specific time and at specific locations, if a pilgrim was lost at the KAIA or at Hajj holy sites for long period of time, he/she could miss Hajj rituals performance.

Al-Hashedi et al. (2013) developed an RFID application and proposed architecture for RFID-based management system. They briefly described the Radio Frequency Identification (RFID) technology, as it is an emerging technology that is used to identify and track objects, people or transactions. It transfers a unique number of the identity and data of an object by wireless communication as radio waves. This paper proposed the RFID technology, as it can help to deal with some Hajj problems. Examples of these problems could be overcrowding at ritual places and the difficulties in identifying, monitoring and tracking pilgrims.

RFID application at Hajj:

All pilgrims would be given a wristband that contains RFID tags, which should be worn all the time at Hajj event. This tag will contain important information about the pilgrims such as name, nationality, age, Tawafa Establishment, campaign name…etc. It could be retrieved and displayed by an RFID reader.

Some of the RFID applications might be used in Hajj:

- Pilgrims tagging: the RFID tags could help all Hajj officials to identify and help the pilgrims. For instants, guiding pilgrims to their campaigns or residences.
- Pilgrims marinating and tracking: with RFID tags, Hajj officials could monitor and track the movements of the pilgrims, and check their number in a specific area. Therefore, once this area reached the capacity limit, Hajj officials can stop other pilgrims from entering this area and redirect them to other areas.
- Transportation services: RFID could be used to count the pilgrims in their buses and how many of them pass the checkpoints. This method could be done by providing certain information such as, the number of the pilgrims in each bus and the pilgrims' names.

- Security and surveillance: for example, Hajj officials could use the RFID readers to monitor all areas of Hajj and locate which area has reached its limit.

The architecture of the RFID system:

- RFID hardware: RFID tag, which is a tiny microchip that contains an antenna, memory and a processing unit. In addition, RFID reader, which is a device the collects tags' information.

- Middleware: in the middleware layer, the data are cleaned from a multiple reading of errors, and then they are buffered in a database. Once the data are buffered, they become available for analysis or reviewing.

The proposed system could help the Hajj officials to manage the pilgrims. By using RFID tags and readers, to identify, track and count them. However, there are some issues regarding using the RFID tags, such as problem of losing RFID tags at Hajj events. For example, the process of making Wudu. This process requires the pilgrims to wash part of their bodies. Therefore, it could be a reason that pilgrims might take their tags off and forget them. As a result, identifying and tracking any of those pilgrims, who forgot their tags, will be hopeless. Another issue could be that making 2 million tags every year is expensive. In addition, technical issues with RFID tags or readers such as, does the reader scan the tags from distance?

Mohandes (2008) mentioned Hajj authorities and officials are facing challenges in crowd management and pilgrims' identification at Hajj events. Therefore, the author proposed and conducted a study using RFID technology at Hajj events.

RFID proposed system: it consists of the following:

- RFID tags
- RFID readers: they consist of antenna, transceiver and decoder that send signals to inquire about any tag in the area. However, on receiving any signals from the tags, the decoder passes on the information to its data processor.
- Data processing subsystem: to embed the information in the reader.

RFID as a solution at Hajj:

The pilgrims would wear the RFID tags all the time as a wristband. When each pilgrim's tag is scanned by an RFID reader, his/her information will be displayed on the reader. This information is such as name, address, blood type, nationality, medical conditions and Tawafa Establishments' contact number. The proposed RFID system might help the Hajj officials to manage the crowds, by estimating the peoples' number at certain locations, where risk of accidents could likely take place at these locations. This system may work with the help of security personnel and volunteers to ease the flow of the pilgrims at jammed locations and to utilize

some spaces at these locations. In addition, it could count the pilgrims by installing the RFID readers at entry and exit points at these locations. Therefore, the readers could ping when the RFID tags pass these points. Additionally, these tags could be helpful in guiding the pilgrims, who are lost, or identify the dead of them in case of accidents at Hajj events.

Pilot project for pilgrim identification:

The author conducted a pilot study by implementing the proposed RFID system at Hajj event. The RFID reader could display all pilgrims' information that is stored on the wristband tag. The main information that every tag has is a unique ID number is stored in that tag, which represent a key to restore the pilgrims' information from the database. From the Practical perspective, 1000 RFID tags and a single reader were used in the pilot study. In addition, Pilgrims for the Ivory Coast country volunteered to use these tags for this study. Moreover, an IT engineer built a database that included the 1000 pilgrims' personal details and medical conditions. As a result, it showed that the RFID system could be helpful in identifying the pilgrims at checkpoints. For example, scanning the tags by the reader took small time fraction to confirm the pilgrims' validity for Hajj.

The author conducted a pilot project to use an RFID system to manage Hajj problems. These problems are, for example, identifying, guiding and managing the pilgrims at Hajj event. After testing the proposed system on 1000 volunteers of Ivory Coast pilgrims, positive results were showed in the stage of the pilgrims'

identification. However, there were a couple of issues when the RFID system was deployed. Firstly, the volunteered pilgrims wanted to keep the tags with them as a memorial that they went to Hajj. Therefore, this could cast excessively to develop nearly two million tags every year. Second, the results of the pilot study could be much better if the proposed system were deployed on different volunteers from different nationalities, to know how the system will manage different pilgrims by the Hajj authority. Thirdly, the author mentioned that RFID readers were installed at entry and exit points at key locations, to count the pilgrims who were entering or exiting from these locations. However, could RFID readers scan more than one tag at the same time? Alternatively, were the pilgrims entering these locations one by one? It seems that the author did not describe this point. If the reader could scan more than one tag at the same time, isn't it overloaded on these readers? Moreover, are they capable of processing too much information for all entry or exit points? In addition, if the pilgrims were entering or exiting one by one, this process will be more complicated, as there are two million pilgrims who will enter and exit at the same location, such as Aljamarat Bridge. Therefore, these points did not mention at this study.

Nevertheless, the author criticized this study by developing another one. The RFID tags faced problems with the pilgrims. As they wash until their elbows for five times a day, this procedure is called "Wudu." Therefore, Wudu could cause the tags to be lost or mixed with other pilgrims' tag. In addition, this Wudu applies to wash the head as well. Therefore, installing the RFID tag in a card and wear it around the neck is unwise, as the pilgrim will eventually take it off for Wudu. Moreover, the author criticized again in another study (Mohaneds et al.

2013), as they agreed that using RFID in identifying and tracking pilgrims was not successful at mega events such as Hajj.

Yamin, Huang and Sharma (2009) mentioned crowd management task in large events such as Hajj is difficult, because of the large number of the people and the difficulty of managing their movement between Hajj ritual places. In addition, they pointed out this large number of people would be managed by applying technologies such as sensors and radio technologies that are already being used in daily activities. For example, checking and controlling traffic movements, payment of toll taxes and monitoring patients at hospitals. Therefore, they proposed deploying RFID system and distribute RFID tags to each pilgrim, to improve the crowd management at Hajj events.

The following are the main areas where RFID system could support Hajj crowd management:

- Immigration management: when pilgrims arrive or depart, they usually fill an immigration form and queue for a long time. By providing RFID tag to them, the immigration process will require the pilgrims to pass the gates where RFID readers are placed on these gates. The reader scans the tag to retrieve the pilgrims' information. This process could take seconds and save time for both pilgrim and immigration officials.
- Disaster management: This means RFID system could minimize the danger of risks that could affect badly in the events crowd, e.g. stampedes.

- Identification and location management: when stampedes happen in the crowds, this could cause serious injuries; pilgrims get missing and even death. Therefore, identifying those dead people would be a challenge for Hajj staff. In addition, crowd movement could cause displacement of people in that crowd. Therefore, those lost people could be gone missing for days and even for weeks. Those pilgrims could be lost because of the poor of identification methods in this event. Yamin, Huang and Sharma stated "…there is absolutely no technology to track the missing person down" (2009, p.6). Therefore, RFID system can track the missing pilgrim, by scanning the pilgrims' RFID tag and the pilgrims' location, is sent to the database. Thus, the pilgrims could be tracked and picked up from his/her location.

The authors mentioned that Hajj attracts huge number of Muslims. However, this event faces some problems. These problems are related with the crowds' movement (or disaster), identifying and locating missing people and health management of pilgrims. Until nowadays, there is not any efficient method to address these problems with crowds. Therefore, utilizing the emerging technologies (e.g. RFID system) could help to achieve one of the crowd management objectives, which is providing safety and comfort for those event participants and visitors. However, these RFID tags are exposed to be lost from the pilgrims, or mixed with another pilgrim. Therefore, the process of identifying and tracking lost pilgrims is useless with each pilgrim uses his/her tag.

Khan (2011), Al-Hashedi et al. (2013), Mohandes (2008) and Yamin, Huang and Sharma (2009) agreed on deploying RFID systems in Hajj crowd management would help Hajj authorities to overcome Hajj problems. For example, problems of identifying, tracking and guiding lost pilgrims at Hajj events. In addition, they agreed to use the RFID systems by giving the tags to the pilgrims as these tags contain their detailed information. For example, their name, age, nationality, Tawafa Establishment, group guide name and contact… etc. Moreover, using the RFID readers by Hajj officials to scan the tags and retrieve this information, to support their decisions. Furthermore, they agreed on the use of the RFID systems could help Hajj staff and operators to estimate the pilgrim's number at Hajj ritual places areas. This estimation could help them to avoid overcrowding at these places. In addition, it is done by installing RFID readers on entry and exit gates at Hajj ritual places as the readers scan the pilgrims' RFID tags once they enter or exit from these places.

However, Khan (2011), focused on deploying the RFID system at King Abdulaziz International Airport (KAIA), as Hajj terminal is passed at this airport. Deploying this system might help airport officials to overcome another problem beside identifying and guiding the pilgrims. This problem is the language barriers between foreign pilgrims and the airport officials.

On the other hand, Al-Hashedi et al. (2013) added that using RFID system might assist the Hajj officials preventing illegal pilgrims from entering Hajj ritual places and Mecca city.

Nevertheless, Mohandes (2008) conducted a pilot study to deploy an RFID system at Hajj event. The RFID tags were distributed to 1000 pilgrims from Ivory Coast, and using a single reader to scan these tags. It was confirmed that scanning these tags was easily determined at Mecca city checkpoints.

Nonetheless, Yamin, Huang and Sharma (2009), described the RFID system could be used efficiently in immigration management at Hajj portals and managing pilgrim's locations.

Comparing with Khan (2011), Al-Hashedi et al. (2013), Mohandes (2008) and Yamin, Huang and Sharma (2009), Abuarafah, Khozim and AbdRabou (2012) agreed the importance of estimating the pilgrims' numbers at Hajj ritual sites. However, they used another technique to do the estimation. They deployed thermal or infrared cameras that are installed at these sites. These cameras measure the pilgrims' body temperatures, to indicate crowd density. When their body temperatures rise, crowd density will start to increase.

Unfortunately, Naser et al. (2010) mention the main limitations of implementing RFID technologies in religious events such as Hajj. These limitations are divided as the following:

- Technical obstacles: the RFID technology is still limited in outdoor system applications, as RFID is based on radio signals and these signals can be interrupted by natural and artificial factors such as wind, rain, and magnetic

fields. In addition, the failure of RFID could be caused by other factors such as creating an overload on the readers by reading a huge number of tags.

- Security threats: such as eavesdropping, replay attacks, unauthorized tag reading and tag cloning.

2.3.2 Implementing other technologies in Hajj Crowd Management

Mohaneds et al. (2013) developed a system for tracking and identifying pilgrims during Hajj season by using mobile phones. It uses mobile phones that equipped with a Global Positioning System (GPS), which is available with pilgrims. In addition, the authors developed a second system, which is a small mobile sensor unit that could be given to each pilgrim and to be attached on his/her Hajj clothes. This sensor includes a GPS chip, a microcontroller, battery and antenna. In both ways, the mobile phone or the mobile sensor sends its ID number, latitude, longitude and time. Therefore, these are location information of the pilgrims will be revealed on a Google map or a similar geographical information system by using map server. In addition, this proposed system could depend on using Wireless Sensor Networks (WSN) for internet connection if the mobile 3G connection were weak or lost. The WSN system consists of a fixed wireless

network infrastructure that is capable of gathering; processing and routing location information and it time of pilgrim's movements.

The authors divided their study into two sections as the following:

1. Mobile phones tracking and monitoring system: this system is based on using 3G mobile connection. In addition, it uses a web service as the backend, and a mobile application is developed to collect the location information and send it to the web service. This service receives the data using a secure channel and saves the received data in a data server. In addition, it retrieves the users (pilgrims) location on a Google maps. The components of the system are:
   - The mobile application: it is developed by using C++ for Symbian operation system. Its function is to collect the current location time and information (longitude, altitude) to the web service. It continues to send to the web service until the administrator closes the application. The location data uses internet provided by cellular networks or WSNs to exchange the data with the server. If the location information were not sent, it would be saved in mobiles' memory until the connection is restored.
   - Web services and software platforms: it is an interface that is used for the mobile application and the website. It saves the users' current location using a mobile application, and it retrieves the pilgrims' location data. It is applied by using ASP.net and Microsoft C#, and it is connected to the database by Microsoft ADO.

2. WSN pilgrims tracking and monitoring system: the WSN consists of a set of fixed wireless nodes. Each node includes a high gain antenna, RF transceiver,

microcontroller and Ethernet for interfacing to the server by the internet. If it is needed to locate a pilgrim, the fixed nodes broadcast his/her unique ID number. Then these nodes send the location information the server.

The authors developed two systems for one purpose, which is tracking and monitoring the pilgrims. The mobile application should be downloaded for each pilgrim who arrives at Saudi Arabia for Hajj. This point raises couple of concerns. This process could expose the privacy of the pilgrim as he/she would not allow anyone to use their mobile phones. In addition, a pilgrim could lose their mobile phones at Hajj. Therefore, when Hajj officials try to track and find the lost pilgrims' location, they could discover the phones' location and not discovering the pilgrims' location. Moreover, there are some pilgrims who do not have smartphones (equipped with GPS), or they could only have regular mobile phones. Therefore, they could not be forced to get one as it is an independent choice. In addition, the issue of distributing a mobile sensor to each pilgrim who does not have a mobile phone, is the same issue of handing RFID tags to them, that could result in losing the device or mixing it with other pilgrims. In addition, these devices are going to be manufactured and hand them to two million pilgrims every year, which is complicated and expensive process for the government.

Aly and Abdelwahab (2012) argued that most challenging in Hajj management is the huge number of missing pilgrims and unidentified deaths every year. They suggest using an efficient monitoring system for tracking missing pilgrims and identify them, in order to make appropriate decisions. Therefore, they developed

new Hajj and Umrah Dataset (HUDA) in collaboration with Crowd Sensing system to detect and identify a missing pilgrim at Hajj.

The authors explained the functions of the two systems and how they collaborate as the following:

1. Hajj and Umrah Dataset (HUDA): in this dataset, hundreds of pilgrims' images were taken during 2011 and 2012 Hajj and Umrah seasons. It contains faces from 25 countries, and more than six images were taken for each pilgrim to be stored in the dataset. These images were taken in different range of positions, facial expression (such as open and closed eyes, normal and smiling), facial details (wearing glasses and not wearing glasses), different lighting conditions (bright and dark) and random backgrounds.

2. Crowd Sensing System: this system has been developed to support Hajj officials to manage the missing pilgrims during the seasons of Hajj and Umrah. The aim of this system is to use techniques from computer vision and image processing to develop a website Hajj and Umrah missing pilgrims. This system consists of three components:

    - A database that contains all the pilgrims' details and images. This information should be uploaded to the HUDA website.
    - Monitoring cameras distributed around the Holy Mosque, ritual places of Hajj, airports, Hospitals and any other areas of interests.

- The HUDA website will be using face detection and recognition algorithms that is developed by the authors, to obtain faces from images that are captured by the monitoring cameras for identifying missing pilgrims.

The authors developed a dataset for Hajj and Umrah events. This dataset contains all pilgrims' details and images that were taken from different angels, to use them in case of missing dead pilgrims. In addition, it is connected with the portal as any Hajj officials could use it to identify the missing pilgrims. However, for example, if some pilgrims were dead at Hajj due to a car accident or a fire in camps at Mina city (one of the ritual places), and the result of this accident could be that pilgrims were brutally injured in their faces. How this system could identify them if their faces were ruined? The authors did not point out if pilgrims might face these situations where their faces could be demolished due to an accident. In addition, they did not mention the process of finding lost pilgrims. For example, how will their group guide or Hajj officials be inform when their lost pilgrims are found?

Amro & Nijem (2012) proposed a communication and information system to help the pilgrims' guide, who is one of the Tawafa Establishments' employees. His duty is to take his pilgrims group and guide them to the ritual places of Hajj. This guide faces one of the disturbing problems, which is missing or lost pilgrim. Therefore, this proposed system, which is called "e-mutawwif," allows this guide to locate lost pilgrims and track their movements using live maps.

The author described briefly an overview of the “e-mutawwif” system:

The proposed system is about handing a GPS receiver to each pilgrim, and they should have it all the time. These GPS devices receive the current location of each pilgrim from GPS satellites and send it the database server, by General Packet Radio Service (GPRS) of one of the cell phone providers. On the other hand, the web server is linked with the database server, to update the pilgrims’ location on the live map. Therefore, the guide could monitor his pilgrims in the group by a portable device using the internet.

The components of the “e-mutawwif” system are:

- The GPS devices: that receives the pilgrims’ location to track his/her movement.
- Database is used to store pilgrims’ locations and other information. This database is built by using MySQL.
- The web application: it is used by the guide to track and monitor pilgrims’ movements. It consists of five interfaces, which are Home page, Registration, Report, Manage and Login/Logout. The guide could log in to locate his pilgrim's group and track their movements on Google maps.
- Mobile application: the guide could log into the system by using a mobile app on his mobile phone wherever there is an internet connection available.

The author of this study developed a system that could assist the pilgrims' group guide by identifying and tracking any lost pilgrims from this group. The system consists of distributing GPS devices to the pilgrims while the guide could identify their location and track their movements through a web server or mobile application. This study showed that pilgrims could get lost from their groups, and the guide faces many problems until lost pilgrims are reunited with his/her group. However, this is another study that described distributing devices such as GPS receiver to the pilgrims. These devices may get lost when the pilgrim is lost. Therefore, the device could be located, but a pilgrim is still missing. In addition, these devices could get lost, as pilgrims do many activities at Hajj, such as stoning the devil or constant movement from ritual place to another or the process of making Wudu, which is washing up five times a day. These are some of the circumstances that the GPS devices could get lost from the pilgrims.

Abuarafah, Khozim and AbdRabou (2012) argued that Hajj events face many accidents in the last twenty years. For example, in 2004, 251 pilgrims were dead in a stampede at Mina city (one of the Hajj ritual places). Therefore, to avoid crowd densities that caused these accidents, Hajj crowd management should be provided with instant information about crowd densities in certain locations that are likely witnessing crowded pilgrims. As a result, the authors proposed a computer vision method for estimating crowd densities at these locations.

The proposed technique:

The proposed system uses thermal or infrared cameras at crowded places integrated with decision support system for Hajj crowd management. It analyzes

video sequences that captured by the cameras and calculates the occupied areas. Therefore, the crowd density of these areas could be calculated. This calculation could be done by using the thermal cameras that indicate crowd density from human temperature, as each time there is high crowd density; the human temperatures will rise. Therefore, this technique could alert the Hajj operators at command and control room by indicating crowd density at a certain location by presenting crowds percentages using different colors. For example, white colour indicates (0-35%) of crowd density, yellow colour (35-45%), green colour (45-55%), blue colour (55-65%), purple colour (65-75%) orange colour (75-85%) and red colour (85-100%).

There are reasons of why thermography is suitable for managing Hajj events:

- Thermal imaging uses remote sensing that keeps the users out of danger.
- Thermal imaging does not affect the target at all.
- The images present excellent overviews of the target without the need of intelligent recognition of faces or body part.

The authors presented another method for crowd monitoring at Hajj events. They used infrared or thermal video sequence by using thermal cameras. Deploying this technique could help the Hajj operators to estimate the crowd density in a particular area. In addition, it could help them to make a real-time decision after it calculates the crowd at these areas, such as stopping pilgrims from entering this area or direct them to enter other gates. Therefore, this technique would effectively increase the quality of crowd management tasks specifically crowd

monitoring to estimate the crowd density before any major problem occur that could effect on this crowd.

Mohandes et al. (2013), Amro & Nijem (2012) and Aly & Abdelwahab (2012) agreed on technologies could be used to track and identify lost pilgrims at Hajj events. Additionally, Mohandes et al. (2013) and Amro & Nijem (2012) agreed that this could be done by handing Global Positioning Systems (GPS) receiver devices to the pilgrims. It could help Hajj officials and their group guide to locate and track them when they are lost at Hajj ritual places. Moreover, they agreed on that the pilgrims' location information (ID. Number, latitude, longitude and time) is presented by using Google maps or alternatives.

Comparing with Amro & Nijem (2012), Mohandes et al. (2013) added that if the 3G connection of the GPS receiver devices is weak or lost; these devices automatically switched their internet connection to Wireless Sensor Networks (WSN). Therefore, these devices are connected all the time and assure that the information of pilgrims' locations is updated continually.

Nevertheless, Amro & Nijem (2012) added that the pilgrims' group guides could use web server or mobile application, to located and track any of their pilgrims, if he/she is lost from his/her group.

However, Aly & Abdelwahab (2012) mentioned that tracking and identifying lost pilgrims at Hajj events is done by using Hajj and Umrah Dataset (HUDA) and

Crowd Sensing System. HUDA is a dataset that stores pilgrims' images in six different positions. When the pilgrim is lost, the Crowd Sensing System use monitoring cameras, to track the lost pilgrim and identifies him/her by comparing his/her image with the stored ones on HUDA database.

Nonetheless, Abuarafah, Khozim and AbdRabou (2012) developed monitoring cameras that use thermal technique, as Hajj operators in the control room could estimate crowd densities in a particular Hajj location. This estimation is done by observing the pilgrim's body temperatures at this location. If the body temperatures are high, this could indicate that crowd density at this location is high. Therefore, the Hajj operators would make precautions regarding managing this crowd density.

2.4 Augmented Reality (AR) technology

Carmigniani et al. (2011) presented a survey on augmented reality systems and applications. They defined Augmented Reality (AR) as "A real-time direct or indirect view of physical real world environment that has been enhanced / augmented by adding virtual computer-generated information to in". This technology aims to simplify the users' tasks by combining virtual information whit direct surroundings and indirect view the real environment.

AR devices:

1. Displays: AR display devices are divided into three types:
    - Head Mounted Display (HMD): this device is worn on the head like a helmet and displays images of the real and virtual environment.
    - Handheld display: uses small computing devices, as the user could hold the display with their hands. This display uses video-see-through technique to overlay graphics onto the real environment. In addition, it uses sensors, such as a digital compass and GPS. AR handheld devices are smart phones, Personal Digital Assistant (PDA) or tablets. Smartphones are portable and widespread. They have a combination of powerful CPU, camera, accelerometer, GPS, and compass. This combination is promising components for using AR. PDAs have the same advantages of smartphones, but they are less widespread because of the recent advantages of Android smartphones and iPhones. On the other hand, Tablet devices are much more powerful than the smartphones. With the iPad devices, it is believed that tablets could be promising platforms for AR handheld displays.

2. Input devices: in the case of smartphones and tablets, these devices themselves could be used as pointing devices. For example, Google sky maps on an Android device requires the user to point the device to the sky and direct it to a star or a planet that he/she would like to know its' name.

3. Tracking devices: consists of digital cameras, optical sensors, GPS, accelerometer, compass and wireless sensors.

AR applications: the authors categorized AR applications into four types that are most being used for AR studies:

1. Advertising and commercial: AR technology is used by marketers to promote their products online. For example, they present their products as a 3D shape that appears on the costumers' screen by using the company's website.

2. Entertainment and education: this type includes cultural applications with sightseeing and guiding at museums, gaming applications using AR interfaces and some smart phones apps that use AR for the purpose of entertainment and education.

3. Medical applications: the majority of these applications deal with using images and robot-assisted surgery. Therefore, there are significant studies that include AR and medical imaging and instruments integrating with the physicians' abilities. For example, video images recorded by an endoscopic camera that are presented on a monitor viewing the operation inside the patient.
4. Mobile applications: there are many mobile applications that already are available for smartphones. For example, Wikitude Drive is an AR mobile application that uses GPS allows the user to keep his/her eyes on the road, to see the navigated directions on his/her mobile all at once. In addition, there are many libraries and kits for smart phones (e.g. Android phones and iPhones) to add AR to mobile applications. For example, iPhone ARKit is a set of class that could offer Augmented Reality to the developers on iPhone applications. This kit could help an AR mobile application to overlay

information on the camera view. Moreover, the development of mobile technologies, augmented reality could be used more outdoors avenues by mobile phones or tablets. Therefore, developers can make the imaging process faster with high resolution of the display.

In conclusion, the literature review of this study presented the theoretical perspective of Hajj crowd management, by presenting the important steps crowd management at events. In addition, the practical perspective of Hajj crowds management. Studies showed that RFID systems (tags, readers) are used to solve Hajj problems, by identifying, tracking and guiding lost pilgrims at Hajj holy sites. In addition, estimating the pilgrims' numbers at these holy sites to avoid crowd incidents such as overcrowding, stampedes and suffocating. On the other hand, other technologies could be deployed to overcome Hajj problems, such as GPS receiver devices given to each pilgrim. These devices could help the Hajj officials to locate and track lost pilgrims, by providing their location information (ID number, longitude, altitude and time) on live maps. In addition, using monitoring cameras to capture lost pilgrims images and compare their images stored at database, to identify those lost pilgrims.

Summary of the Literature Review topics:

A. Using RFID technology in Hajj crowd management:

Author(s)	Topic	Problem	Proposed solution(s)
Khan (2011)	Deploying RFID system at KAIA	• Guiding and directing pilgrims to correct areas at KAIA. • High number of pilgrims arriving at KAIA. • Language Barriers.	• Pilgrims could use RFID tags to be guided, identified, categorized by their nationalities and direct to specific areas at KAIA. • Once they pass the immigration checkpoints, monitors will greet and guide them to the specific areas by their languages. • Every nationality has a Twawfa Establishment guide waiting for his groups to be guided at the specific areas of KAIA. Therefore, pilgrims could be directed to their guides.
Al-Hashedi et al. (2013)	RFID application and RFID architecture	Overcrowding at Hajj ritual places, and difficulties in	Deploying an RFID system: • Each pilgrim will be given a

	management system	identifying, monitoring and tracking pilgrims	wristband that contains RFID tags. • RFID tags contain pilgrim's information, such as name, age, nationality, TE guide …etc. • RFID readers to retrieve pilgrims' information from the RFID tags. RFID services at Hajj management could be: • Pilgrims tagging: identify and guide them. • Pilgrims monitoring and tracking: Hajj officials could detect the pilgrims' number in the area, to avoid overcrowding. • Transportation services: count the pilgrims in each bus at checkpoints • Security and surveillance: Hajj officials could estimate any area if it reached its' limit. In addition, preventing illegal pilgrims to enter Mecca city and Hajj ritual

			places.
Mohandes (2008)	Using RFID technology in Hajj management.	Hajj officials face problems in controlling and identifying pilgrims at Hajj events.	• Using RFID system at Hajj management by deploying RFID tags, RFID readers and data processing subsystem. • Each pilgrim will have RFID tag in wristbands. • RFID reader retrieves pilgrims' information from RFID tag. • Pilgrims could be managed by estimating their numbers in certain areas where risks are likely to occur. This is done by installing the RFID readers at entry and exit gates. • RFID tags are helpful in identifying and guiding lost pilgrims. A pilot study: RFID tags were distributed to 1000 volunteered pilgrims from Ivory Coast and to use one reader. An engineer built a

			database to store the data for those pilgrims and the purpose of this study. Result: the RFID system was helpful especially in identifying pilgrims at checkpoints, like checking their documented was not appropriate.
Yamin, Huang and Sharma (2009)	Wireless and sensors technology and crowd management	Hajj problems are challenging because of the pilgrims large number and their mass movements between Hajj ritual places. In addition, difficulties in tracking and identifying pilgrims	Using RFID systems (tags are readers), by providing the tags to pilgrims, and the readers to be installed in Hajj ritual places, Mecca city and airports. This system could improve the problems in areas such as, the immigration process, track and locating pilgrims and reducing disasters at Hajj events.

B. Using other technologies in Hajj crowd management:

Author(s)	Topic	Problem	Proposed solution(s)
Mohandes et al. (2013)	Tracking and identifying lost pilgrims by mobile phones and WSN	Tracking and identifying lost pilgrims at Hajj events.	There are two proposed systems: • Tracking and identifying lost pilgrims by using GPS on mobile phones. • Alternatively, mobile sensors (includes GPS receiver, microcontroller and antenna) are given to each pilgrim who does not have mobile phones. • Both systems send ID number, latitude, longitude and time (location information) to the web server to revealed this information on Google maps or similar by using map servers. • Both systems can connect to WSN if 3G connection is weak or lost.

Aly and Abdelwahab (2012)	Hajj and Umrah Dataset (HUDA)	Huge numbers of pilgrims are missing of unidentified at Hajj events.	Using monitoring system for tracking and identify missing pilgrims. Therefore, HUDA has been developed and integrated with another system called Crowd Sensing System. • HUDA is a dataset that contains all pilgrims' images in six different possessions. • Crowd Sensing System uses monitoring camera to detect lost pilgrims by comparing their images with their other images that are stored on HUDA.
Amro (2012)	e-mutawwif	Help the pilgrims group guide (one of TEs) to track and locate missing pilgrims.	• Handing GPS receivers to each pilgrim. • The GPS device receives the pilgrim current location from GPS satellites and sends their location information to database server by GPRS.

			• The database server is connected to the web server to update the pilgrims' current location on a live map.

Abuarafah, Khozim and AbdRabou (2012)	Real-time crowd monitoring using thermal video sequence	Preventing overcrowding at Hajj ritual places	Estimate crowd density at Hajj ritual places, by using thermal cameras integrated with decision support system for Hajj crowd management. The thermal cameras measure the human body temperature. When crowd density starts to develop, the Hajj operators in the control room could indicate the increasing of human temperature as the system provide certain color with a certain percentage of crowd density. For example, if the crowd density is 0-35%, then it gives white color. In addition, the rest crowd density colors and percentages are: 35-45% yellow, 45-55% green, 55-65% blue, 65-75% purple, 75-85% orange, 85-100% red

Chapter 3: The Hajj event, as a case study

3.1 Introduction to Hajj Pilgrimage

Reffat (2012, p.365) described the “Hajj” as it is an Islamic pilgrimage that gathers different people, as they travel to the Holy city of Mecca, in the kingdom of Saudi Arabia, whatever they are different in their ethnic groups, colors, and social status for the sake of performing this pilgrimage. In addition, it is a one of the Islamic religions' pillars or duties, which every Muslim should perform it at least once in a lifetime of every able-bodied Muslim who can offer it. In addition, this occasion can be one of the most crowded occasions that can be ever made, as it could be estimated that the pilgrims could reach 3 - 4 million Muslims gathered in the holy city (Alwakeel et al., 2014, p.425). Therefore, many Saudi authorities and research institutions are focusing on how these crowded people can be controlled, managed, and organized according to the steps of performing Hajj.

3.2 The Hajj Time and Dates Processes

Dhaou (2010, pp.1043) pointed out that foreign and Saudi pilgrims should join an authorized travel campaigns while they are performing Hajj. Each campaign is responsible for providing accommodations in the ritual places of Hajj, transportation between these places, food supplies and Hajj rituals instructions. In addition, Harmain et al. (2004, p.547) described the Hajj rituals, as it starts when pilgrims arrive at Mecca city. The pilgrims should go to the Sacred Mosque, to do arrival Tawaf, which is circumambulation around the "Kabah", and doing Sa'i, Which is going between two places in the Sacred Mosque "Safa" and "Marwah". After finishing from the Sacred Mosque, the journey of the Hajj starts by visiting the ritual places in sequences, which are Arafat, Muzdalifah and Mina. When the pilgrim finishes the arrival Tawaf, he goes straight on to Mina at the 8th of Dull Alhijjah in the Arabic calendar and spends the day and night there.

The next day, on the 9th of Dull Alhijjah, the pilgrims leave Mina and go to Arafat, where they stay there until sunset. After sunset, the pilgrims leave Arafat and go to Muzdalifah, to collect seven small stones and spend the night at this ritual place.

On the 10th of Dull Hijjah, the pilgrims are directed to Mina to perform the duty of "Stoning the Devil" begins. At Mina, there are three places to preform this duty. These places are called "Jamarat," where pilgrims stone the devil. These Jamarat are the smaller Jamarat, the middle Jamarat and the greater Jamarat.

Therefore, on this day, the pilgrims stone only the greater Jamarat with the seven stones that he collected from Muzdalifah. After that, they go to Mecca city to the Sacred Mosque, to do another Tawaf called "Tawaf Al-ifadah" and again do the Sa'y between Safa and Marwah. After finishing from this Tawaf, the pilgrim retunes to Mina to spend the night over there.

At the days 11th and 12th of Dull Alhijjah, the pilgrims go to Mina to stone all the Jamarats in sequence, the smaller, the middle and the greater. Each one of them is stored by seven stones one after another. After finishing stoning the devil on day of 12, there are two options for the pilgrims to decide with. First option, they go to Mecca city to the Sacred Mosque, to do "Tawaf Alwada" or the farewell Tawaf. Second option, they spend another night at Mina, and on the day of 13, they repeat what they did in the previous two days. Additionally, they go to the Sacred Mosque in Mecca city to do the farewell Tawaf.

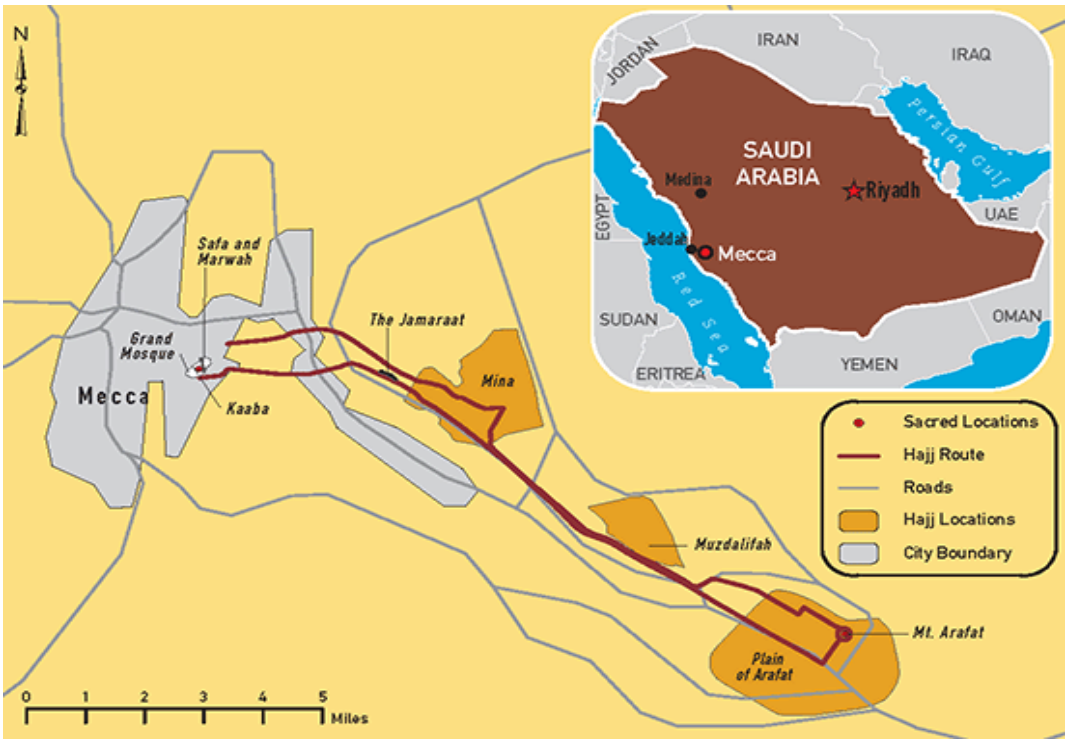


Figure 5: Hajj ritual locations- **http://hikm.wordpress.com/category/saudi-arabia/**

3.3 The Saudi Authorities in Hajj

The Hajj event is managed by the following authorities (Ministry of Hajj, 2012):

3.3.1 Ministry of Interior (MOI)

This ministry is responsible for most priority planning and executive matters, which are related to Hajj and pilgrims. It focuses on stabilizing security and the safety of the pilgrims in Hajj seasons. In addition, it is responsible for all the pilgrims, who come to Saudi Arabia by air, land and sea gateways.

3.3.2 Ministry of Hajj (MOH)

It is the authority that concentrate on any implementations and any issues related to Hajj. It coordinates with all government authorities and sectors that are related with Hajj. In addition, it coordinates and makes agreements with the officials of Islamic countries and their representatives. MOH is the main authority to role planning, supervision and control in order to ensure that all the services are provided to the pilgrims.

3.3.3 National Tawafa Establishments

These governmental establishments are Directing Hajj campaigns for foreigners. These establishments are responsible for serving only the foreign pilgrims, taking

care of them all the time. In addition, providing them all kinds of assistance in the Holy city of Mecca and the ritual places, facilitate their procedures from when they arrive until they complete the Hajj performance and departure to their countries. In addition, Khozium et al. (2012, pp.278) mentioned that They represent the locations of South Asia, Non-Arab Africans, South East Asia, Arabians, Iranians (Shi'a), Turkish, European Muslims, Americas and Australia. Each of those establishments has 100 offices, and each office is responsible for about 5000 pilgrims. On the other hand, Hajj authorities in Saudi Arabia are responsible for receiving pilgrims, housing them in the Hajj ritual places, serving and maintaining pilgrims' safety (Al-Hashedi et al., 2011, pp.1)

3.4 Hajj Regulations

There are certain steps must be completed before performing Hajj (Ministry of Hajj, 2012):

3.4.1 Applying for Hajj Visa

The application Hajj Visa form should be obtained, fill out and submitted to the nearest Saudi Consulate or Embassy. However, it is wise to appoint a licensed travel agent (campaign), who will arrange a visa, as well as your travel, accommodation and anything else pilgrim may need to perform the Hajj. The travel agent (campaign) will send the application form to the Saudi Consulate or

embassy. The Hajj visa is free, but for Hajj expenses, every pilgrim should pay two checks to cover the costs of guides, Zamzam water agents, tent accommodation in Mina and Arafat and transportation costs. In addition, Dhaou (2010, pp.1043) explained that these visa and license contain card number provided by the ministry of interior, ID number for each pilgrim, pilgrim's nationality, pilgrim's name and the travel campaign name, pilgrim's picture and blood type.

3.4.2 Arriving at Saudi Arabia

Once the foreign pilgrims arrive at King Abdulaziz International Airport (KAIA), their documents should be processed at the immigrations & customs. After that, the pilgrim will travel by a bus to Mecca. The journey between Jeddah and Mecca takes approximately one hour. In addition, travel within Saudi Arabia is restricted for foreign pilgrims. Their travel is limited to the cities of Mecca and Al-Madinah, and the holy places of Hajj Mina, Arafat and Muzdalifah.

3.4.3 Appropriate Documents in Hajj

Every pilgrim should carry with him/her the following documents while they are performing Hajj:

• Authenticated copies of passport, in case it lost.

• Photo-ID Card, which is issued upon arrival to Jeddah. Every pilgrim should carry this ID card at all times.

• Vaccination record book.

• Names and addresses of hotels you are staying in Makkah and Madinah. If any pilgrim is lost, he/she can call them or get directions.

• Plastic bracelet with the name, address and telephone number of your Tawafa Establishment printed on it.

Chapter 4: Research method, results and discussion

4.1 The research method, a quantitative study

Halabi (2006, p.94) defined the research methods as "…the techniques and the strategies that are used to achieve the desired research aims and objectives." These methods are divided into two main types, which are Qualitative and Quantitative. This research focused on the Quantitative method. It is a basic strategy of research that involves analysis of patterns of difference through a large number of cases (Ragin, 1994, p.91; Halabi, 2006, p.95). Therefore, this research selected distributing questionnaires among a sample of people. Those people were selected due to their relation to Hajj events. For example, some of them performed previous events, conducted academic studies or working with the Hajj authorities.

Questionnaires are used to support the collection data for quantitative analysis, to cover a large number of research samples (Halabi, 2006, p.96). In addition, it is a method of obtaining specific information regarding a problem, as after analyzing

the questionnaires' data, the result would be in a better "appreciation" of the problem (Chisnall, 1992, p.24; Halabi, 2006, p.96).

In this research, a questionnaire was designed, to gather information about the Hajj events. The questionnaire has been divided into eight sections with the same sequence. In addition, these questionnaires were distributed on and were collected from seven groups.

The population of this research contains the following categories:

- **Saudi and Arabic Students:** who are studying postgraduates and undergraduates in Glasgow city and other UK cities. (31 respondents).

- **Academics or scholars**: who are working in Saudi universities; especially those who are working at Umm-Alqura University, and Hajj Institute and Centre of Excellence in Hajj and Umrah Research. Those Academics have conducted many studies related to the Hajj event. (14 respondents).

- **King Abdulaziz International Airport (KAIA) Officials**: who are working at Hajj terminal, and dealing with foreign pilgrims when they arrive and depart. (24 respondents).

- **Directors of foreign pilgrim's campaigns (group guides from Tawafa Establisments)**: they are responsible for foreign pilgrims, as they manage their movements and transportation between (Jeddah, Mecca and Almadinah) cities. In addition, managing their movements between the Hajj ritual places in Mecca

city. In addition, provide accommodations for them at these cities and Hajj ritual places (renting tents in Mina city). (11 respondents).

- **Mecca government employees:** those who are working in the Mecca government, to develop Mecca city. (6 respondents).

- **Previous Pilgrims:** who performed Hajj at previous events. (14 respondents).

- **Others such as employees from Ministry of Hajj** (4 respondents).

Therefore, the total of all respondents to the questionnaires were **104 respondents.**

4.2 The questionnaires results

The questionnaires results were analyzed by using Microsoft Excel. It helped to analyze the results by presenting frequencies and percentages of all the respondents who answered each question. In addition, the closed-end questions were required to be answered. However, the open-end questions were not; as each person could write his/her answer freely.

<u>Section 1 - Crowd Controlling:</u> This issue is about foreign pilgrims are managed at King Abdulaziz International Airport (KAIA) or other gateways.

Questions	Answers options					
	Don't know	Strongly Disagreed (SD)	Disagreed (D)	Neutral (N)	Agreed (A)	Strongly Agreed (SA)
1. The immigration procedures at KAIA are easily accomplished.	**51** **49.04%**	7 6.73%	13 12.5%	19 18.27%	13 12.5%	1 0.96%
2. Immigration procedures at checkpoints in the high road, between Jeddah and	11	4	10	24	**30**	**25**

Mecca, are appropriate.	10.58%	3.85%	9.62%	23.08%	**28.83%**	**24.04%**
3. Do you think that some of the local pilgrims perform Hajj without joining any Hajj campaign?	6 5.76%	4 3.85%	5 4.81%	15 14.43%	**34** **32.69%**	**40** **38.46%**
4. In Hajj, some local pilgrims sleep anywhere in the ritual places. Therefore, they block the traffics in the ritual places.	6 5.76%	15 14.45%	14 13.46%	10 9.61%	**27** **25.96%**	**32** **30.76%**

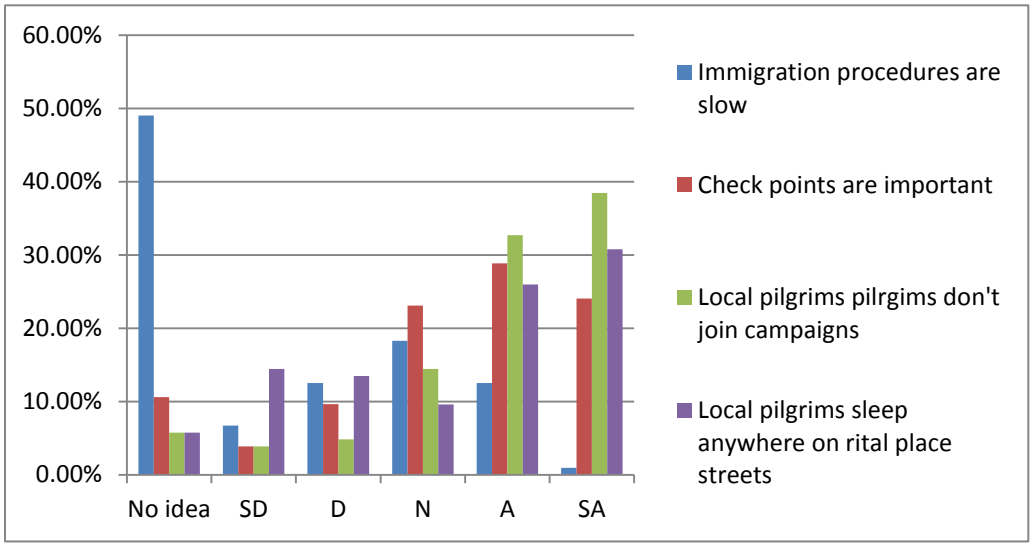


Figure 6: Closed-end questions results from section 1

In sections 1, not all respondents knew about the immigration procedures at KAIA (51 of the respondents from 104). However, 55 from the respondents agreed on the question of the checkpoints before entering Mecca city are appropriate ((agree = 30) + (strongly agree = 25) /104). In addition, 74 of them agreed on most of the local pilgrims do not join Hajj campaigns. Additionally, 59 of them agreed on most of the local pilgrims sleep anywhere on the ritual places streets, which could cause crowd blocking these streets.

However, in the opened end questions in section 1, the most answers that were in common among the respondents regarding the immigration checking-in producers are slow, were due to **the lack of immigration employees at the airports**, then **the crowd of the arriving pilgrims** in the airport, and finally **the bad organization at the airport**. In addition, most of the respondents agreed at there are advantages of joining the Hajj campaigns for both local and foreigner. These advantages are **providing services, accommodations and transportation between the ritual places in Hajj**. Please note, all opened end questions charts are in the Appendix.

Section 2: Medical procedures: this section discusses how the pilgrims are been services, especially at emergencies.

Questions	Answers options					
	Don't know	Strongly Disagreed (SD)	Disagreed (D)	Neutral (N)	Agreed (A)	Strongly Agreed (SA)
9. The arrival of the medics is delayed because of the crowded pilgrims.	10 9.61%	2 1.94%	13 12.5%	14 13.46%	**33** **31.73%**	**32** **30.76%**
10. There are medical clinics in the ritual places of Hajj.	4 3.84%	0 0%	3 2.88%	14 13.46%	**53** **50.96%**	**30** **28.86%**
11. Each pilgrim's medical history is available with him/her.	27 25.96%	**19** **18.27%**	**18** **17.3%**	14 13.46%	15 14.43%	11 10.58%
12. Serious emergency conditions are transferred to Mecca's hospitals.	15 14.43%	1 0.96%	6 5.77%	19 18.27%	**31** **29.8%**	**32** **30.77%**
13. There are infections during the Hajj season.	11 10.58%	1 0.96%	5 4.8%	17 16.35%	**29** **27.88%**	**41** **39.43%**

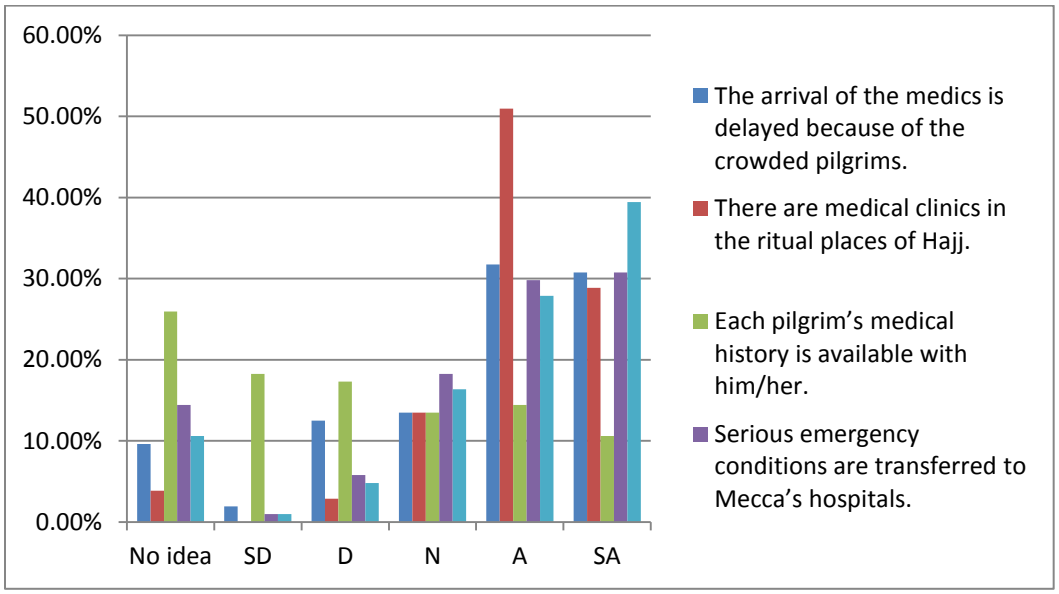


Figure 7: Closed-end questions results from section 2

In section 2, 65 of all respondents (104) agreed the medics are delayed on their arrival, due to the crowd of the pilgrims. However, in the opened end question, most of the respondents mentioned that the most difficulties that face medics in Hajj were **the crowd,** then **difficulties to reach to the sick pilgrims and the emergency site**, and **the language barriers when they try to understand the illness causes from foreign pilgrims.**

<u>Section 3 - Guiding Pilgrims:</u> How can lost pilgrims be guided and know how to return to their residences before, during and at the end of Hajj.

Questions	Answers options					
	Don't know	Strongly Disagreed (SD)	Disagreed (D)	Neutral (N)	Agreed (A)	Strongly Agreed (SA)
15. The language barrier is one of the significant problems that face the foreign pilgrims in Hajj seasons.	2 1.92%	0 0%	10 9.61%	18 17.3%	**34** **32.7%**	**40** **38.47%**
16. Non-Arabic Foreign pilgrims understand the signboard instructions in Mecca city, or in the ritual places of Hajj.	6 5.77%	6 5.77%	17 16.36%	25 24.03%	**40** **38.46%**	**10** **9.61%**
17. Non-Arabic pilgrims find some difficulties to figure out their way back to their residences.	6 5.77%	0 0%	11 10.57%	35 33.65%	**35** **33.65%**	**17** **16.36%**
18. Some of the non-Arabic pilgrims are guided to their residences when they get lost.	9 8.67%	3 2.88%	14 13.46%	29 27.88%	**35** **33.65%**	**14** **13.46%**
19. Foreign pilgrims could easily find the ritual places of Hajj.	8 7.69%	5 4.8%	28 26.95%	27 25.96%	**32** **30.76%**	**4** **3.84%**
20. It is hard to find translators between the ritual places and nearby the Sacred Mosque.	13 12.5%	7 6.73%	23 22.11%	22 21.16%	**26** **25%**	**13** **12.5%**

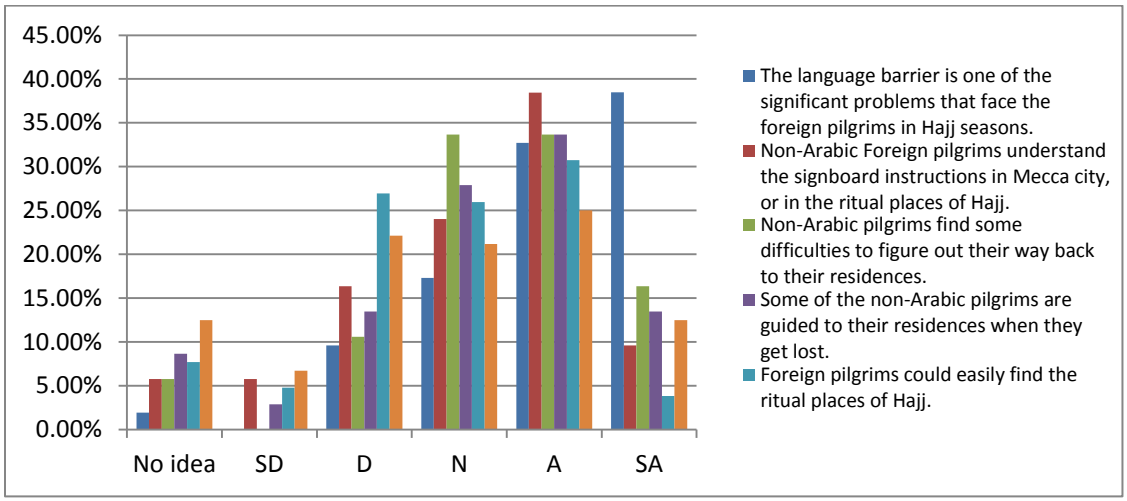


Figure 8: Closed-end questions results from section 3

In section 3, 74 of the respondents agreed that the "language Barrier" is one of the biggest obstacles that could face both a foreign pilgrim and Hajj official. This situation could cause some complications when they are communicating. In addition, 52 of them agreed that foreign pilgrims face difficulties in returning to their accommodations. However, in the open end questions, the common answer on the most difficulties that face the foreign pilgrims to get directions or guidance is the language barriers. In addition, about using technology in Hajj, the respondents agreed that it is a good idea to use ICTs in Hajj management. In addition, the most second answers were it is a good idea and designing software that locates pilgrims with updating his/her location and direct him/her by use the ritual places maps with multi-languages

<u>Section 4 - Identifying the Pilgrims:</u> this issue is about pilgrims who are lost in Hajj, especially between the ritual places of Hajj.

Questions	Answers options					
	Don't know	Strongly Disagreed (SD)	Disagreed (D)	Neutral (N)	Agreed (A)	Strongly Agreed (SA)
23. The language barrier is the most important issue in identifying the loss of non-Arabic pilgrims.	3 2.88%	1 0.96%	5 4.8%	17 16.38%	**33** **31.73%**	**45** **43.25%**
24. Pilgrims carry any ID while performing Hajj.	17 16.34 %	0 0%	7 6.73%	14 13.46%	**37** **35.59%**	**29** **27.88%**
25. Crowd movement could cause the pilgrims to be lost from their campaign while moving between the ritual places of Hajj.	5 4.8%	0 0%	6 5.77%	9 8.67%	**56** **53.84%**	**28** **26.92%**
26.Some of the lost foreign pilgrims prefer to stay illegally in Saudi rather than returning back to their countries	9 8.66%	6 5.77%	13 12.5%	22 21.15%	**26** **25%**	**28** **26.92%**

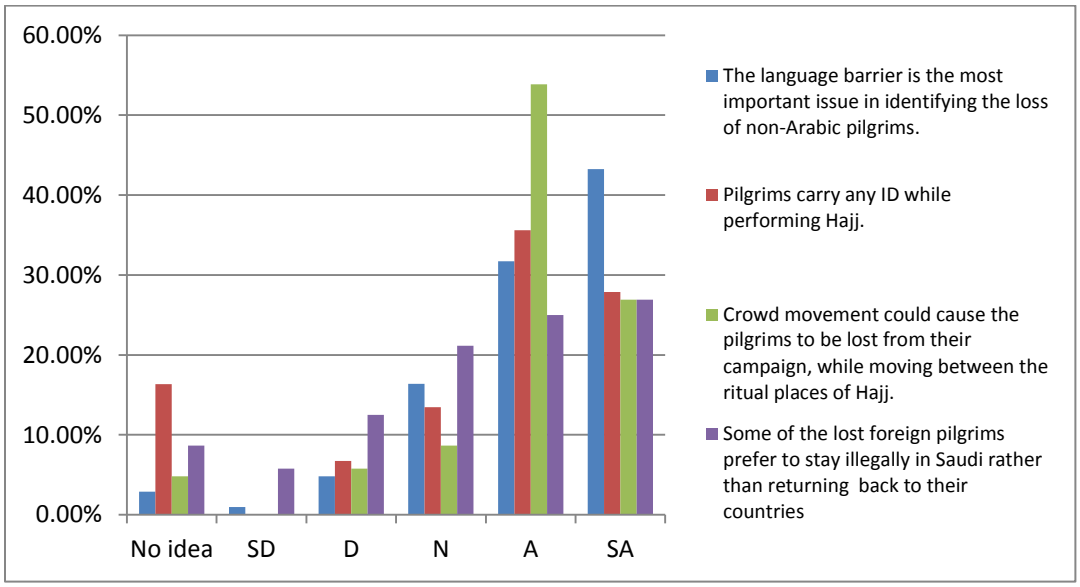


Figure 9: Closed-end questions results from section 4

In section 4, 78 of the respondents agreed that the language barriers face most of the foreign pilgrims. In addition, 84 of them agreed on pilgrims could get lost, due to the crowds that appear between the Hajj ritual places, as this could lead to pilgrims getting departed from their groups. However, in the opened end questions, the majority of respondents agreed on pilgrims get lost in Hajj due to the crowd of Hajj, then there is stampede in the crowd and there are many elderly pilgrims among the crowd. On the other hand, they agreed on mobile phones are been used at Hajj events, and the use these phones were to call their families abroad. In addition, they suggested that ICT systems could be used when any pilgrim get lost in Hajj. For example, using navigation systems and devices with

GPS, Tracing and locating Pilgrims at the ritual places via software, and using Google maps and its features (transportation services).

Section 5: Crowding of Pilgrims: how crowds are created and the reasons of it.

Questions	Answers options					
	Don't know	Strongly Disagreed (SD)	Disagreed (D)	Neutral (N)	Agreed (A)	Strongly Agreed (SA)
33. One of the reasons of crowded pilgrims is that the ritual places (Arafat & Muzdalifah) are narrow.	4 3.84%	6 5.77%	21 20.2%	21 20.2%	**29** **27.88%**	**23** **22.11%**
34. Congestions lead to complications in traffic movement between ritual places.	2 1.92%	0 0%	3 2.88%	10 9.6%	**52** **50%**	**37** **35.6%**
35. Railways between the ritual places are one of the solutions to decrease pilgrims' congestions in those places.	3 2.88%	1 0.96%	3 2.88%	19 18.26%	**41** **39.42%**	**37** **35.6%**
36. There are technologies applied to manage the crowded pilgrims.	13 12.5%	4 3.84%	10 9.6%	27 25.96%	**41** **39.42%**	**9** **8.68%**
37. Pilgrims are well organized in Hajj.	4 3.84%	**12** **11.53%**	**25** **24.06%**	27 25.96%	28 26.92%	8 7.69%

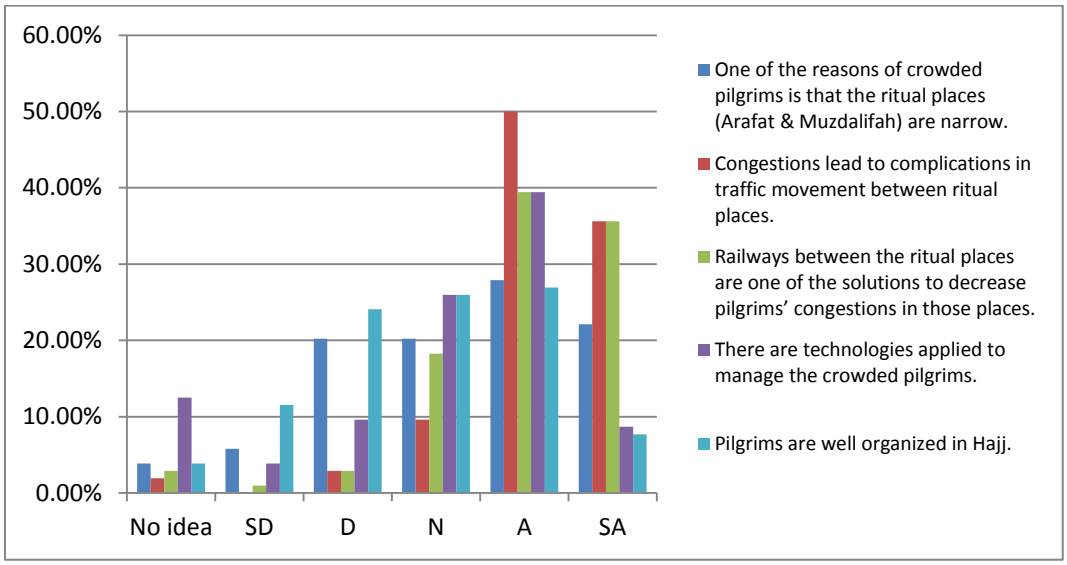


Figure 10: Closed-end questions results from section 5

In section 5, 52 of the respondents agreed that the other ritual places of Hajj, such as Arafat and Muzdalifah are narrow. These places would lead in complications in performing worships especially among the crowd. In addition, 89 of them agreed on congestions at these ritual places could create crowd, which would be so difficult for pilgrims to move from ritual place to another. Nevertheless, in the open end questions, respondents agreed on the most congestion problems in Hajj were **No organization** and **crowd pilgrims**.

Section 6: Hajj incidents: types of incidents that occur at Hajj events and how these incidents happen.

Questions	Answers options					
	Don't know	Strongly Disagreed (SD)	Disagreed (D)	Neutral (N)	Agreed (A)	Strongly Agreed (SA)
40. A crowd of pilgrims is one reason of traffic roadblock in Mecca city.	5 4.4%	1 0.96%	7 6.8%	4 3.84%	**36** **34.7%**	**51** **49.3%**
41. The transportation between the ritual places, such as buses, are involved in accidents, which can lead to injuries or death to those pilgrims.	5 4.4%	3 2.88%	10 9.6%	23 22.11%	**37** **35.57%**	**26** **25%**
42. Awareness of pilgrims by screen videos and audio might help to reduce incidents in Hajj.	5 4.4%	0 0%	2 1.92%	12 11.53%	**54** **51.92%**	**31** **29.8%**
43. Because of the large number of the pilgrims, they could cause serious incidents to themselves.	4 3.84%	1 0.96%	4 3.84%	17 16.37%	**48** **46.15%**	**30** **28.84%**

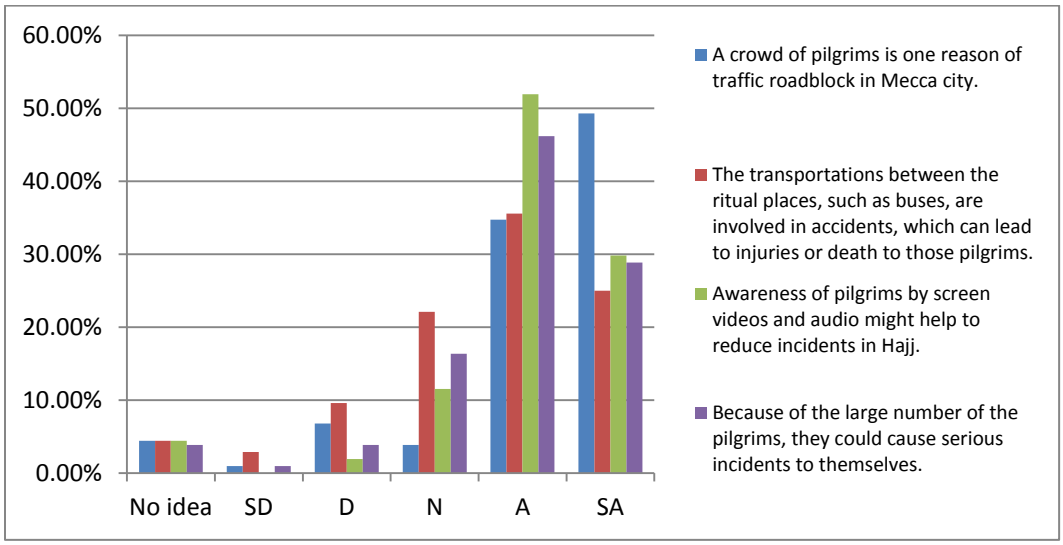


Figure 11: Closed-end questions results from section 6

In section 6, 87 of the respondents agreed on the crowd pilgrims cause traffic blocks in Mecca streets. Thus, they could be exposed to traffic accidents. In addition, 63 of them agreed on transportation such as buses could involve in pilgrims accidents due to their crowd. Moreover, 78 of them agreed on incidents such as suffocation and stampede occur because of the large number of pilgrims at Hajj ritual places. However, in the opened end questions, most of the respondents agreed on the most crowded place(s) in Hajj season is the movement of the pilgrims between Arafat and Muzdalifah in the first day of Hajj event.

Section 7: the Hajj authorities at Hajj events.

Questions	Answers options					
	Don't know	Strongly Disagreed (SD)	Disagreed (D)	Neutral (N)	Agreed (A)	Strongly Agreed (SA)
51.Saudi authorities are in places in the ritual places of Hajj and Mecca city.	8 7.69%	1 0.96%	4 3.84%	12 11.53%	**44** **42.3%**	35 33.68%
52.There is an efficient cooperation between the Saudi authorities in Hajj.	10 9.6%	1 0.96%	6 5.77%	18 17.3%	**41** **39.45%**	28 26.92%
53.Saudi Hajj Authorities are helpful, especially with foreign pilgrims.	11 10.57%	0 0%	6 5.77%	21 20.2%	**40** **38.46%**	26 25%
54.Saudi Hajj Authorities interfere immediately to any kinds of problems in Hajj.	11 10.57%	1 0.96%	7 6.73%	9 8.65%	**43** **41.36%**	33 31.73%
55.Saudi authorities use technologies in Hajj.	14 13.46%	8 7.69%	5 4.8%	28 26.92%	**29** **27.88%**	20 19.25%

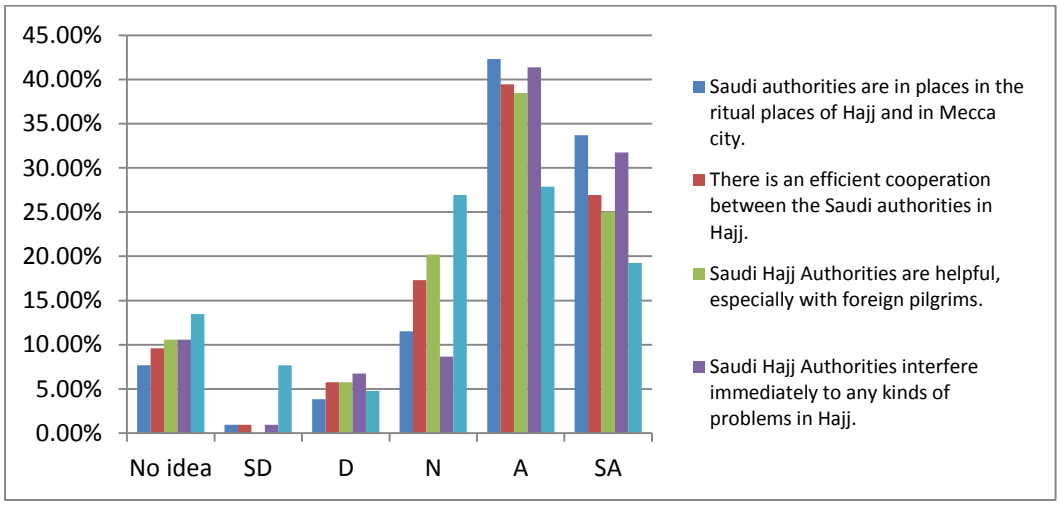


Figure 12: Closed-end questions results from section 7

In section 7, all respondents agreed that the Saudi Hajj Authorities are cooperating with each other, and with pilgrims specially the foreigners, and interfere to solve any problem. However, in the opened end questions, the common respondent's answers of the Saudi authorities that participate in Hajj were **Civil defense, Ministry of Interior, Ministry of Hajj and Police officers as well as The Red Crescent.** In addition, most of them agreed on Hajj authorities organize pilgrims' movements by **specifying their movement in a certain ways or directions**, and **monitoring the Hajj event by CCTVs.**

Section 8 - the new Aljamart Bridge project in Mina.

Questions	Answers options					
	Don't know	Strongly Disagreed (SD)	Disagreed (D)	Neutral (N)	Agreed (A)	Strongly Agreed (SA)
58. Pilgrims do not follow the instructions, especially in Aljamarat Bridge where stoning the devil ritual.	11 10.57%	0 0%	3 2.88%	15 14.42%	**36** **34.63%**	**39** **37.5%**
59. The old Jamarat Bridge was so dangerous to perform the stoning ritual on it.	14 13.46%	0 0%	6 5.77%	17 16.35%	**28** **26.92%**	**39** **37.5%**
60. Congestions, crowd and stampede were often on the old Jamarat Bridge.	10 9.6%	0 0%	4 3.84%	11 10.57%	**33** **31.73%**	**46** **44.26%**
61. The new project has removed the bottleneck and congestions in the ritual place of Mina.	10 9.6%	0 0%	6 5.77%	12 11.53%	**34** **32.7%**	**42** **40.4%**
62. Congestions appear in the new Jamarat Bridge.	18 17.3%	**10** **9.6%**	**26** **25%**	20 19.25%	21 20.2%	9 8.65%

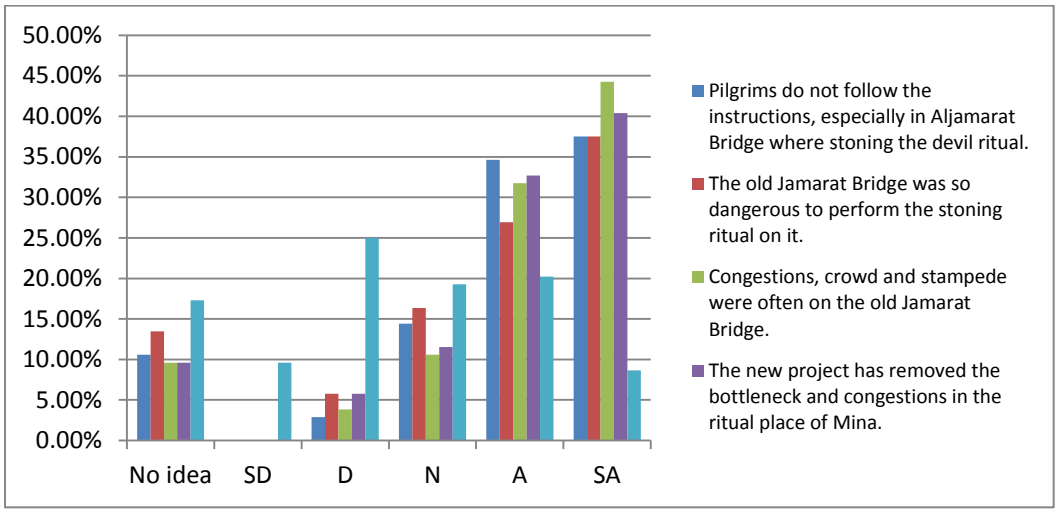


Figure 13: Closed-end questions from section 8

In section 8, the majority of respondents agreed on the new project of Aljamarat Bridge helped the Saudi authorities to make Hajj organization more efficiently. This new project has reduced the congestions of the crowd pilgrims that existed in the old bridge. However, the unorganized pilgrims, who do not obey the Hajj rules and instructions, are still a threat to the Saudi Hajj authorities' efforts especially on Aljamarat Bridge. On the other hand, in the opened end section, the most common answers from the respondents about the advantages of the new Aljamarat Bridge were **wide area, many levels (4 levels), and many entrance and exit gates on each level.** However, most of them agreed on **the other two Hall locations (Arafat and Muzdalifah) are still narrow.** Most of them justified their answers as **pilgrims do not spend (stay) much time at these places (only several hours). Therefore, there is no need for these kinds of projects.**

The following table presents the main results of the questionnaires.

Emergency services at Hajj events:	65/104 of the respondents strongly agreed and agreed that the arrival of the medics is delayed because of the crowded pilgrims. (62.50% of the research population).
Problems in serving visitors (pilgrims) e.g. guidance:	74/104 of the respondents strongly agreed and agreed that the language barrier is one of the significant problems that face the foreign pilgrims in Hajj seasons (71.17%).
Problems in identifying lost visitors and their causes:	• 78/104 of the respondents strongly agreed and agreed that the language barrier is the most important issue in identifying the loss of non-Arabic pilgrims (75%). • 81/104 of the respondents strongly agreed and agreed that crowd movement could cause the pilgrims to be lost from their campaign while

	moving between the ritual places of Hajj (77.88%).
Overcrowding problems:	• 89/104 of the respondents strongly agreed and agreed that congestions lead to complications in traffic movement between ritual places (85.6%). • 87/104 of the respondents strongly agreed and agreed that a crowd of pilgrims is one reason of traffic roadblock in Mecca city. (83.65%).
Crowd incidents at Hajj:	• 63/104 of the respondents strongly agreed and agreed that the transportation between the ritual places, such as buses, are involved in accidents, which can lead to injuries or death to those pilgrims (60.57%). • 78/104 of the respondents strongly agreed and agreed that because of the large number of the pilgrims,

	they could cause serious incidents to themselves (75%).
Visitors' behavior:	75/104 of the respondents strongly agreed and agreed that pilgrims do not follow the instructions, especially in Aljamarat Bridge where stoning the devil ritual (72.11%).

Table 3: Summary of closed-end results

In conclusion, this research discussed Hajj problems that could face both Hajj authorities and pilgrims at Hajj events. First, the problems crowd organizations at Hajj ritual places. This problem occurs because of the huge number of the pilgrims at these locations, which are geographically limited in spaces. Therefore, this could lead to overcrowdings, stampedes and congestions. The second problem is lost pilgrims at Hajj ritual locations. There are many reasons that would cause this problem. For example, the massive movement of pilgrims between these locations, lack cooperation between Hajj stakeholders; some pilgrims are not familiar with Hajj environment, the language barriers and the exhaustion of Hajj activities. Third problem is a lack of directional information and guidance, such as lack of maps, signage and the language barriers as well.

Therefore, this study proposed deploying an augmented reality application used by Hajj authorities. This application could manage the crowds' movements and assist lost pilgrims and provide them with directional information.

In addition, the research literature review presented the Hajj problems and how they were managed. The problems were focused on difficulties in tracking, identifying and guiding lost pilgrims at Hajj holy locations. Additionally, managing and estimating the crowds' densities at these places, to avoid overcrowdings and stampedes. Therefore, there were technologies that were developed and proposed, to be implemented at Hajj. Examples of these technologies were RFID systems, GPS devices, thermal monitoring cameras and facial recognition.

The research results confirmed the Hajj problems as the following:

- Overcrowdings, congestions, and stampedes happen at Hajj locations, because of the lack of crowds' organization, and these locations are limited in spaces, comparing with the large number of pilgrims.
- When overcrowdings occur, pilgrims could block the roads between the Hajj holy locations. In addition, they could be exposed to traffic accidents.
- Pilgrims get lost because of the huge number of the crowds, especially when moving from ritual place to another. In addition, pilgrims, whose performing for the first time, are not aware of the Hajj locations. Moreover, elderly and illiterate pilgrims among the crowd and the language barriers.
- The difficulties that could face foreign pilgrims are lack of directional information and signage at Hajj event.

Therefore, the respondents of the research methods suggested that using technology in Hajj crowd management could reduce these problems. As the majority of them suggested deploying software system, which identifies lost pilgrims, updates their locations, alert their group guide and use digital maps such as Google maps. In addition, using GPS systems was suggested as well.

4.3 Discussion of the research results

The aim of this research is to implement a technology presented by Mobile Augmented Reality application. This application would be effective for the operations of Hajj crowd management, to help Hajj authorities managing and organizing crowds' movements between the Hajj ritual locations. In addition, this application would assist lost pilgrims, by providing them with information, and reunite them with their groups.

The research results showed there are problems that face both Hajj authorities and pilgrims at the event of Hajj. The main results were: crowds, congestions and stampedes occur between the ritual places of Hajj, difficulties in organizing crowds' movements because of their huge number at limited spaces. In addition, pilgrims could get lost at Hajj locations because of the crowds, especially moving from place to another, and lack of directional information, static signs and guidance. Therefore, these results have confirmed the Hajj problems that were presented in Chapter 1, and in the research Literature Review chapter. These problems were: organizational problems, pilgrims getting lost and difficulties in finding them, and lack of directional information and guidance for lost pilgrims.

However, there were some limitations that faced this research. First, time consuming in distributing, collecting and analyzing the questionnaires. As these questionnaires were written in two languages (English and Arabic), and it took much time interpret the Arabic questionnaires. Second, it would be much better if

the research population were more than 100 as more ideas and information may be presented in the open end questions in each section. Finally, other research methods, such as focus groups, would also be beneficial to brainstorm much information and details about Hajj problems.

Chapter 5: The Proposed Solution for Hajj Crowd Management at Hajj Events

5.1 Augmented Reality (AR) technology

Nofal (2013, p.2) described Augmented Reality (AR) as a technology that uses computer programming to process augmenting videos or displaying images by overlaying them using computer generated data. In addition, AR could be defined as "…AR combines real and computer-generated digital information into the users' view of the physical real world in a way that they appear as one environment" (Olsson et al., 2013, p.287). Moreover, Wang et al. (2010, p.414) described AR as, a system that mix virtual and real information together, to help users do things better or conduct tasks in an easy and accurate way.

AR aims to add real world to its systems rather than creating entirely artificial environments (Olsson et al., 2013, p.288). In addition, it aims to automate, collaborate and facilitate activities, by integrating various and emerging technologies (Bimber and Raskar, 2005; Katier, 2011, p.16). Moreover,

Carmigniani et al. (2011, pp.342) pointed out that AR simplifies the users' life by bringing virtual information to his immediate surroundings and any indirect view of the real environment. In addition, it improves the user's perception and interaction with the real world.

5.1.1 The three architectures/factors to build AR

Henrysson (2007, p.6) pointed out the three technologies that are used to build AR systems:

1. Tracking: the system should know the users' needs to retrieve and present related virtual information. It should also know the position and orientation of the display in the real world using mapping as a virtual technique. Therefore, the formation of position and orientation parameters is known as tracking.

2. Registration: it is an alignment process of real and virtual information, which is presented to the user. This process should be made with accuracy at interactive frame to reserve the illusion of real and virtual coexisting in the same field.

3. Display: an AR system can combine real and virtual information. Therefore, the AR systems' display should allow the user to see the real world overlaid with virtual information such as 3D graphics.

Accurate tracking and registration are important (in case of using AR on mobile devices). For example, when a user aims to get an image, the camera should be pointed to real objects to present its virtual information (Portales, 2010; Katier, 2011, p.16).

5.1.2 AR requirements

Van Krevelen & Poelman (2010, p.10) illustrated that Hollerer and Feiner (2004) mentioned some requirements for the mobile augmented reality. For example, AR frameworks, networking, and database. AR frameworks would help the system to perform tasks such as tracking (location), sensing (capturing information), display (information such as video, audio…etc.) and interacting with the surrounding environment. These tasks could be done by using frameworks such as ARToolKit, which is the most popular and wieldy used. In the case of networking and database, AR systems, such as mobile augmented reality applications, regularly present much information. These applications require wireless networks, to support data retrieval and multiple user interactions over large distances.

5.1.3 AR applications

Navigation:

Craig (2013, p.197) described the use of navigation in AR systems, as it is related to how people move through the world, or how they act moving through their environment. In addition, it is associated with how they know where they are, and their needs to be transported to other places they want to be. Therefore, they could use many things as navigation aids that could help them to reach their destinations. These aids have many selections from the simple of using landmarks to technical solutions, e.g. Global Positioning System (GPS) applications. In addition, it is useful and compelling matter to add navigation aids into an AR application in the real world. There are some methods that could be used as navigation aids in an AR application (Craig, 2013, p.199):

- Using a virtual map that shows the users' location on that map.
- Provide indicators of the path to be followed, such as virtual lines or arrows.
- Using spoken directions, such as "go ahead east for 100 feet".
- Using virtual binoculars as users could see long distances help them find their way.

If a user would like to get help finding his/her way from an AR application, the application must require the users' current location. In addition, know where he/she wants to go by using databases of locations and objects of the environment, to determine a reasonable route for him/her to take.

Communication:

Craig (2013, p.200) explained users can communicate with each other in different ways with an AR application. For example, if the users are far from each other, they could use an audio channel in the AR application that allows them to talk and hear each other. In addition, those users could share and track each other's locations and display their locations on the AR application.

Tourism:

Gervautz and Schmalstieg (2012, p.30) illustrated using AR application for tourism could be done by displaying information about famous buildings or historical landmarks. Simply, the AR application retrieves this information of any object by positioning the camera at it. In addition, a combination of information located on the internet and social networks could help AR applications to enhance the way of presenting additional information about buildings and landmarks to the users. The presented information would remind them of previous memories about these objects (Marimon et al., 2010, pp.1).

5.1.4 Deploying AR technology in events' management

Maffioletti (2001, p.1) pointed out the motivation of building systems, such as augmented reality applications, is to present computation into the real world, to support non-computational activities. In addition, to allow people (users) to interact with these systems, as they interact with other users by gesture, movement, voice and context. Moreover, the technology of augmented reality is classified as one of the ubiquitous computing systems. This means that more than one user can use the system at the same time, and this kind of technology could be available wherever the user needs it. Therefore, AR services could work anywhere by visualizing the digital information of the users' surroundings whenever he/she desires (Olsson et al., 2013, p.288). AR technology is been utilized in many areas such as, medicine, manufacturing, entertainment, and military applications. In addition, this technology has been attracted as a new method for displaying location-based information in the real world (Mulloni et al., 2009; Al-Nuaim & Al-Masry, 2012, p.51).

5.2 Mobile Augmented Reality (MAR)

5.2.1 Mobile technology

Olsson et al. (2013, p.288) specified that mobile devices, such as mobile phones; digital cameras and navigators have become significant platforms to deploy AR applications. These devices are becoming great sources of information, users'

social networks, device orientation and any other context (e.g. images, videos and audios). The reason of that is because the rapid development sensors and communication technologies. In addition, Jang & Hudson-Smith (2012, p.1) mentioned the appearance of smartphones features a Global Positioning System (GPS) receiver, a digital compass and accelerometers has led to accelerate the use of spatial information in the mobile technologies. This combination of sensors has made it more feasible to build Augmented Reality application on mobile phones. AR has been used as a new method on smartphones in different fields such as, games, retail, social network services…etc. In addition, these smartphones have allowed the users to detect user's location and the data that they have incorporated on their display systems.

Al-Nuaim & Al-Masry (2012, p.51) mentioned that Mulloni et al. (2009) described that the result of integrating AR and mobile technologies with the GPS presents applications that could work outdoors. Because the satellite signals are blocked or unreliable inside buildings, and the GPS receivers require a clear view of the sky (see figure 14). In addition, they illustrated the benefits of utilizing GPS applications in AR as the following:

- Location: to determine the basic position.
- Navigation: to get from one location to another.
- Tracking: monitoring the movement of people.
- Mapping: to create maps of the world.
- Timing: to bring the exact timing to the world.

Figure 14: Mobile Augmented Reality- <http://one.arch.tamu.edu/news/2013/2/19/mcnamara-nsf-award/>

5.2.2 What is Mobile Augmented Reality (MAR)?

Craig (2013, p.209) mentioned Mobile Augmented reality (MAR) is an AR that it can be taken wherever the user goes. That means that the hardware (smartphones and tablets) required deploying an AR application when the user desires to take it wherever he/she goes.

5.2.3 History of MAR

Historically, Lee et al. (2012, p.57) illustrated some examples of mobile outdoor AR systems that were used in different specializations. For example, a mobile outdoor AR system was developed, to guide and assist users to explore outdoor environments, by wearing an AR system as a backpack. Therefore, the AR system visualized virtual tags on buildings, to help the user navigate the urban environment. In addition, this system could provide historical information by pointing on any sites (Feiner et al., 1997; Lee et al., 2012, p.57). Another example of mobile AR system is "Archeogiude project", which is a mobile outdoor AR application that has been used in tourism to visualize historical sites. It has been used to guide the user around archeological sites. This guidance is done by using wearable system that runs AR application. This application shows 3D models of historical buildings on these archeological sites (Vlahakis et al., 2002; Lee et al., 2012, p.57).

5.2.4 Reasons of deploying MAR

There are some reasons to build AR applications using mobile technologies. Katier (2011, p.17) pointed out the following reasons:

- Mobile technologies (e.g. such as smartphones and tablets) are reliable in outdoor augmented reality applications. That is because these technologies have been increased in their graphical processing powers. These powers come

from a combination of high-speed wireless data exchange (3G, 4G and Wi-Fi), high-end camera sensors, low cost GPS receivers, accelerometers and gyro sensors. Therefore, mobile technologies are collecting many emerging technologies in one device.

- This combination in mobile technologies have made the process of tracking and registration technologies (which are key technologies in building AR systems) very high.

- Using the increasing graphical processing power of mobile technologies makes the power of display technology of the AR system more substantial.

- The camera of mobile technologies helps users to see the surroundings and captures live streams of the environments. Theses streams could be overlaid by using graphical augmentations before displaying them.

Langlotz & Schmalstieg (2014, p.156) mentioned that on the MAR applications' browser, images are object-referenced point of interests (POIs), For example, Lee et al. (2012, p.57) illustrated POIs information about buildings, businesses, public transportation, landmarks…etc. Appear on MAR browsers. This geographical information is shown as virtual pop-ups attached with text and photos of the related POIs. For example, Billinghurst (2013, p.318) illustrated MAR applications that present POIs, such as Layar, Wikitude and Junaio. These applications present virtual of POIs overlaid the real environment. In addition, they display virtual contents as live video views of the real environment. Moreover, the mobile technologies combinations (GPS, campuses and

accelerometers) sensors are used to locate the smartphone or tablet that uses one of these applications, and what the users are looking at in the environment.

Finally, there are a number of factors that could help developers to use mobile technologies (smart phones and tablets) as a platform for AR applications. These reasons or factors are such as, computing power, power consumption, graphics and multimedia abilities, availability interface ports, memory, storage space and technical support (Hollerer and Feiner, 2004, p.13). Therefore, because of the rapid development of these technologies, they have become more powerful to run AR applications.

5.2.5 Advantages of MAR

There are many advantages using mobile technologies (smart phones and tablets) to support AR applications, as the following (Craig, 2013, p.212):

- AR application can gain different kind of information, such as video, audio and text.
- Mobile technologies are likely low cost comparing with special purpose technologies. These technologies are gaining power and features while their prices are dropping.
- Mobiles technologies contain sensors, processing, and displays from AR applications.

On the other hand, Craig (2013, p.214) mentioned technical constraint on most devices is limited in memory, which could effect on the mobile AR implementation. However, to overcome this problem, schemes could be used to limit the amount of memory of the occupied content. This limitation could be done by limiting the number of polygons, and textures size that are related to the visual objects, and limiting the number of objects that are required. In addition, the other way of limiting the memory is to create a scheme that helps the content to load onto the device when it is needed, and unload it when it is not needed.

5.3 The proposed system architecture

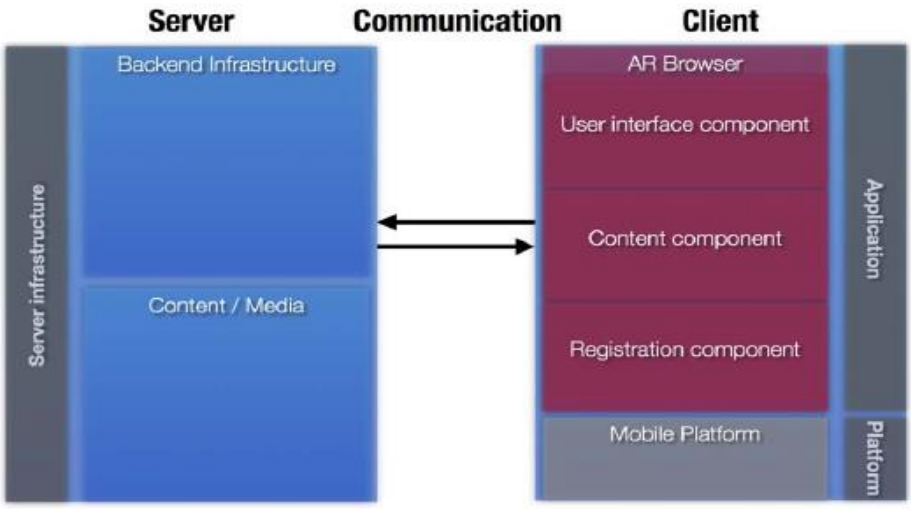


Figure 15: the proposed application architecture

Billinghurst (2013, p.319) pointed out the advantages of using the client/server architecture for mobile AR applications. For example, this architecture helps to use a single reliable interface for experiencing different materials of AR. In addition, the need to install a small piece of browser software on the mobile technology device (smartphone or tablet) and then download local content of interest when needed. Finally, the ability of modifying the content at the server, and send it to all applications' users.

Figure 15 shows that the MAR application architecture of this case study is a "Client-Server" Model. In addition, there will be slight additions in the overall system. With these changes and with what Langlotz & Schmalstieg (2014, p.157) described the general architecture of MAR applications, the components of the proposed MAR application would be like the following:

- The server: is responsible for content storage and retrieve the data from a database as enquired by the client.
- The client (the user): is responsible for content adaptation and letting the user interact.
- Registration component: the process of assisting the mobile device, to determine its position in the real world to identify the surrounding information, and transform any local information into the users' view.
- Content component: using the information to initiate streaming-relevant content from the server to the client.
- User interface component is responsible for presenting the content on a mobile device's screen.
- Hajj Databases (HDBs): proposed distributed databases to collect, analyze and organize the pilgrim's data. These databases have the potential to search and mine among the pilgrim's data. In addition, it could be conjunct with other wireless and sensor technologies (e.g. GPS) of the proposed application. In addition, these databases will be accessed with everyone, who has the authorization and works for the Saudi government, especially the Saudi Hajj Authorities (event's organizers). They will be distributed all over the Hajj ritual places and in Mecca city.

5.4 The proposed system: Crowd Management Mobile Augmented Reality application (CMMAR)

5.4.1 MAR in Hajj Crowd Management

As mentioned in previous chapters, the main problems of Hajj are mostly about organizational issues, such as lack of organizational operations, high numbers of crowd and lack of directional information and guidance. These problems could result in lost pilgrims at Hajj events. Therefore, applying the technology of augmented reality, using mobile technologies might be an effective assistant for Hajj authorities and staff in different methods. For example, because of the lack of guidance services at Hajj, using MAR by Hajj staff could gather information for pilgrims, to guide and help them to reunite with his/her group. This guidance could be dine by directing them and alerting their group guide. In addition, This pilgrims could be guided by using various information such as audio, text, video (Elzahrany and Mirza, 2011, p.4). In addition, Taileb et al. (2014, p.137) mentioned MAR could help the Hajj staff to facilitate Hajj organizational operations for pilgrims. For example, it displays all the needed information about the surroundings of Hajj environment. For example, by using MAR, Hajj staff could locate and identify the geolocated places (POIs of Hajj) by positioning the camera of MAR devices, such as smartphones or tablets. When a location is identified, the process of AR takes place by describing the pointed place on the staffs' screen device. Moreover, Al-Salhie et al. (2014, p.384) pointed out that

MAR applications could be used as video camera sensors, and connected to a central control station for Hajj surveillance systems. Therefore, these applications are considered as links between the Hajj operators on this station and Hajj staff on the ground. Because of the high capability of MAR for communications and data transmissions between the Hajj staff, the control station is remotely monitoring the Hajj areas and capturing different types of information that is gathered by the Hajj staffs.

5.4.2. The proposed MAR application

CMMAR, which is the proposed Crowd Management Mobile Augmented Reality application for this study, is developed for Hajj crowd management. Therefore, this application will be deployed by authorized All Hajj staff working on the ground at Hajj events, to monitor crowd's movements. The fundamental of this application is adopted from Boron (2011), who developed the application of Crowd Management Mobile Augmented Reflection (CroMR). The main feature of this system is providing different types of information constantly and instantly. In addition, this information is shared among the users of this system. Moreover, the components of this application are GPS, digital compass and accelerometer. These components help the application to determine user's location and angle view, as the overloading of the information on the devices' (smartphone or tablet) screen could be adjusted. Boron (2011, p.68) described some important mechanisms that could be utilized in Hajj crowd management as the following:

- Data Capture: during the Hajj event, information in constantly exchanged to coordinate the crowd management activities; and to make sure everyone is safe in the crowd. Hajj staff and other stakeholders at Hajj event could inform any unpleasant situation. This information would be, such as textual messages, radio communications, sharing the view from their camera feeds of their devices…etc., from their handheld devices (smartphones or tablets) to each other. In addition, they could send their location information to each other. In addition, this information could be also sent to their supervisors in Hajj control room, who are in charge of them, as they could track their teams all the time (see figure 16).

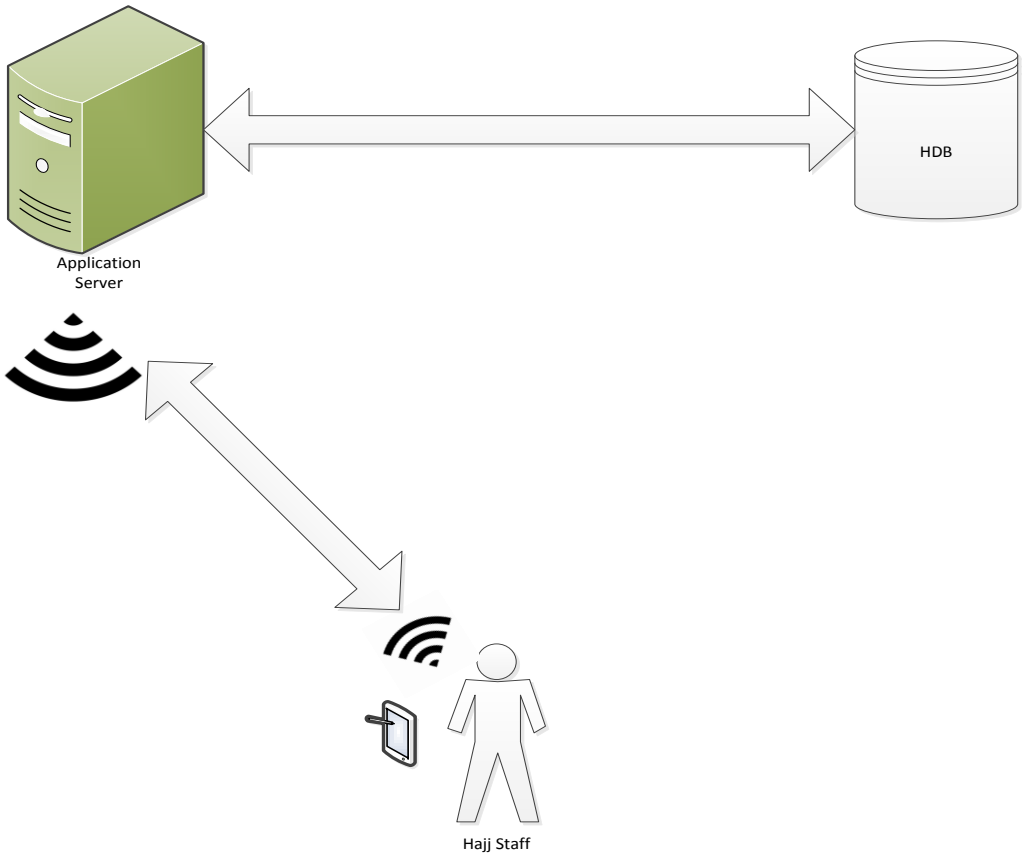


Figure 16: Data capturing phase

As in figure 16, during the event, the data are collected and sent to the Application server by using Wi-Fi's. Hajj staff collects These data, whose using the application at the handheld devices.

- Data retrieval: Figure 17 shows that after the data are captured, they are analyzed, to retrieve the required information that was requested by the client. The information is ready to be retrieved to the client by the application server. In addition, based on the user's location, this information is shown on his tablets' screen. Moreover, this information is shared among other Hajj staff, to manage the crowd and identify their locations.

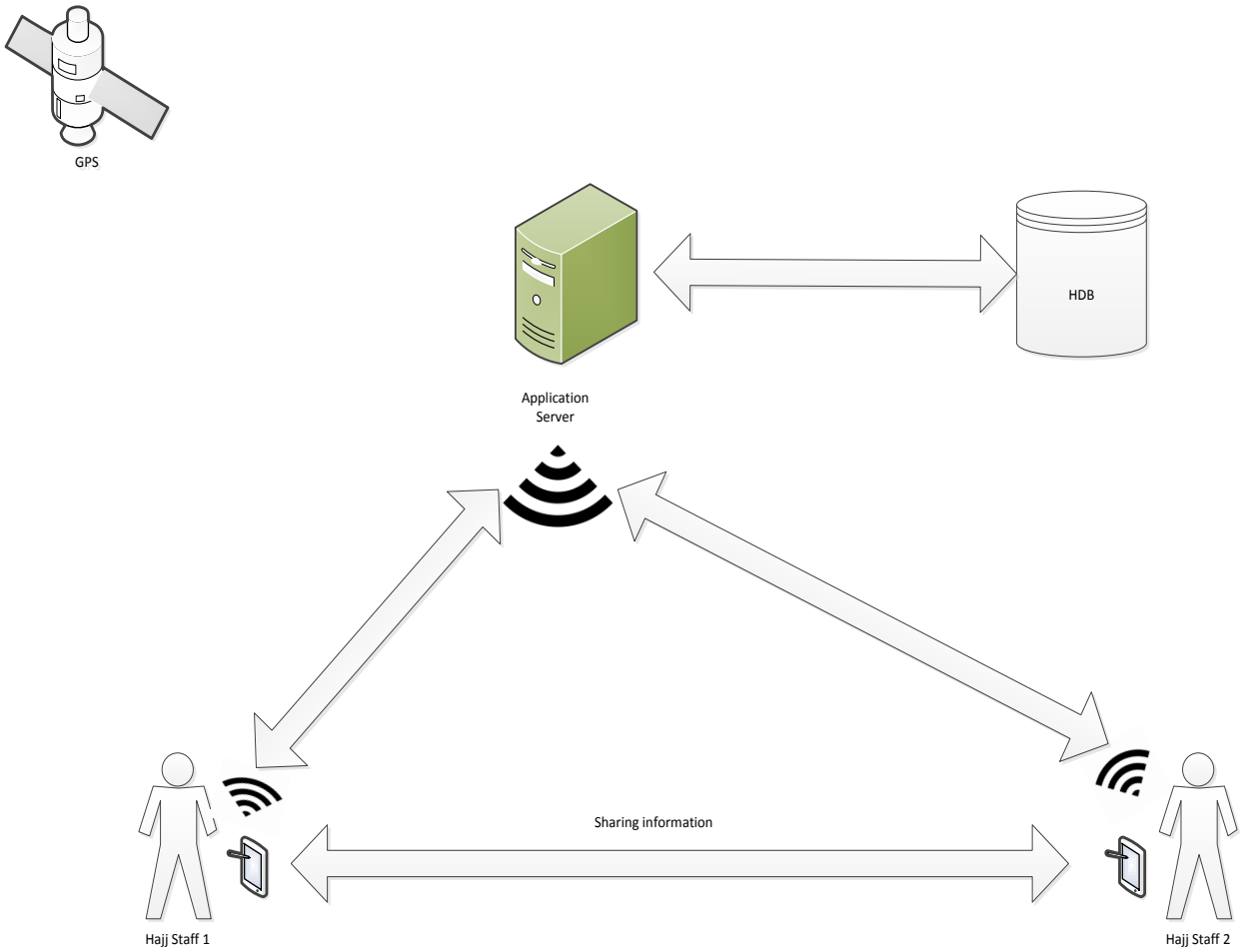


Figure 17: Data retrieval phase

5.4.3 The functional components of the application

- MAR engine and viewer: the engine calculates a certain piece of information within the ground field of view that is captured by the user (Server). However, the viewer is responsible for visualizing the information (Client). These components are based on ARToolKit that builds AR technologies for the iOS operating system. However, alternatively, there are other SDKs Kits that could be used to develop MAR applications for Android operating systems. Marshall (2011, p.11) mentioned that Qualcomm's QCAR, Unifeye mobile SDK and Wikitude SDK are software development kits that are used to create MAR platforms for Android operating systems. Therefore, a decision will be made about which operating systems to choose (IOS or Android) depending on the funding resource.

Navigation process: information is presented as pop-ups on the users' smartphone or tablet device screen. Information is presented as SMS, radio communication, field views, CCTVs records from the Hajj control room, and Mecca city monitoring cameras. According to Boron (2011, p.77), MAR applications use navigation by GPS, compass and accelerometer, in order to identify the users' location. In addition, Jang & Hudson-Smith (2012, p.2) described the some functions of using AR in the navigation process. For example, Display route information at the MAR display screen, such as location destination. In addition, detect, update and share Hajj staff locations among another staff automatically.

- Cooperation process: this process is vital, especially during Hajj event. Because the coordination helps the users to exchange and share information with each other, and with Hajj operators in the control room as well. For example, Boron (2011, p.80) mentioned when a user finds something strange happening at a certain location, he could share his view, from his screen device, with his colleagues or his superiors to get feedback. This view is geotagged with users' ID, time and location.

5.4.4 Proposed Crowd Monitoring at Hajj Event

During the Hajj event, it is important to monitor the crowd regularly, to detect for any sign of the problem that could effect on the crowds flow or movement. Therefore, in order to manage and organize the crowds, monitoring from various resources is an efficient method, to assess the crowds' movements at the holy places. For example, monitoring the crowd could be from other Hajj staff on the ground, undercover officers in the crowds and CCTV's, to share/receive information to/from all of these resources.

In addition, this study is proposing the three elements (that are vital in the process of monitoring the crowds at Hajj event (see figure 18). These elements to overcome the factors of crowd incidents (figure 3). In addition, they are combined by using MAR application, to monitor the crowds:

- Coordination: information is distributed to the right staff or unit, at the right time. For example, if some of the Hajj staff is monitoring an incident such as fire, this staff will send information to the department of fire rescue, which contains location of the fire, time…etc.
- Information: types of information, from where is collected and to whom this information will be shared it.
- Communication: This means the method(s) of sharing and coordinating information among the event's organizers.

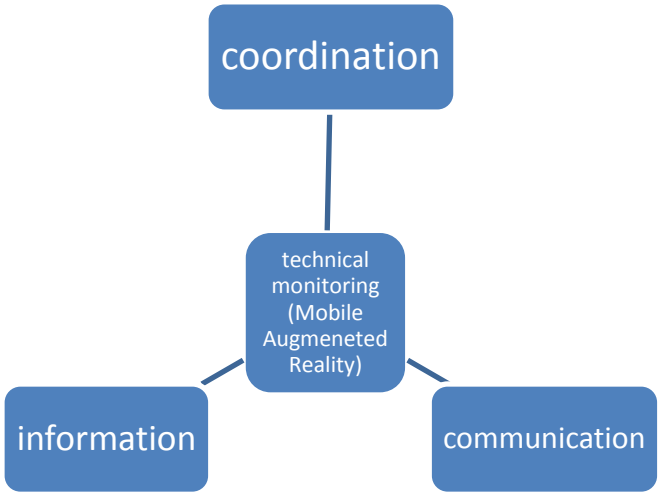


Figure 18: Elements of crowd management success

5.4.5 CMMAR application monitoring

Mora, Boron and Divitini (2012, p.91) mentioned that MAR applications could be adapted during emergencies or events that involve large crowds. Therefore, it is possible to support reflection by providing access to different types of information at the event. This application additionally could help Hajj staff to see the information that is collected during the event, and is shared among another staff. Furthermore, the information is continuously exchanged to coordinate activities among the ground organizers. In addition, there are other types of information that could be collected from such as, CCTVs from Hajj control room, captured photos by a mobile phone or information from other application as a radio communication. However, in an incident like lost or missing pilgrims, by implementing this application, sharing information about them will be easy and efficient. Therefore, the process of locating and tracking a missing person will be reduced at Hajj events. In addition, regarding crowd disasters at Hajj events, by using this application, exchanging information with good coordination and timely communication, could help Hajj staff to manage the crowds' movements at Hajj ritual places.

5.4.6 Scenarios of the proposed MAR application

Cabinet Office (2009 (B), p.61) described important processes about how to deal with the crowds in emergencies. In hazards, communication and information between the Hajj staff from different angles, as well as providing clear instructions to the crowds about how to deal with hazards are vital to initiate crowd management at this emergency. In addition, information that is provided to the crowd should be accurate, specific, timely, updated, comprehensible, visual and audio. If the provided information is delayed or telling to the crowd "not to panic", this could cause increasing the anxiety level of the crowds, which could increase the risk of causalities. Therefore, providing useful information and communicating with the crowds is crucial in maintaining order and managing the crowds movements.

5.4.6.1 Scenario 1: A Hazard Situation

When crowds are built at entrances or exits of Aljamarat Bridge at Mina, the flow of the crowds will start to slow down gradually and creates overcrowding. The overcrowding indicates that there is a problem (hazard) that is preventing the crowds flow from constantly moving. This situation could cause the crowds to behave badly or panic out. Therefore, all Hajj staff at this location should gather and share various types of virtual **information**. For example, SMS, audios and video streaming. This information is shared by using **communication** tools (e.g.

radio communications, group chat and video sharing). The process of gathering the information about the ovecrowding and sharing it is done by the use of the proposed Crowd Management Mobile Augmented Reality application **(CMMAR).** This application gathers this information and sends it to the databases, to be analyzed for making decisions regarding this problem. Therefore, decisions will be executed by **Coordination** between Hajj staff on the ground, and Hajj operators in Hajj control room. This step is about Hajj operators choosing the related staff or stakeholders (e.g. police, civil defense, special forces…etc.) to solve this problem. Thus, those staff will execute the decisions, to reduce the problem and try to manage the crowds flow.

In addition, it is essential that Hajj staff provide the crowds with **information** about this situation. Therefore, pilgrims in that crowd should respond to that Hajj staff, to let them manage their movements, and to reduce the crowdedness at that bridge. It is important to consider that the more information is obtained and sent to the application, the more the crowds are managed efficiently.

As a result, CMMAR application could assist the Hajj staff and operators, to detect crowd density by gathering and sharing different information timely and constantly. Therefore, this application could reduce hazards and overcrowding at Hajj ritual places (figure 19).

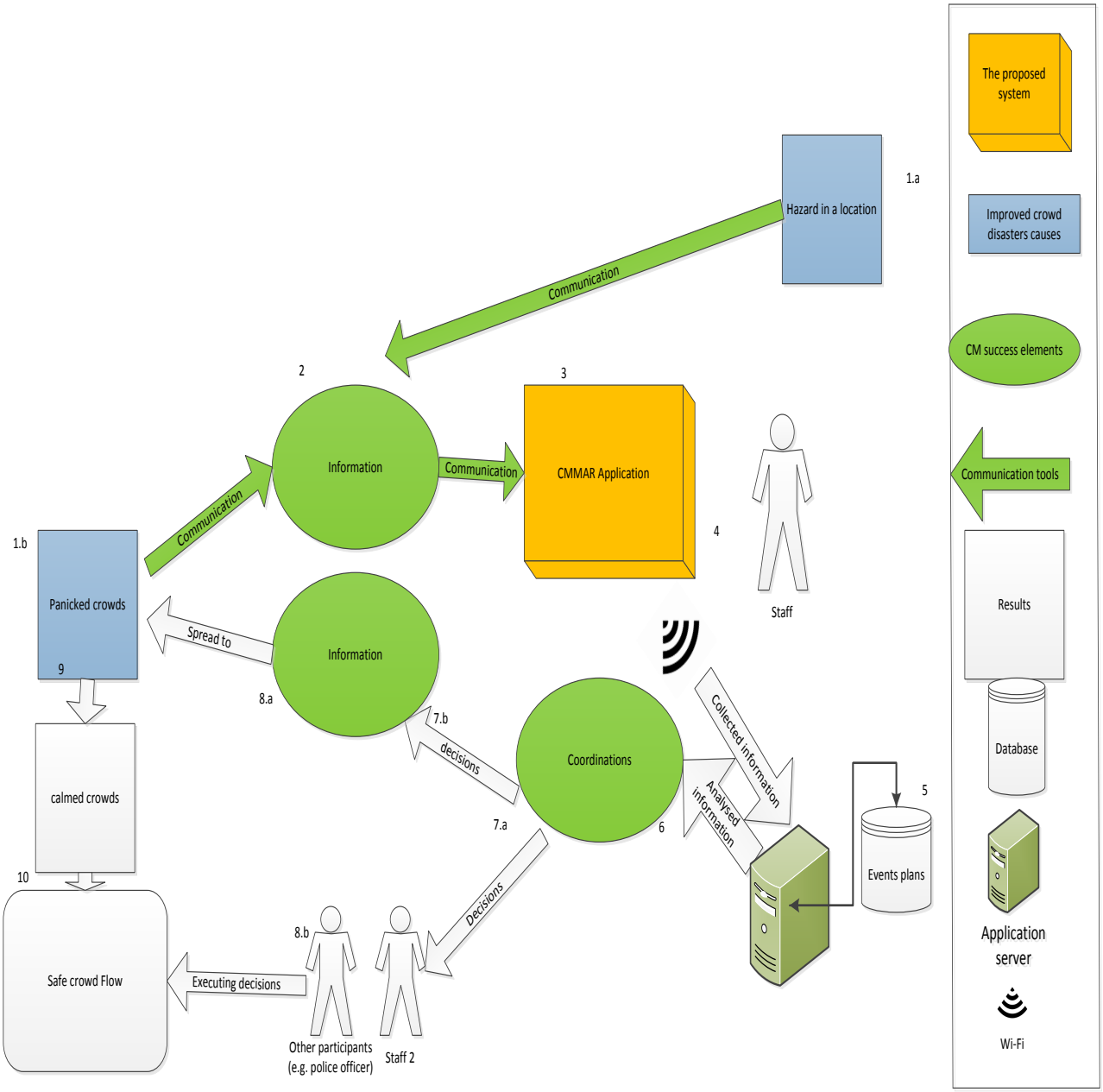


Figure 19: Improving event's management – crowd building, scenario 1

5.4.6.2 Scenario 2: lost pilgrim

As in figure 20, when a pilgrim is lost from his/her group, s/he starts to panic out and wonders how to return to his/her family or group again. Therefore, s/he tries to find any Hajj official, who works on the ground, to seek help from him. At this point, this official starts to use the CMMAR application on his tablet for instance, to identify this lost pilgrim, by scanning his/her ID number. The application will start to analysis and search for his/her data at HDB. The application server will fetch the result of this search, and then it is sent to the application again, to view the result on the official's tablet. In addition, he could send an SMS to his group guide. This SMS contains the lost pilgrims' details as well as his location information (time, longitude and altitude), to get him/her back to his/her group.

On the other hand, if the lost pilgrim requests to obtain directions to a specific location, the official could provide him/her with any direction that is surrounding him. This provision could be done by choosing the requested location on the applications' screen (browser) and showing it to the pilgrim. When the location is chosen, the application will present virtual information to the location by using lines and arrows on the screen. In addition, how long it will take from the pilgrim to reach the location.

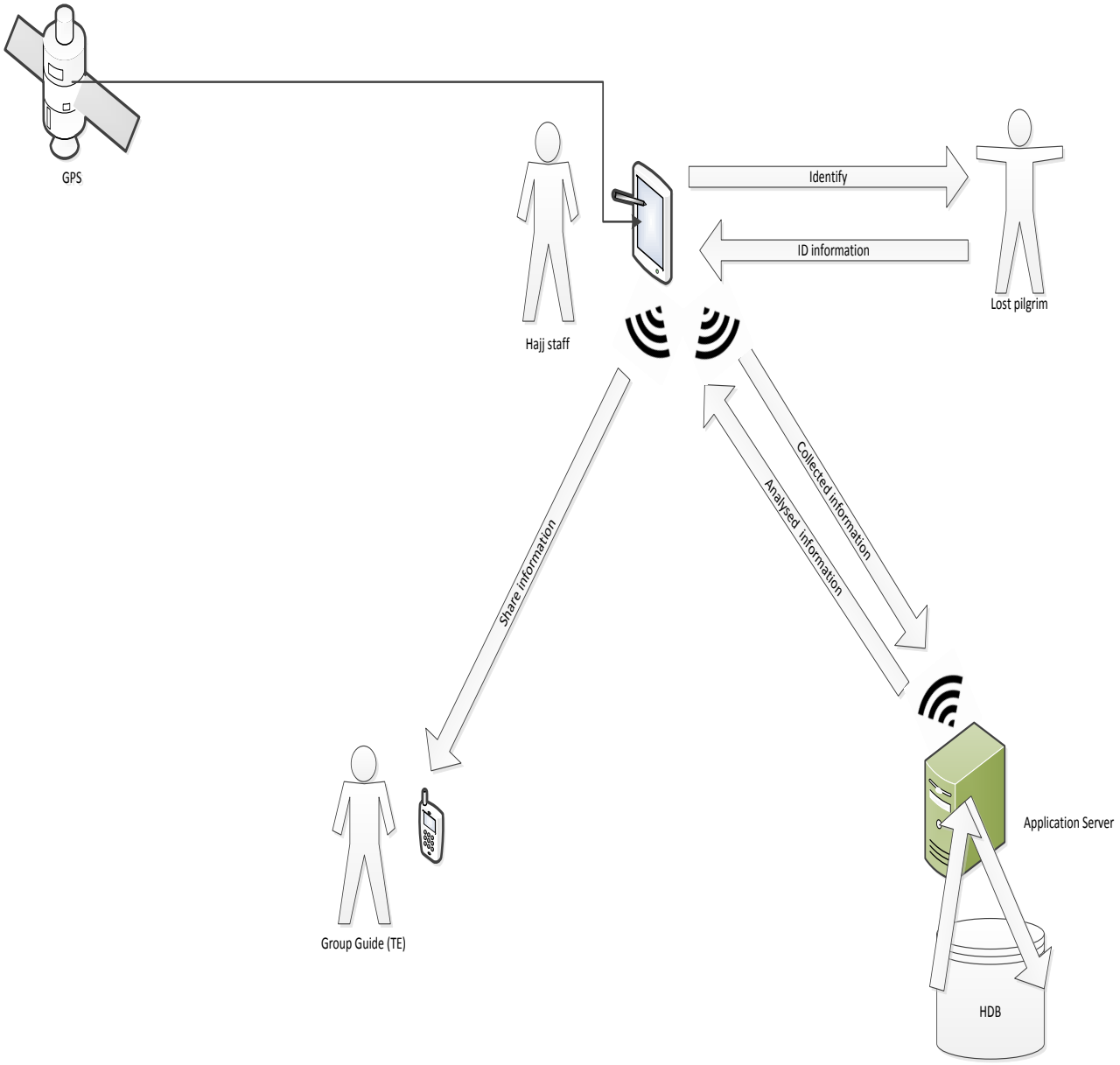


Figure 20: A lost pilgrim - scenario 2

5.5 Conclusion

Hajj events could cause some serious problems that lead to unpleasant results. It could lead to overcrowdings and stampedes that lead to missing pilgrims or losing their lives. In addition, when pilgrims get lost in the crowd, this might lead to other problems. For example, language barriers, unknown information about lost person, inability to get direction. These problems occur because of difficulties in realizing the surroundings and lack of signage or technologies to assist them. Therefore, applying technologies such as mobile augmented reality application, by Hajj authorities, might help to reduce these problems. This application could manage the Hajj crowds efficiently by monitoring and analyzing their movements between the Hajj ritual places. In addition, identifying lost pilgrims and provide them with directions to their desired destinations. In addition, alerting their groups' guides about them, by providing those guides with location information of those pilgrims.

5.6 Ethical concerns in adopting a ubiquitous system (limitations)

The following limitations could appear when adapting new technologies. Therefore, they should be considered before and during implementing any technology, to avoid any harm use. They main limitations are the following:

5.6.1 Ethical issues in tracking and locating a person by GPS

Wang and Loui (2009, p.1) described the Global Positioning System (GPS) receives measures of transit time of messages from four satellites. It calculates the distance from each satellite and then calculates the location. In addition, Michael, McNamee and Michael (2006, p.4) explained the most fundamental ethical issues when using the GPS and its' applications in tracking. They are:

Privacy: it concerns about using the GPS to track someone. It uses information that could be gathered from person's movements. For example, using devices contain GPS to track a child that might get lost or missing, as he/she will have a better chance to be found. However, does the child have the right whether or not to be tracked? At what age could be tracked? On the other hand, in case of tracking suspected criminals, using GPS to track them is like following them on the street. A GPS tracker can find person location anytime and anywhere. Therefore, police issue warrants for those criminal to place tracking devices on them. Furthermore, some employers track their employees if they are truck drives, to make sure that they are heading to the correct destination in time. However, some of those drivers complain that using GPS upon them is unfair for counting every minute that they might, might not be on, or off-duty and employers are holding that against them.

Accuracy: sometimes GPS devices could give error readings in specific locations, such as forests, tall buildings and cloud cover. Therefore, who is responsible GPS

accuracy? The US government designed this system, but they are not under any obligation to ensure the GPS accuracy.

Property: it is about, "who owns the information"? If the US government designed the GPS satellites, how own the information once it is collected?

Accessibility: who is allowed to use the GPS services? One of the GPS objectives is to provide services around the world, such as positioning, navigation and timing services. However, these services could be shut down in any dangerous situations such as terrorist attacks.

5.6.2 Ethical issues in using RFID technology as an ID

Naser et al. (2010, p.135) mentioned some limitations of implementing RFID tags like the following:

Technical issues: RFID technology is still limited in outdoor system applications, as it is based on radio signals. Therefore, these signals can be interrupted by natural and artificial factors such as wind, rain, and magnetic fields. In addition, the failure of the RFID system could be caused by other factors, such as creating an overload on the readers by reading a large number of tags in the reading zone.

Security threats: such as eavesdropping, which means, the transmitted data between the tag and the reader could be monitored and attacked by hackers. In

addition, unauthorized tag reading, this means that the tag readers could be fake. Finally, the threat of tag cloning, which means that the RFID tags could be duplicated in same of different size than the original tag while acting the same functionality of the original one.

Chapter 6: conclusion and recommendations

6.1 Introduction

This final chapter reviews and summarizes each chapter that was covered in this dissertation. The research summary presents all the chapters of this research briefly. The conclusion explains the benefit of the proposed system, and how this system answered the research questions. Finally, the research recommendations provide points of implementing the proposed system at Hajj events, and how it could be used for future studies.

6.2 Research Summary

In Chapter 1 explained that this study focused on developing a technological system, to assist in solving problems in Hajj crowd management. These problems were divided into three main problems. First, the problem of the unorganized crowds of pilgrims, as the number of pilgrims is massive, and they are gathered in limited spaces at Hajj holy places. Therefore, this problem leads to overcrowdings, congestions, and stampedes at these locations. The second

problem was pilgrims might get lost from their groups, especially while pilgrims are moving from ritual place to another. In addition, the third reason was lack of information provision, directions and guidance at Hajj events. Therefore, this research proposed to deploy the technology, to facilitate Hajj authorities to solve or at least reduce these problems at Hajj events.

Chapter 2 was the Literature review of the research. It was divided into three main sections. Firstly, the theory of crowd management, which explained the main steps of managing crowded events such as Hajj event, in order to guarantee success in managing the pilgrim's movements safely. Secondly, the practical studies of Hajj crowd management. These studies proposed and developed systems to solve Hajj problems. These problems were difficulties in identifying and locating lost pilgrims at Hajj ritual places, and difficulties in estimating the crowded pilgrims at this place, to avoid overcrowdings, congestions and stampedes. The main systems were RFID systems; GPS devices were given to pilgrims and monitoring cameras for estimating crowd densities at Hajj holy locations. Thirdly, a brief study that presented augmented reality technology and its' applications.

Chapter 3 was about a description of the case study the Hajj. It presented the process of this event, the Hajj authorities that are participating in Hajj management, and its' regulations.

In Chapter 4, the research method discussed the distributed questionnaires and their results. The questionnaires were distributed to 104 respondents as all of them have been related to the Hajj events. In addition, the results confirmed the

problems that occurred at Hajj events. The problems of overcrowdings, congestions and stampedes occurred at Hajj, due to lack of organizations of the pilgrims huge numbers, and the geographical limited spaces of Hajj holy sites. These problems could cause pilgrims blocking the traffic roads between these sites, and those pilgrims were exposed to traffic incidents. In addition, foreign pilgrims faced lack of directional information at these sites as well. Moreover, pilgrims were lost from their groups at Hajj events, due to the high numbers of the crowds while they were moving from ritual site to another. Additionally, if pilgrims were performing Hajj for their first time, they might not be aware of its' holy sites. Furthermore, the language barriers occurred when there was a communication between foreign pilgrims and some of the Hajj officials. As a result, it has been suggested to use technology in Hajj crowd management, to manage crowds' movements and help lost pilgrims. The respondent's suggestion was to implement software that helps the Hajj officials to identify lost pilgrims and guide them at Hajj events. Google maps and GPS could assist this software.

Chapter 5 described the proposed system, which was the Crowd Management Mobile Augmented Reality (CMMAR) application. Two scenarios were illustrated explaining the deployment this application for two purposes. First, this application would assist the Hajj authorities, both staff and operators, to manage crowds' movements constantly. This assistance would be by sharing and analyzing information between the Hajj staff (on the ground) and the Hajj operators (in the control room). Second, this application would assist the Hajj staff to identify lost pilgrims, provide them with directional information. In addition, sending to their group guide the lost pilgrims location information (time of finding, longitude and altitude).

6.3. Conclusion

To conclude this research, the application of CMMAR would be beneficial in crowd management at Hajj events. It presents a different kind of information (images, videos, audio…etc.) about the surrounding environment. In addition, it could be used for different purposes, such as navigation, communication and identifying city landmarks. The information that is presented about the surroundings is overlaid on the targeted objects. Moreover, application users' locations are identified all the time because this application uses GPS as one of its components. Finally, it could be used by more than one user at the same time.

The importance of deploying MAR application in Hajj events would be:

- This application could be used at outdoor locations, to assist the users in exploring the surrounding environment.
- It provides information about buildings, landmarks, discretions…etc.
- It deploys emerging technology, which is the mobile technology (smartphone and PC tablet). The features of this technology have been developed and increased in power of graphical processing. Therefore, the visualization of the presented information will be instant. In addition, it has high speed in sharing and sending information between its users.
- The main features of this application would be high process, ability to present different information and multimedia and technical support.

The MAR application could be used in Hajj crowd management at these situations:

- Organizing crowds' movements: Hajj operators from the control room could monitor crowds' movements through the application that is used by Hajj staff. This application would help them to detect immediately for any problem that could occur at Hajj ritual places (overcrowdings and stampede). The application detects immediately because it has high-speed in sharing and sending information between Hajj staff (on the ground), and Hajj operators (in the control room).
- Lost pilgrims: this application could gather and present different information, to directly lost pilgrims, alert and hear their location information to their group guides.

The technical resources of this application are GPS, accelerometers and digital compass. This combination of resources would provide location information for each user who is using the application. Therefore, these resources are used to detect other user locations, navigate to other locations, and track other users' movements and use live maps, to present location information for other users.

Expected outcomes of using MAR application in Hajj crowd management would be:

- Hajj problems could be reduced at its' holy locations, because of the high speed of sharing and sending the information between the users.

- The problem of lost pilgrims at Hajj holy sites could be decreased, and therefore they could follow their groups and perform Hajj rituals on time.
- The problem of language barriers would be decreased as this application could use voice translation between the lost pilgrim and Hajj official, to communicate without difficulty.

6.4 Recommendations

The following points are some recommendations regarding implementing this system effectively for managing the crowds at Hajj events:

- During the event, all Hajj officials (staff and operators) should constantly use the Mobile Augmented Reality application, to make sure that the information about crowds' movements and lost pilgrims locations is exchanged continuously between them.
- Each Hajj staff, who is using the system on the ground, must know his priorities and duties, to avoid any conflict in doing their tasks.
- The Hajj staff should be trained to use the system before the start of Hajj event.
- This system is developed for crowded events, to manage crowds' movements, and provide assistance to lost people.
- For future studies, this system could be tested several times before it is implemented officially by the Hajj authorities. In addition, it could be deployed at other musical or sporting events.

References

- Abuarafah, A, Khozium, M & AbdRabou, E 2012, "Real-time Crowd Monitoring using Infrared Thermal Video Sequences", *Journal of American Science*, vol. 8, no. 3, pp. 133-140.
- Al Bosta, S 2011, "Crowd management based on scientific research to prevent crowd panic and disasters". In: *Pedestrian and Evacuation Dynamics* (pp. 741-746). Springer US.
- Al-Gadhi, S 1996, "A review study of crowd behavior and movement", *Journal of King Saud University, Engineering Sciences*, vol. 8, no. 1, pp. 77-108.
- Al-Hashedi, A, Arshad, M, Hj Mohamed, H, Baharuddin, A 2011. "Identifying the determinants of RFID adoption intention in Hajj organizations". In: *Research and Innovation in Information Systems (ICRIIS).* Kuala Lumpur, Malaysia, 23-24 November 2011. IEEE.
- Al-Hashedi, A, Arshad, M, Baharudin, A & Hj Mohamed, H 2013, "RFID applications in hajj management system, In: *RFID-Technologies and Applications (RFID-TA), 2013 IEEE International Conference on*, Johor Bahru, Malaysia, 4-5 September 2013, IEEE.
- Aljamarat Bridge, accessed 01/11/2014 http://hikm.wordpress.com/category/saudi-arabia/

- Al-Kodmany, K 2013, “Crowd management and urban design: New scientific approaches”, *Urban Design International*, vol. 18, no. 4, pp. 282-295.
- Al-Nuaim, H and Al-Masry, M 2012, “The Use of Mobile Technology Applications for Crisis Management During Hajj”, *Journal of Occupational Safety and Health*, vol. 9, no. 2, pp. 47-60.
- Al-Salhie, L, Al-Zuhair, M & Al-Wabil 2014, “Multimedia surveillance in event detection: crowd analysis in Hajj”, *Design, User Experience, and Usability*, vol. 8518, pp. 383-392.
- Aly, S & Abdelwahab, M 2012, “Hajj and Umrah Dataset for Face Recognition and Detection”. http://arxiv.org/pdf/1205.4463.pdf
- Amro, A & Nijem, Q 2012. “Pilgrims" Hajj" Tracking System (e-Mutawwif)”, *Contemporary Engineering Sciences*, vol. 5, no. 9, pp. 437-446.
- Bahurmoz, A 2006, “A strategic model for safety during the Hajj pilgrimage: An ANP application”, *Journal of Systems Science and Systems Engineering*, vol. 15, no. 2, pp. 201-216.
- Batty, M 2006, “Agent-based technologies and GIS: Simulating crowding, panic, and disaster management”, In Rana, S & Sharma, J (eds), *Frontiers of geographic information technology*, Springer, Berlin Heidelberg, pp. 81-101.
- Billinghurst, M 2013, “Augmented Reality Interfaces in Human Computation Systems”, in Michelucci, P (ed.), *Handbook of Human Computation*, Springer New York, pp. 317-331.
- Boron, A 2011. “Mobile Augmented Reality for Supporting Reflection”, Mater thesis, Norwegian University of Science and Technology, Norway.

- Cabinet Office, 2009 (A), Understanding crowd behaviors: Guidance and lessons identified.

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/62638/guidancelessons1_0.pdf

- Cabinet Office, 2009 (B), Understanding crowd behaviors: Supporting evidence.
  https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/192606/understanding_crowd_behaviour-supporting-evidence.pdf

- Carmigniani, J, Furht, B, Anisetti, M, Ceravolo, P, Damiani, E, & Ivkovic, M 2011, "Augmented reality technologies, systems and applications. Multimedia Tools and Applications", *Multimedia Tools and Applications*, vol. 51, no.1, pp. 341-377.
- Craig, A 2013, "*Understanding augmented reality: concepts and applications*", Morgan Kaufmann, Amsterdam.
- Dhaou, I 2010, "Client-Server network architecture for safe pilgrim journey in the Kingdom of Saudi Arabia", In: *Intelligent Vehicles Symposium (IV), 2010 IEEE*, University of California, San Diego, CA, USA, 21-24 June 2010, IEEE.
- Drury, J, Novelli, D, & Stott, C 2013. "Representing crowd behavior in emergency planning guidance: 'mass panic 'or collective resilience?", *Resilience*, vol. 1, no. 1, pp. 18-37.
- EARL, C 2006, "Public Health Management at Outdoor Music Festivals", PhD thesis, Queensland University of Technology, Australia.

- Elzahrany, R & Mirza, M 2011, "Using Augmented Reality to Introduce Historical Sites in Makkah "Mecca", Saudi Arabia: Conceptual Framework", In: *UGI 2011 Geography Regional Conference*, Santiago, Chile, 14-18 November 2011.
- Gervautz, M & Schmalstieg, D 2012, "Anywhere Interfaces Using Handheld Augmented Reality", Computer, vol.45, no. 7, pp. 26-31.
- Hajj ritual steps accessed 01/11/2014 http://imgarcade.com/1/hajj-pilgrimage-map/

- Halabi, W 2006. "Overcrowding and the Holy Mosque, Makkah, Saudi Arabia", PhD thesis, Newcastle upon Tyne, UK.
- Hameed, S 2010, "ICT to serve Hajj: Analytical study, In: *Proceedings of the 2010 International Conference on Computer and Communication Engineering (ICCCE)*, International Islamic University Malaysia, Kuala Lumpur, Malaysia, 11-12 May 2010.
- Hamhoum, F, & Kray, C 2012, "Supporting pilgrims in navigating densely crowded religious sites", *Personal and Ubiquitous Computing*, vol. 16, no. 8, pp. 1013-1023.
- Harmain, H, Khatib, H, Saeed, N & Aljohar, B 2004, "Web Services-Based Hajj Information System", In: *International Conference on Information & Computer Science, ICICS'04*, Dhahran, Saudi Arabia 2004, pp. 547-555.
- Health and Safety Executive (HSE), 2000, "Managing crowd safely". https://www.sussex.ac.uk/webteam/gateway/file.php?name=managing-crowds-safely.pdf&site=332

- Helbing, D, Johansson, A & Al-Abideen, H 2007, "The Dynamic of Crowd Disasters: An Empirical Study", *Physical review E*, vol. 1, pp. 1-7.
- Helbing, D & Johansson, A 2011, "Pedestrian, crowd and evacuation dynamics", *Extreme Environmental Events*, pp. 697-716.
- Henrysson, A 2007, "Brining Augmented Reality to Mobile Phones", PhD thesis, Linköping University, Sweden.
- Hollerer, T & Feiner, S 2004, "Mobile Augmented Reality", in Karimi, H & Hammad, A (eds), *Telegeoinformatics: Location-Based Computing and Services*, Taylor & Francis Books Ltd., pp. 1-39.
- Illiyas, F, Mani, S, Pradeepkumar, A & Mohan, K 2013, "Human stampedes during religious festivals: A comparative review of mass gathering emergencies in India", *International Journal of Disaster Risk Reduction*, vol. 5, no. 1, pp. 10-18.
- Jang, S & Hudson-Smith, A 2012, "Exploring Mobile Augmented Reality Navigation System for Pedestrians", In: *Proceedings of the GIS Research UK 20th Annual Conference GISRUK*, Lancaster University, UK, 11-13 April 2012.
- Katier, B 2011, "Mobile Augmented Reality, A medium for extending business opportunities and value chain innovation", Master Thesis, University of Amsterdam, Netherlands.
- Khan, E 2011, "An RFID-Based System for Pilgrim Management in King Abdul Aziz International Airport", *Information Management, Innovation Management and Industrial Engineering (ICIII)*, Shenzhen, China, 26-27 November 2011.

- Khan, I & McLeod, R 2012, "managing hajj crowd complexity: superior throughput, satisfaction, health and safety", *Arabian Journal of Business and Management Review,* vol. 2, no. 4, pp. 45-59.
- Khozium, M, Abuarafah, A & AbdRabou, E 2012, "A proposed computer based system architecture for crowd management of pilgrims using thermography" *Life Science Journal,* vol. 9, no. 2, pp. 277-282.
- Koshak, N. (2005, June). A GIS-based spatial-temporal visualization of pedestrian groups movement to and from Jamart area. In: *Proceedings of Computers in Urban Planning and Urban Management (CUPUM'05) Conference*, London, UK, 29 June – 1 July 2005.
- Krausz, B & Bauckhage, C 2012. "Loveparade 2010: Automatic video analysis of a crowd disaster", *Computer Vision and Image Understanding,* vol. 116, no. 3, pp. 307-319.
- Langlotz, T, Nguyen, T, Schmalstieg, D & Grasset, R 2014. "Next-Generation Augmented Reality Browsers: Rich, Seamless, and Adaptive", *Proceedings of the IEEE,* vol. 102, no. 2, pp. 155-169.
- Lee, G, Dunser, A, Kim, S & Billinghurst, M 2012, "CityVeiw AR: A Mobile Outdoor Application for City Visuliation", In: *11th IEEE International Symposium on Mixed and Augmented Reality (ISMAR 2012) - Arts, Media, and Humanities Proceedings,* Atlanta, Georgia, USA, 5-8 November 2012, IEEE.
- Maffioletti, S 2001, "Requirements for an Ubiquitous Computing Infrastructure", accessed 25/09/2014, http://203.250.33.57/UbiCom2010/ParadigmForUbiComp.pdf

- Mantoro, T, Jaafar, A, Aris, M & Ayu, M 2011, "HajjLocator: A Hajj pilgrimage tracking framework in crowded ubiquitous environment", In: *Multimedia Computing and Systems (ICMCS)*, Ouarzazate, Morocco, 07-09 April 2011.
- Mantoro, T, Ayu, M & Mahmud, M 2012, "Hajj Crowd Tracking System in a Pervasive Environment", *International Journal of Mobile Computing and Multimedia Communications (IJMCMC)*, vol. 4, no. 2, pp. 11-29.
- Marimon, D, Sarasua, C, Carrasco, P, Álvarez, R, Montesa, J, Adamek, T, Romero, I, Ortega, M & Gascó, P 2010, "MobiAR: Tourist Experiences through Mobile Augmented Reality", *Proceedings of 2010 NEM Summit*, Barcelona, Spain, 13 – 15 October 2010.
- Marshall, T 2011, "Moving the museum outside its walls: An Augmented Reality Mobile Experience", Master thesis, School of Information and Communication Technology (ICT), Communication Systems, Stockholm, Sweden.
- McNamara, A 2013, "Prestigious NSF award funds augmented reality research", accessed 08/11/2014, http://one.arch.tamu.edu/news/2013/2/19/mcnamara-nsf-award/

- Memish, Z, Stephens, G, Steffen, R & Ahmed, Q 2012, "Emergence of medicine for mass gatherings: lessons from the Hajj", *The Lancet infectious diseases*, vol. 12, no. 1, pp. 56-65.
- Michael, K, McNamee, A, & Michael, M 2006, "The emerging ethics of humancentric GPS tracking and monitoring", In: *Mobile Business, 2006.*

ICMB'06. International Conference on, Copenhagen, Denmark, 26 – 27 June 2006.

- Ministry of Hajj, 2012 http://www.hajinformation.com/main/m702.htm
- Ministry of Hajj, 2012 http://www.hajinformation.com/main/u5.htm

- Mohandes, M 2008, "An RFID-based pilgrim identification system (a pilot study)", In: *Optimization of Electrical and Electronic Equipment, 2008. OPTIM 2008. 11th International Conference on*, Transilvania University of Brasov, Romania, 22 – 24 May 2008, IEEE.
- Mohandes, M 2010, "A case study of an RFID-based system for pilgrims identification and tracking", in Cristina Turcu (ed.), *Sustainable Radio Frequency Identification Solutions*, InTech, Croatia, pp. 87-104.
- Mohandes, M 2012, "Near Field Communication for pilgrim services", In: *Computing Technology and Information Management (ICCM), 2012 8th International Conference on*, Seoul, Korea (South), 24 – 26 April 2012. IEEE.
- Mohandes, M, Haleem, Kousa, M & Balakrishnan, K 2013, "Pilgrim tracking and identification using wireless sensor networks and GPS in a mobile phone", *Arabian Journal for Science and Engineering*, vol. 38. No. 8, pp. 2135-2141.
- Mora, S, Boron, A & Divitini, M 2012, "CroMAR: Mobile augmented reality for supporting reflection on crowd management", *International Journal of Mobile Human Computer Interaction (IJMHCI)*, vol. 4, no. 2, pp. 88-101.

- Naser, M, Rafie, M, Budiarto, R & Alsalihy, W 2010, "Security Considerations in Embedding RFID in 'Hajj' System", *European Journal of Scientific Research*, vol. 42, no. 1, pp. 133-138.
- Nofal, E 2013, "taking advantages of augmented reality technology in museum visiting experience", In: 6th International Congress "Science and Technology for the Safeguard of Cultural Heritage in the Mediterranean Basin", Athens, Greece, 22-25 October 2013.
- Olsson, T, Lagerstam, E, Karkkainen & Vaananen-Vainio-Mattila, K 2013, "User experience of mobile augmented reality services: a user study in the context of shopping centers", *Personal and Ubiquitous Computing*, vol. 17, no. 2, pp. 287-304.
- Osman, M & Shaout, A 2014, "Hajj guide systems – past, present and future", *International Journal of Emerging Technology and Advanced Engineering*, vol.4, no. 8, pp. 25-31.
- Prof. Dr. G. Keith Still 2013, "Crowd Disasters", accessed 26/05/2013, http://www.gkstill.com/ExpertWitness/CrowdDisasters.html
- Reffat, R 2012, "An Intelligent Computational Real-time Virtual Environment Model for Efficient Crowd Management", *International Journal of Transportation Science and Technology*, vol. 1, no. 4, pp. 365-378.
- Schneider, J, Garatly, D, Srinivasan, M, Guy, S, Cutis, S, Cutchin, S, Manocha, D, Lin, M & Rockwood, A 2011, " Towards a Digital Makkah – Using Immersive 3D Environments to Train and Prepare Pilgrims", In: *International Conference on Digital Media and its Applications in Cultural Heritage (DMACH)*, Amman, Jordan, 16-17 March, 2011.

- Shiwakoti, N & Sarvi, M 2013. "Understanding pedestrian crowd panic: a review on model organisms approach", *Journal of Transport Geography*, vol. 26, no. 1, pp. 12-17.
- Siddiqui, A & Gwynne, S 2012, "Employing pedestrian observations in engineering analysis", *Safety Science*, vol. 50, no. 3, pp. 478-493.
- Van Krevelen, D & Poelman, R 2010. "A survey of augmented reality technologies, applications and limitations", *The International Journal of Virtual Reality*, vol. 9, no. 2, pp. 1-20.
- Wang, J & Loui, M 2009, "Privacy and ethical issues in location-based tracking systems", In: *International Symposium on Technology and Society (ISTAS)*, Tempe, AZ, USA, 18 – 20 May, IEEE.
- Wang, J, Shyi, C, Hou, T & Fong, C 2010, "Design and implementation of augmented reality system collaborating with QR code. In: *International Computer Symposium (ICS)*, National Cheng-Kung University, Tainan, Taiwan, 16 – 18 December 2010, IEEE.
- Weiss, R & Craiger, J 2002, "Ubiquitous Computing", *Leading Edge*, vol. 39, no. 4, pp.44-52.
- Yamin, M & Albugami, M 2014, "An architecture for improving hajj management", *Service Science and Knowledge Innovation*, vol. 426, pp. 187-196.
- Yamin, M, Huang, X & Sharma, D 2008, "Wireless & Sensor Technology and Crowd Management", *CURIE Journal*, vol. 2, no. 1, pp. 66-74.

Appendix

Hajj Crowd Management via a Mobile Augmented Reality Application: A case of The Hajj event, Saudi Arabia – the Questionnaire

My research is concentrating on Hajj event, especially on its problems that is facing both Saudi Hajj Authorities and the pilgrims. As a requirement of my research, this questionnaire has been done trying to collect some information about these problems such as, where and when these problems occur and how they can be solved. This questionnaire will be distributed to **Academics**, who work in Saudi universities; especially those who conducted studies related to Hajj, **King Abdulaziz International Airport officials**, especially who are working in Hajj terminal, **Directors of foreign pilgrims campaigns**, who are responsible of foreign pilgrims from when they arrive until they leave Saudi Arabia, **Police and civil defence officers** and **previous pilgrims.** In addition, these questionnaires could also be distributed to any person or authority that is related to Hajj, such as **Ministry of Hajj** and **Mecca Government**. Therefore, please fill in this questionnaire. No other person will see you answer.

Almoaid A. Owaidah

Postgraduate Research Student,

School of Computing Science,

University of Glasgow.

Instructions: this questionnaire is divided in eight sections. Each section includes closed and open questions. In the closed questions, please put a tick in the box corresponding to your answer, like this:

Questions	Answers options					
	1.Strongly agree	2.Agree	3. Neutral	4.Disagree	5.Strongly disagree	6.Don't know
1.	✓					

In the open questions, there are spaces provided. Please feel free to express you answers.

Before completing the questionnaire, please answer these questions: (optional)

- **Your Name:……**
- **Are you Male ☐ Female ☐ ?**
- **Country of Birth: ……**
- **What is your age?**

18 to 24 years ☐ 25 to 34 years ☐ 35 to 44 years ☐

45 to 54 years ☐ 55 to 64 years ☐ 65 or older ☐

- **What is the highest degree or level of education you have completed?**

Less than high school. ☐

High school graduate (includes equivalency). ☐

Some college, no degree ☐

Bachelor's degree. ☐

Master's degree. ☐

Ph.D. ☐

- **Your Occupation: …….**
- **Which organization or company do you work for?**

  …….

- **Years of Experience: ……**

- **Have you been to Hajj before?** **Yes** ☐ **No** ☐

<u>Section 1 - Crowd controlling:</u> this issue is about how to control both local and foreign pilgrims when they arrive at King Abdulaziz International Airport (KAIA), or other gateways, especially in immigration and check points, there are procedures to be done for those pilgrims to enter Saudi Arabia.

Questions	Answers options					
	1.Strongly agree	2.Agree	3. Neutral	4.Disagree	5.Strongly disagree	6.Don't know
5. The immigration procedures at KAIA are easily accomplished.						
6. Immigration procedures at checkpoints in the high road, between Jeddah and Mecca, are appropriate.						
7. Do you think that some of the local pilgrims perform Hajj without joining any Hajj campaign?						

8. In Hajj, some local pilgrims sleep anywhere in the ritual places. Therefore, they block the traffics in the ritual places.						

9. If immigration procedures in airports and other gateways are slow, then what are the reasons?

---

10. Are there advantages for local pilgrims to perform Hajj by joining any Hajj campaign? What are they?

11.Do you think there are regulations requiring local pilgrims to join any Hajj campaign?

12.Do you think these regulations are applied? Why?

<u>Section 2 - Medical Emergencies:</u> how the pilgrims are treated in emergency situations during Hajj performance.

Questions	Answers options					
	1.Strongly agree	2.Agree	3. Neutral	4.Disagree	5.Strongly disagree	6.Don't know
13.The arrival of the medics is delayed because of the crowded pilgrims.						
14. There are medical clinics in the ritual places of Hajj.						
15.Each pilgrim's medical history is available with him/her.						
16.Serious emergency conditions are transferred to Mecca's hospitals.						

17. There are infections during the Hajj season.						

18. What are the difficulties that face medics in Medical Emergencies in Hajj seasons?

<u>Section 3 - Guiding Pilgrims:</u> How can lost pilgrims be guided and know how to return to their residences before, during and at the end of Hajj.

Questions	Answers options					
	1.Strongly agree	2.Agree	3. Neutral	4.Disagree	5.Strongly disagree	6.Don't know
19. The language barrier is one of the significant problems that face the foreign pilgrims in Hajj seasons.						
20. Non-Arabic Foreign pilgrims understand the signboard instructions in Mecca city, or in the ritual places of Hajj.						
21. Non-Arabic pilgrims find some difficulties to figure out their way back to their residences.						

22. Some of the non-Arabic pilgrims are guided to their residences when they get lost.						
23. Foreign pilgrims could easily find the ritual places of Hajj.						
24. It is hard to find translators between the ritual places and near by the Sacred Mosque.						

25. What are the difficulties that face foreign pilgrims to get directions or guidance?

---

26. What do you thing about using Information and Communication Technologies (ICT)s such as mobile phones, laptops, or tab devices in guiding and directing pilgrims? Could you explain your answer?

<u>Section 4 - Identifying the Pilgrims:</u> this issue is about pilgrims who are lost in Hajj, especially between the ritual places of Hajj.

Questions	Answers options					
	1.Strongly agree	2.Agree	3. Neutral	4.Disagree	5.Strongly disagree	6.Don't know
27. The language barrier is the most important issue in identifying the loss of non-Arabic pilgrims.						
28. Pilgrims carry any ID while performing Hajj.						
29. Crowd movement could cause the pilgrims to be lost from their campaign, while moving between the ritual places of Hajj.						
30. Some of the lost foreign pilgrims prefer to stay illegally in Saudi						

rather than returning back to their countries						

Questions	Answers options					
	1. less than hour	2. 1-3 h	3. 4-7 h	4. a day-3days	5. longer than that	6.Don't know
31. How long does it take to find a lost pilgrim in Hajj season						

32. What are the common methods that identify pilgrims in Hajj season?

---

33. Could you explain why some of the pilgrims get lost in Hajj seasons?

---

34. Do pilgrims carry with them mobile phones or other communication devices in Hajj? What are they commonly used for? What are the percentage of those pilgrims how are using these devices?

35.Could these devices be charged or plugged to the electricity in the Hajj ritual places?

---

36. If any technology is applied e.g. mobile phone or tab devices how it could solve the problem of lost pilgrims?

Section 5 – Crowding of Pilgrims:

Questions	Answers options					
	1.Strongly agree	2.Agree	3. Neutral	4.Disagree	5.Strongly disagree	6.Don't know
37. One of the reasons of crowded pilgrims is that the ritual places (Arafat & Muzdalifah) are narrow.						
38. Congestions lead to complications in traffic movement between ritual places.						
39. Railways between the ritual places are one of the solutions to decrease pilgrims' congestions in those places.						
40. There are technologies applied to						

manage the crowded pilgrims.						
41.Pilgrims are well organized in Hajj.						

42. Could you list some problems of congestions in Hajj?

---

43. What are your suggestions for solving congestions problems in Hajj?

Section 6 - Hajj Incidents:

Questions	Answers options					
	1.Strongly agree	2.Agree	3. Neutral	4.Disagree	5.Strongly disagree	6.Don't know
44. A crowd of pilgrims is one reason of traffic roadblock in Mecca city.						
45. The transportations between the ritual places, such as buses, are involved in accidents, which can lead to injuries or death to those pilgrims.						
46. Awareness of pilgrims by screen videos and audio might help to reduce incidents in Hajj.						
47. Because of the large number of the pilgrims, they could cause serious						

incidents to themselves.						

Questions	Answers options					
	1. 10-15 m	2. 16-30 m	3. 31-45 m	4. 1h-1.5h	5. longer than that	6.Don't know
48.How much time does it take to control an incident when it occurs?						
49.The most crowded place in Hajj is:	Answers options (tick one)					
	1.Arafat	2.Muzdalifah	3.Mina	4.The movement between Arafat&	5.The movement between Muzdalifaa	6.Don't know

				Muzdalifah	and Mina.	

50.Which place(s) was/were dangerously crowded in the past?

51.Which place(s) is crowded in present?

52.Which place(s) will expect to be crowded in the future?

53.What kind of incidents that pilgrims could face them in Hajj season?

Section 7 - the Saudi authorities in Hajj:

54. Could you list the Saudi authorities and forces, which participate in Hajj season?

Questions	Answers options					
	1.Strongly agree	2.Agree	3. Neutral	4.Disagree	5.Strongly disagree	6.Don't know
55. Saudi authorities are in places in the ritual places of Hajj and in Mecca city.						
56. There is an efficient cooperation between the Saudi authorities in Hajj.						
57. Saudi Hajj Authorities are helpful, especially with foreign pilgrims.						
58. Saudi Hajj Authorities interfere immediately to any kinds of problems in Hajj.						
59. Saudi authorities use technologies in Hajj.						

60. How Saudi authorities deal with crowd pilgrims and organize them?

---

61. Which authority is the most efficient in Hajj? Why?

Section 8 - the new Aljamart Bridge project in Mina:

Questions	Answers options					
	1.Strongly agree	2.Agree	3. Neutral	4.Disagree	5.Strongly disagree	6.Don't know
62. One of the reasons of crowded pilgrims is some of them do not follow the instructions, especially in Aljamarat Bridge where stoning the devil ritual.						
63. The old Jamarat Bridge was so dangerous to perform the stoning ritual on it.						
64. Congestions, crowd and stampede were often on the old Jamarat Bridge.						

65. The new project has removed the bottleneck and congestions in the ritual place of Mina.						
66. Congestions appear in the new Jamarat Bridge.						

67. Could you explain the features of the new Jamarat Bridge?

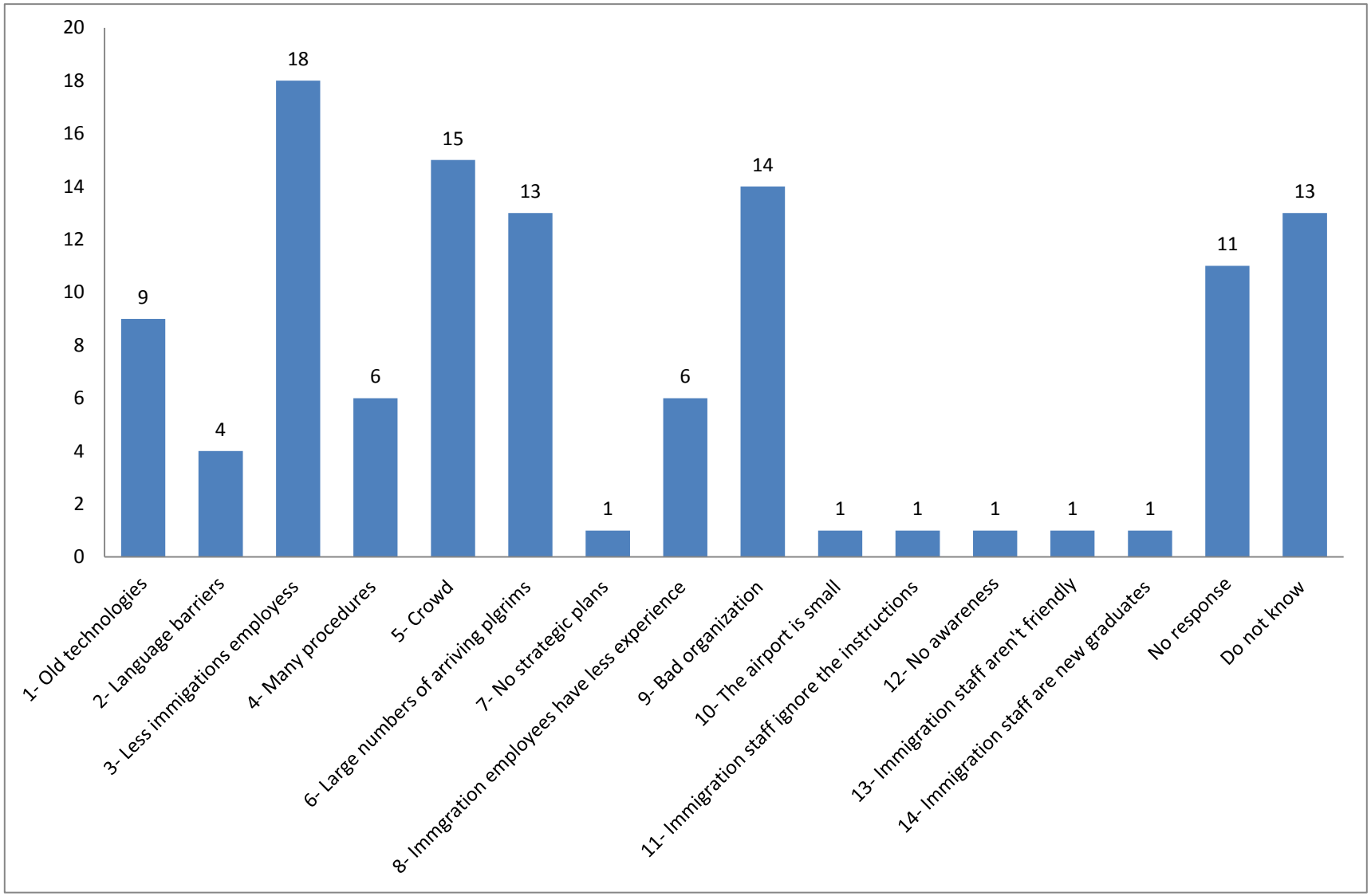
---

68. What are the reasons of not executing any infrastructure projects other ritual place (Arafat & Muzdalifah)?

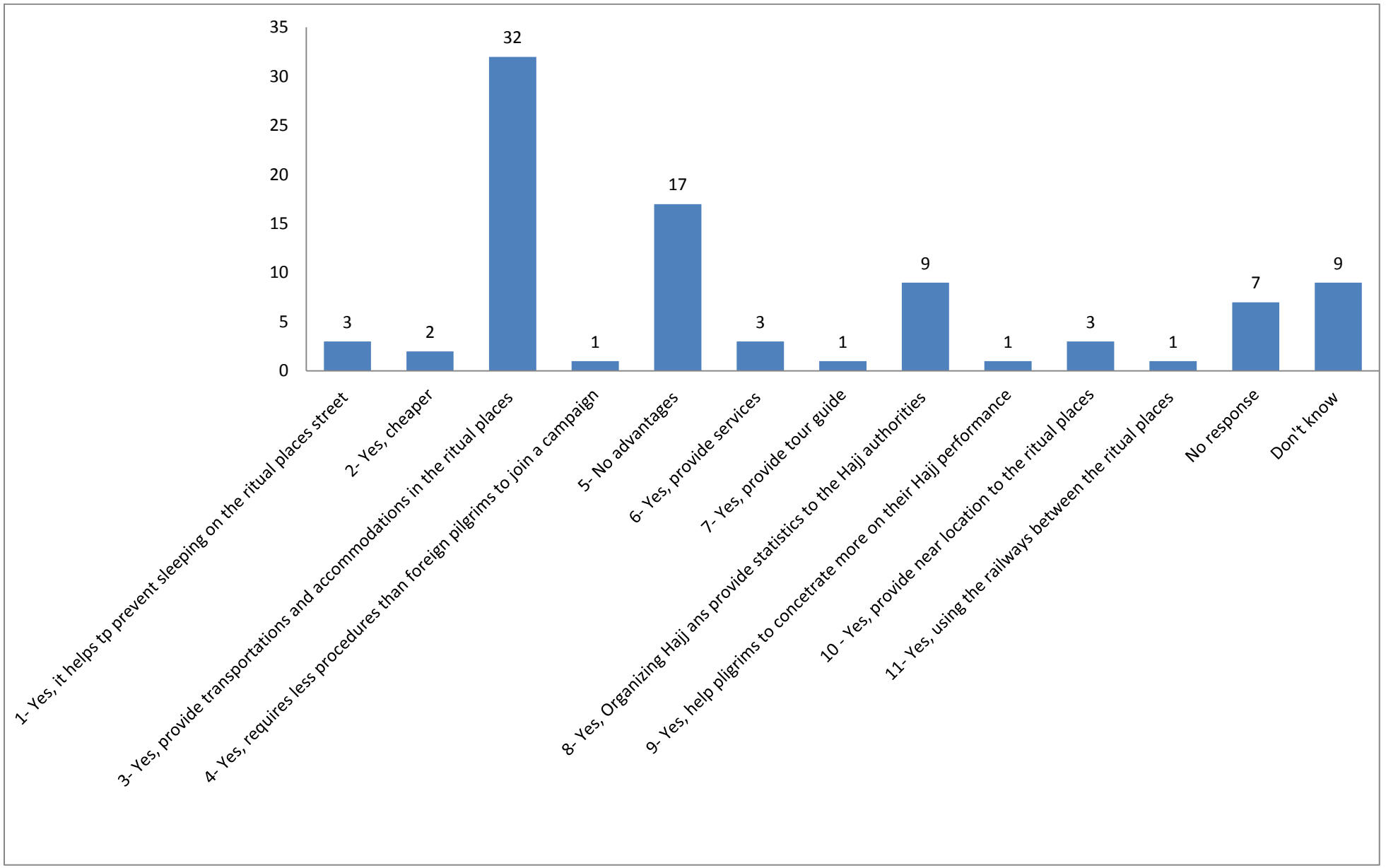
Any other comments on improving Hajj management:

-Thank you for completing this questionnaire -

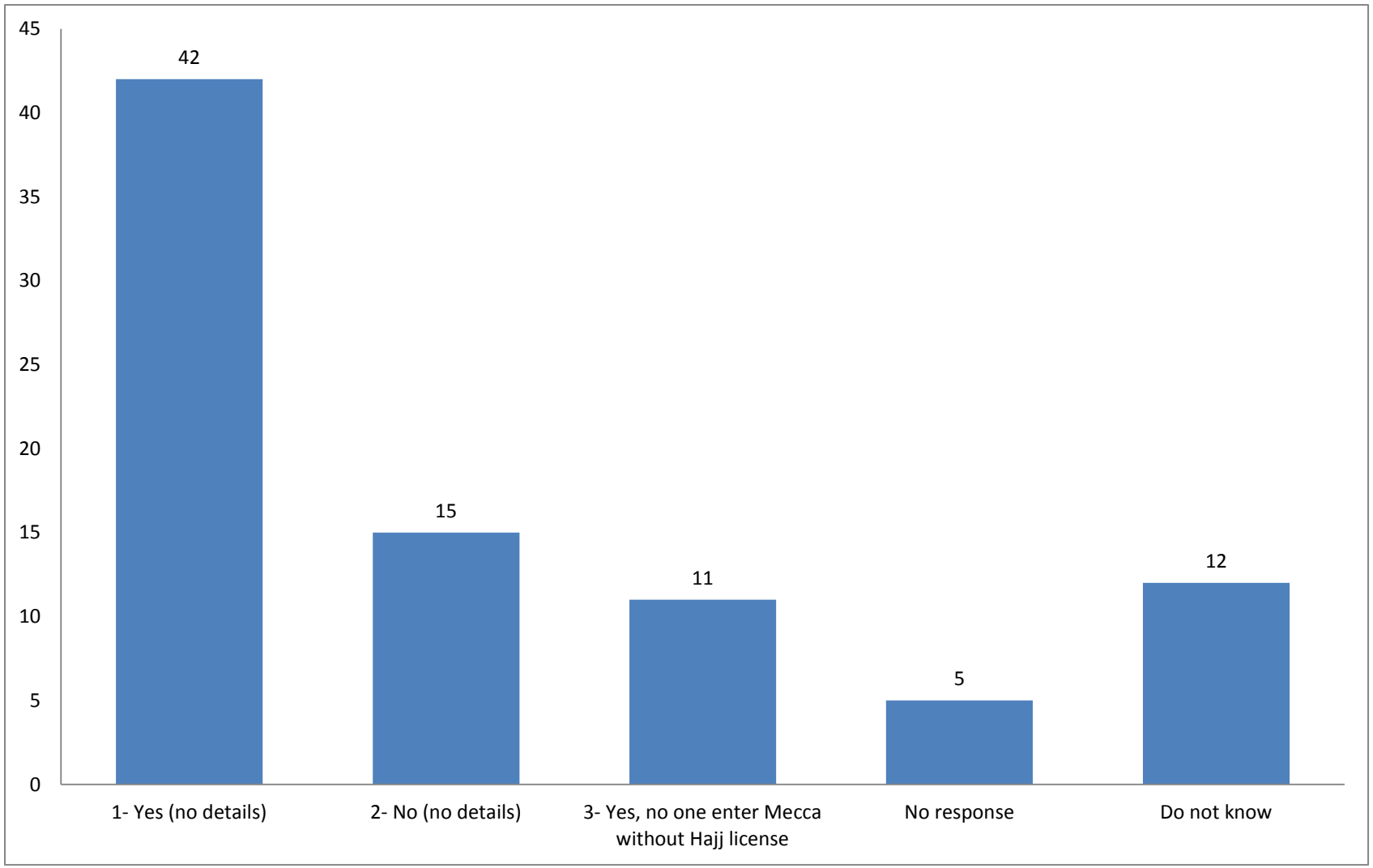
Section1. Q.5 If immigration procedures in airports and other gateways are slow, then what are the reasons?



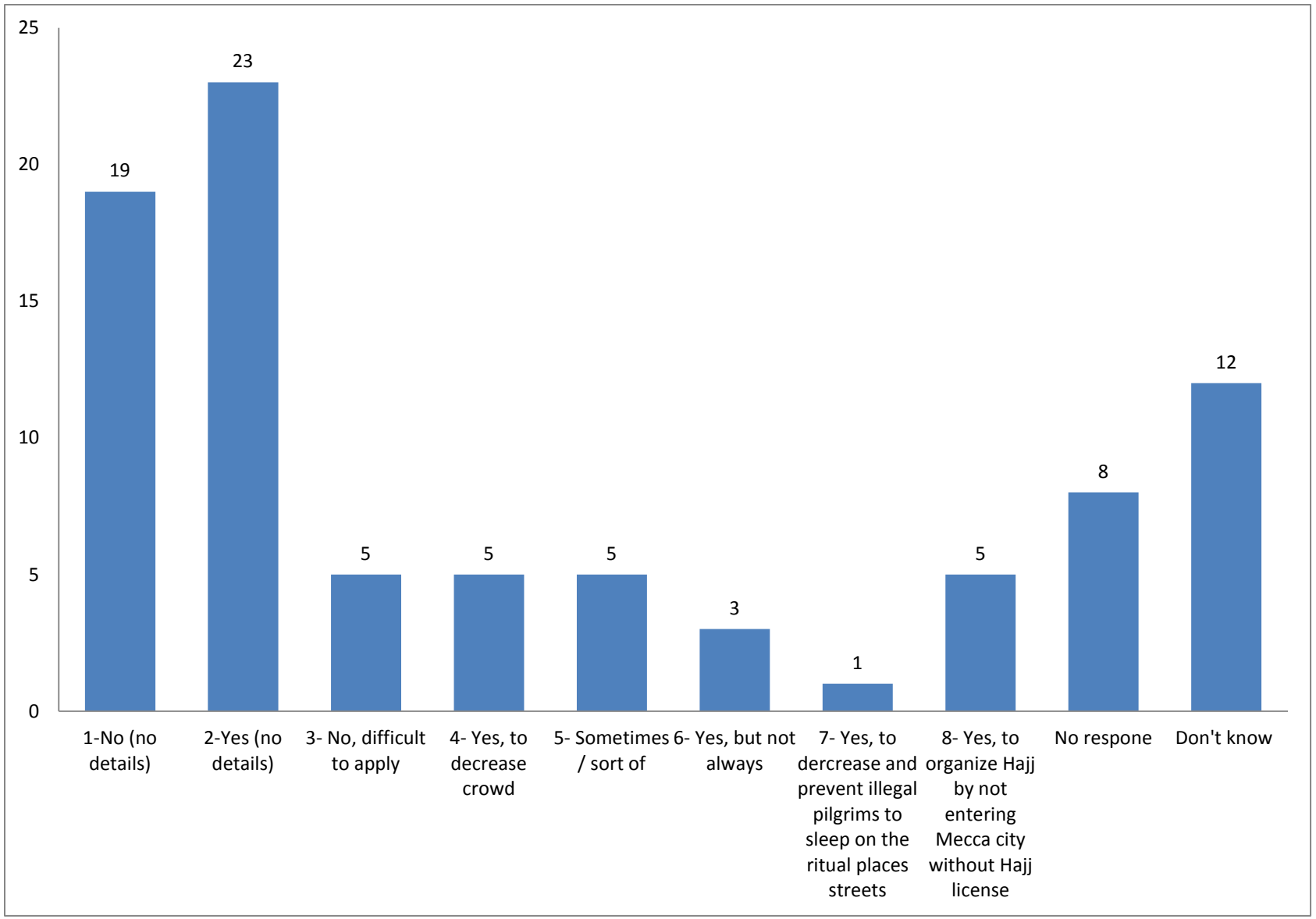
Q.6 Are there advantages for local pilgrims to perform Hajj by joining any Hajj campaign? What are they?



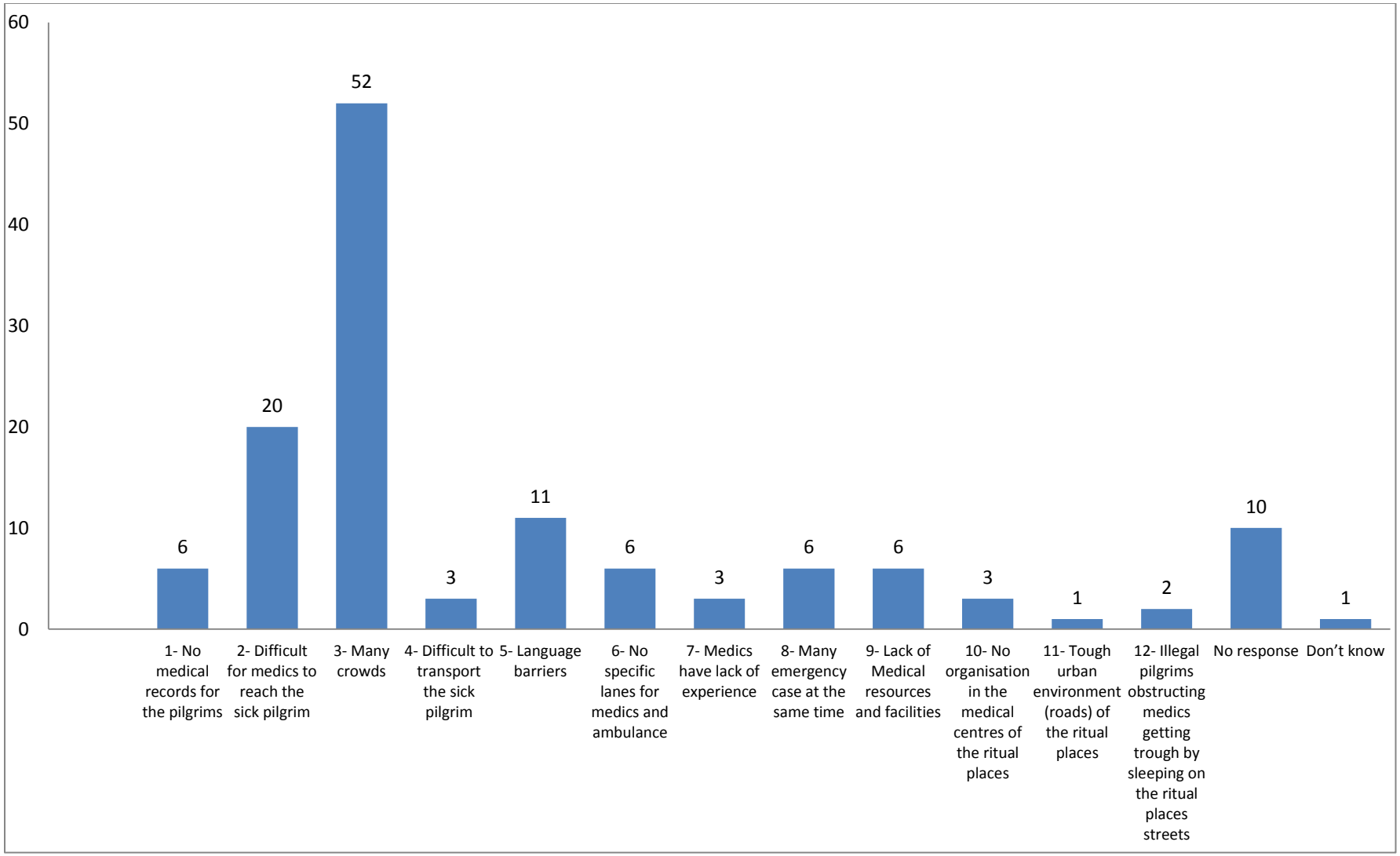
Q.7 Do you think there are regulations requiring local pilgrims to join any Hajj campaign?



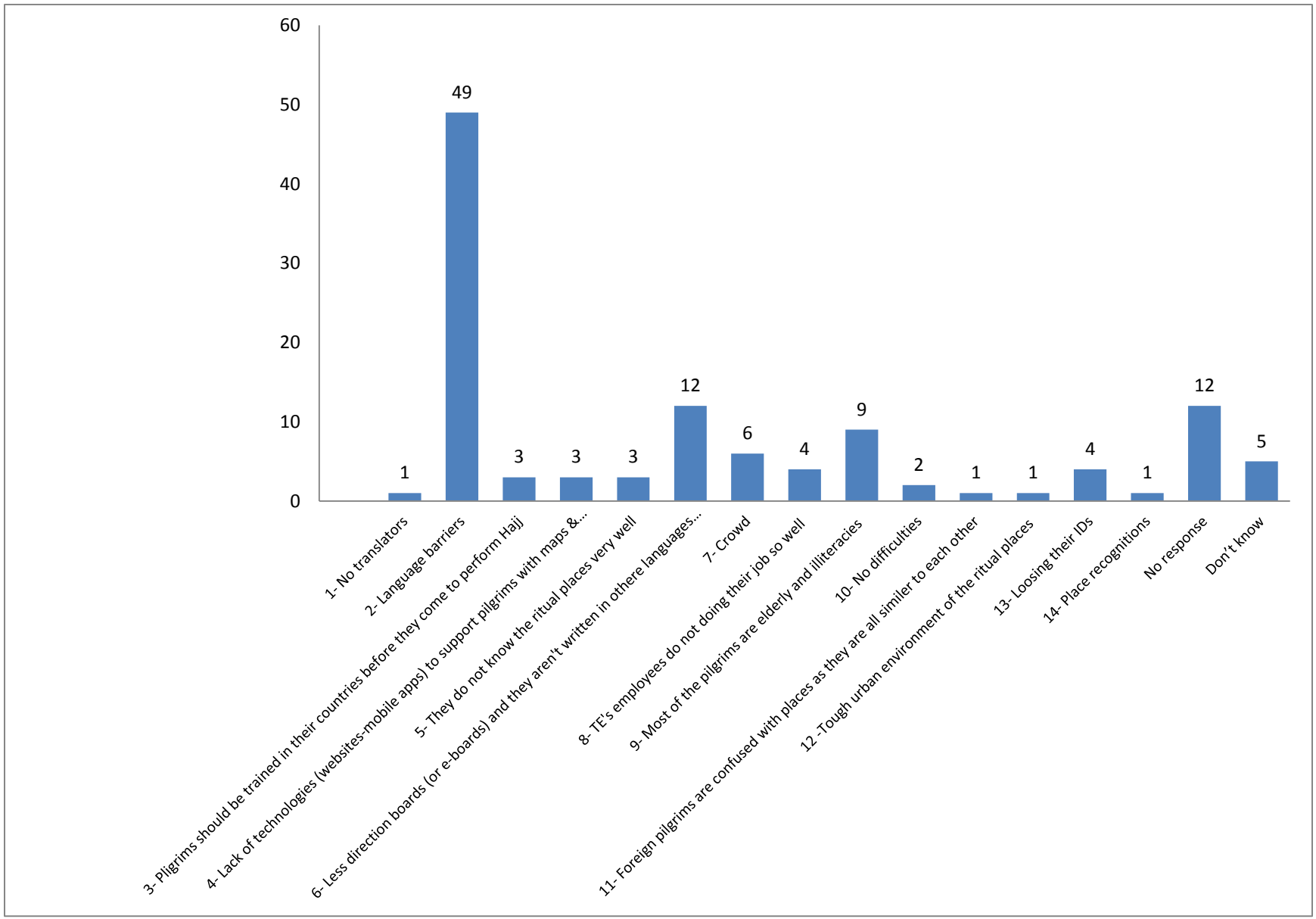
Q.8Do you think these regulations are applied? Why?



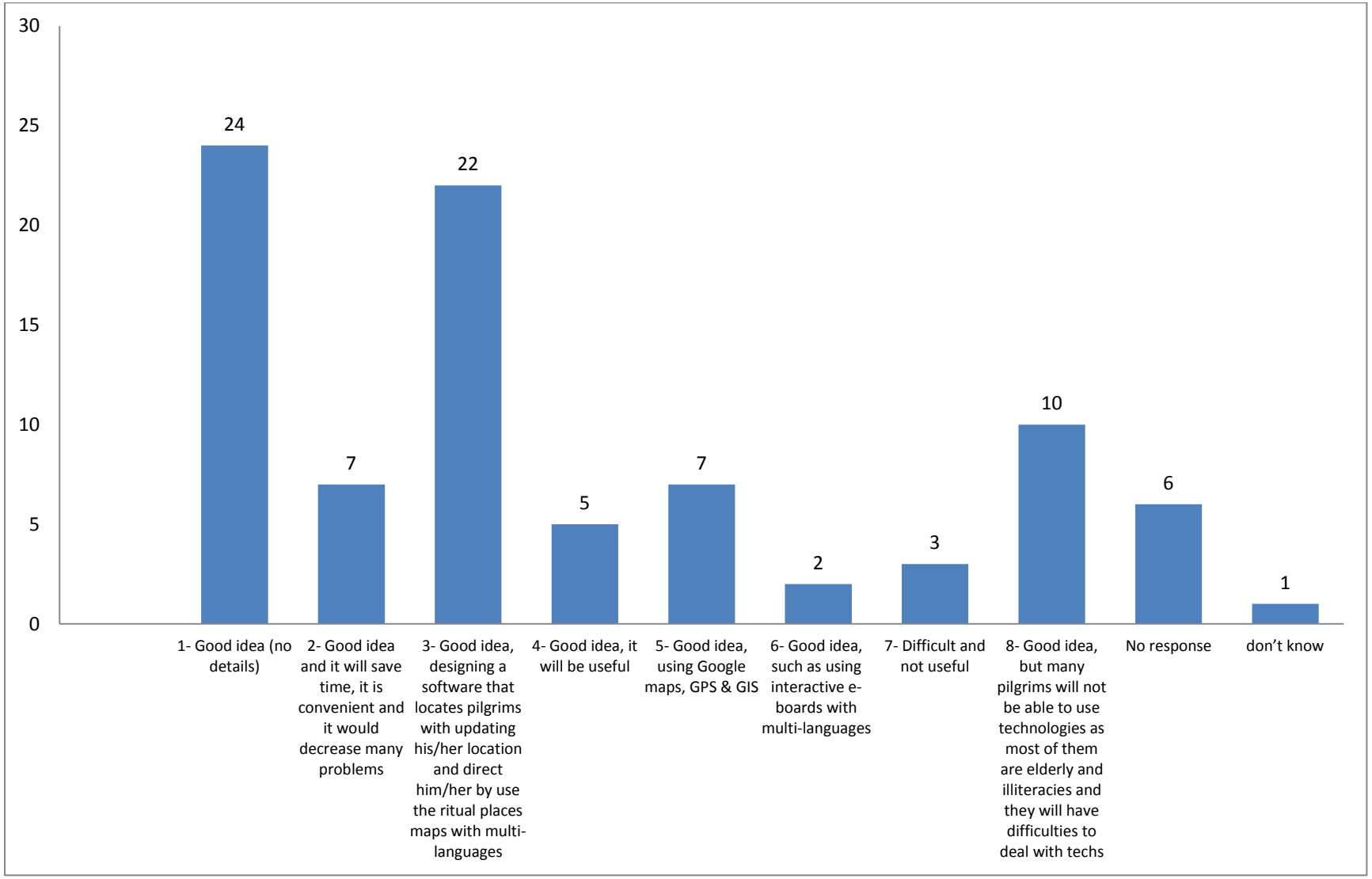
Section 2. Q.14 what are the difficulties that face medics in Medical Emergencies in Hajj seasons?



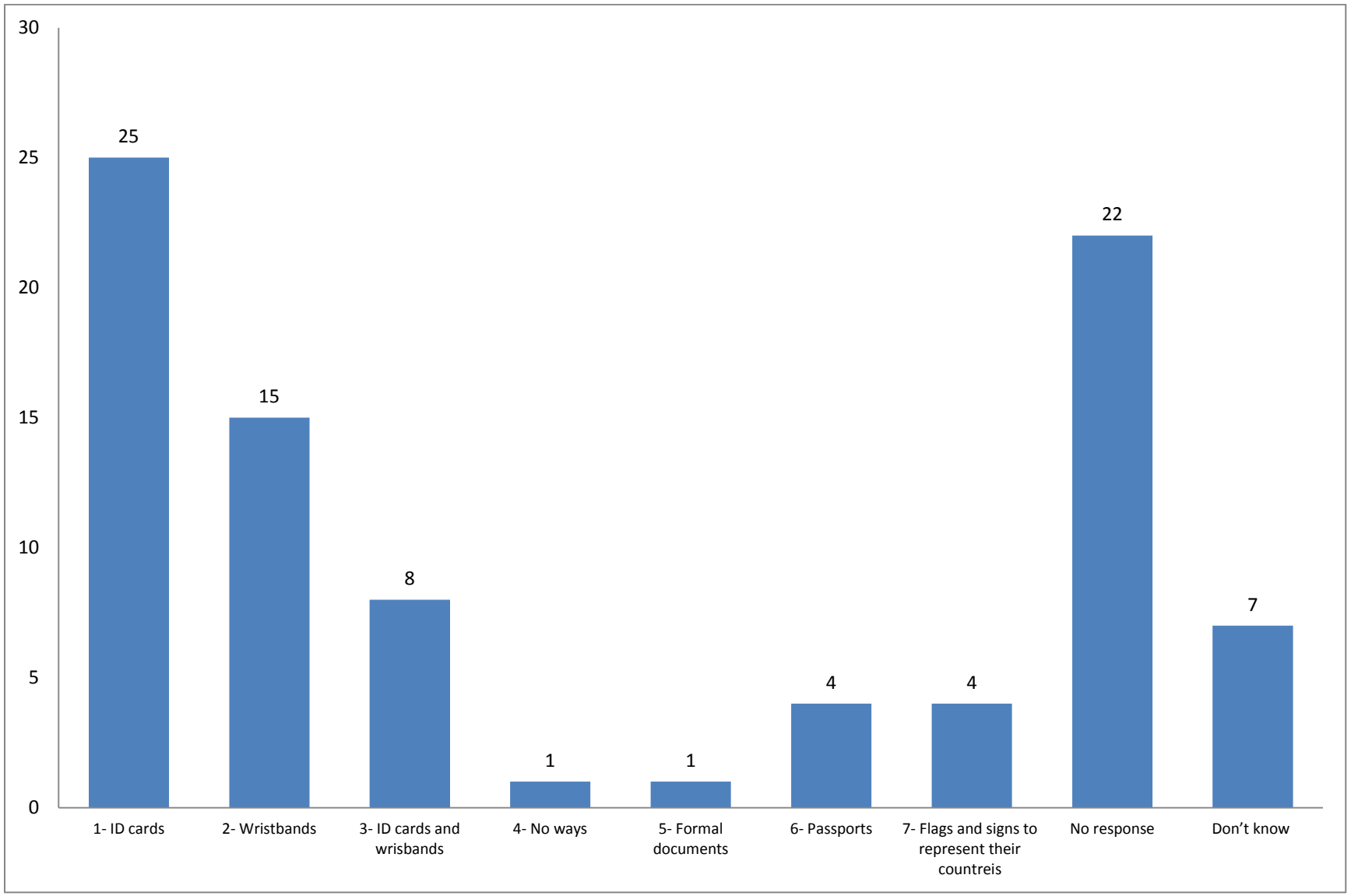
Section.3 Q.21 What are the difficulties that face foreign pilgrims to get directions or guidance?



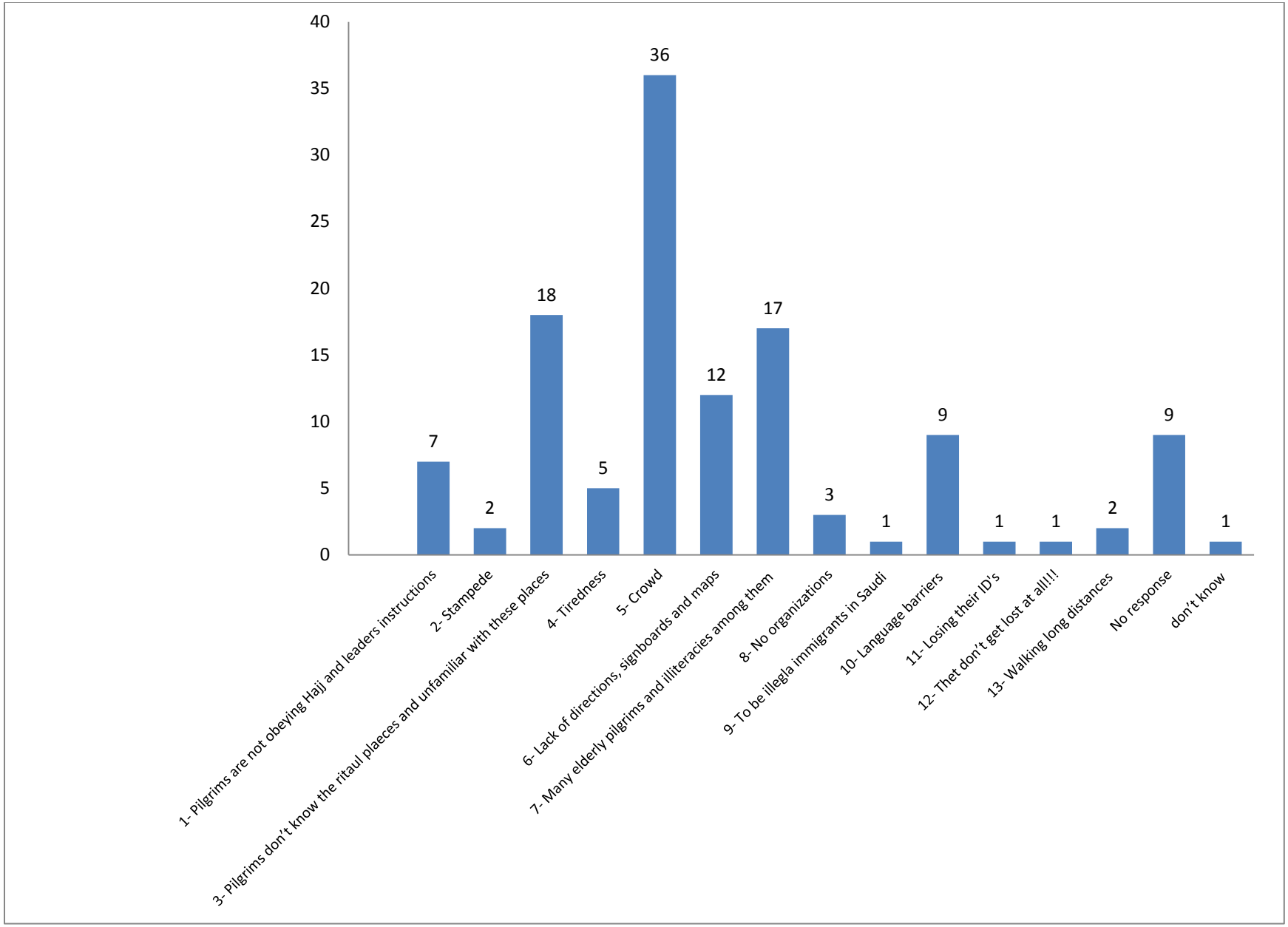
Q22. What do you thing about using Information and Communication Technologies (ICT's) such as mobile phones, laptops, or tab devices in guiding and directing pilgrims? Could you explain your answer?



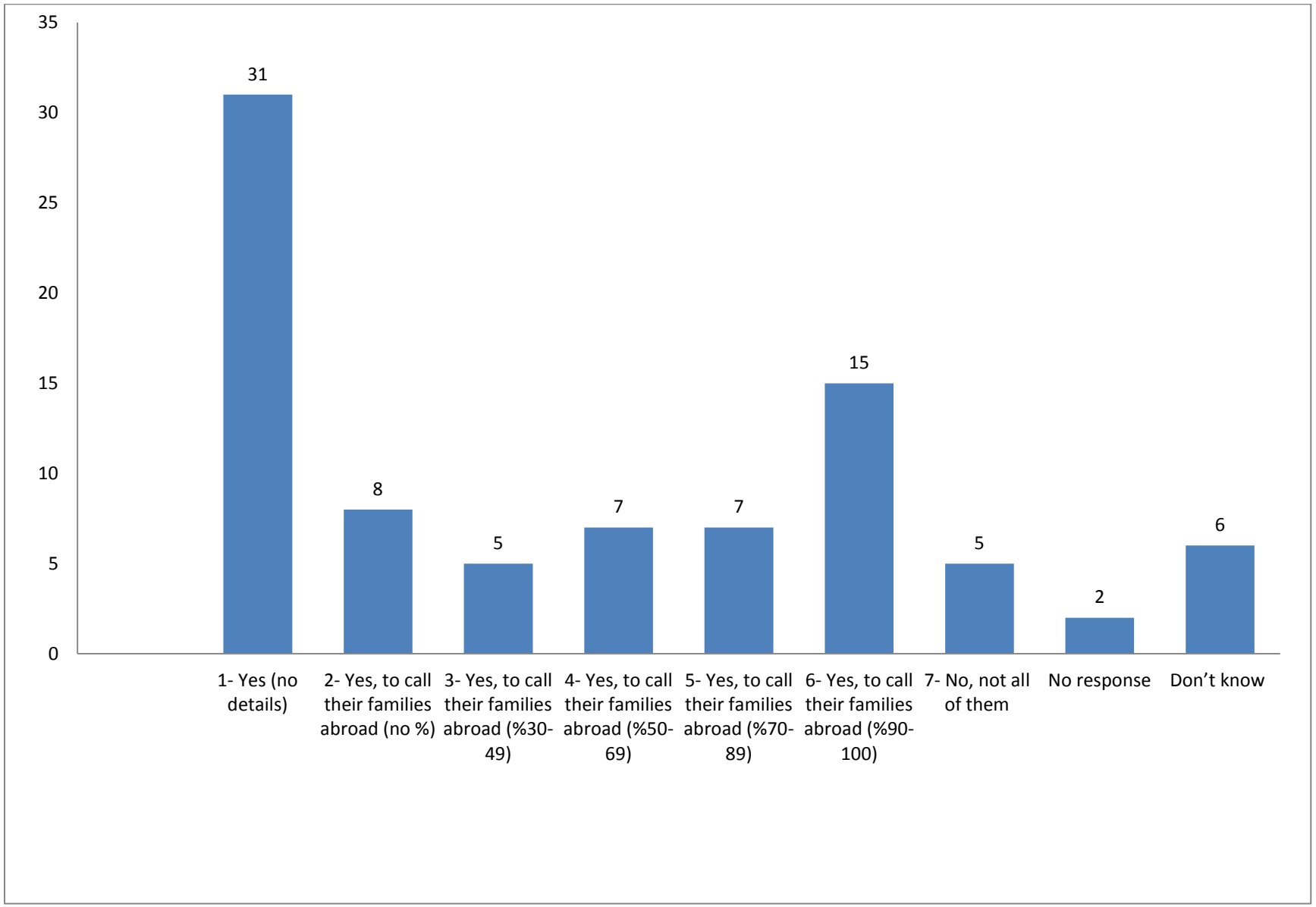
Section 4. Q28. What are the common methods that identify pilgrims in Hajj season?



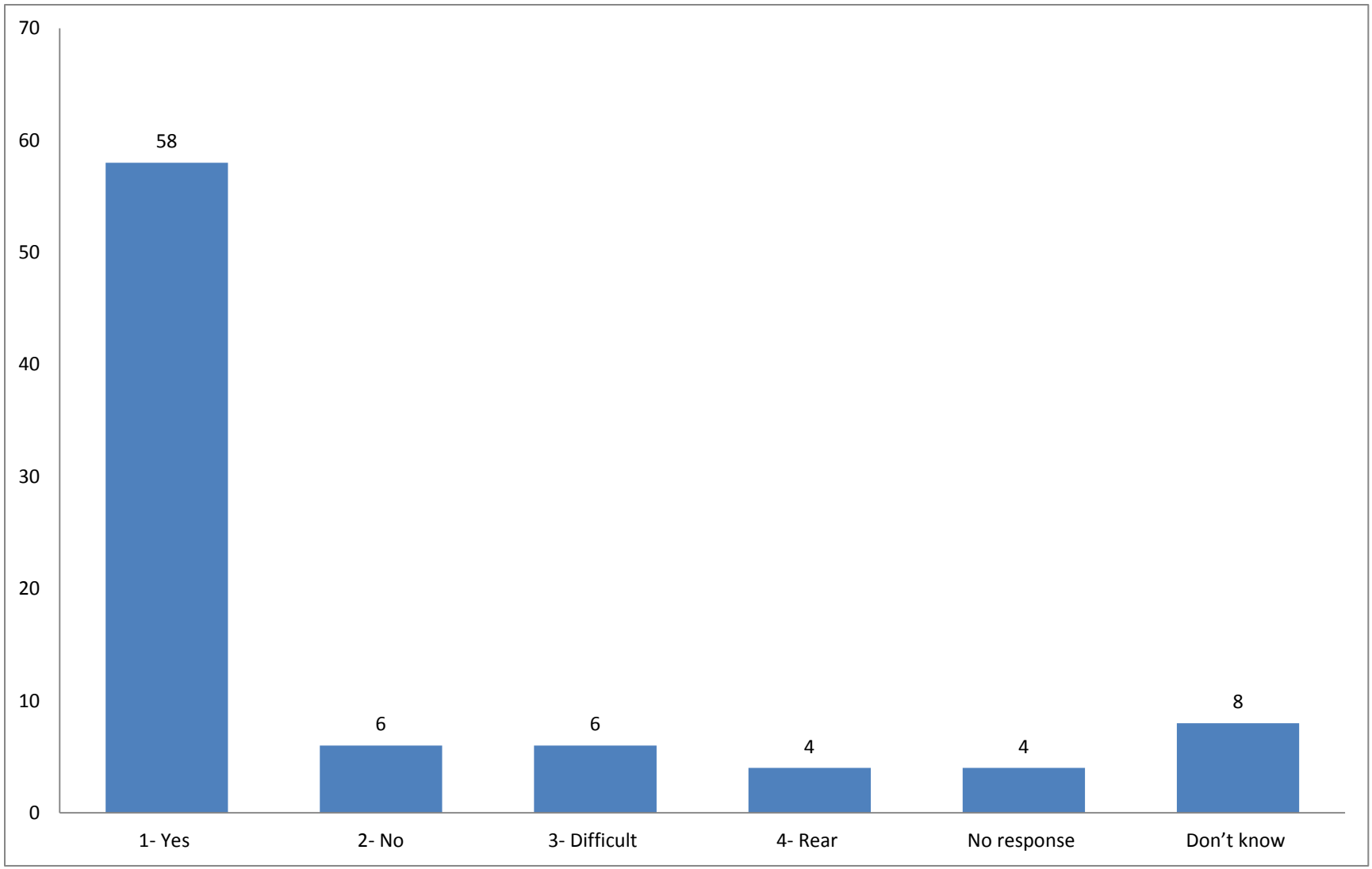
Q29. Could you explain why some of the pilgrims get lost in Hajj seasons?



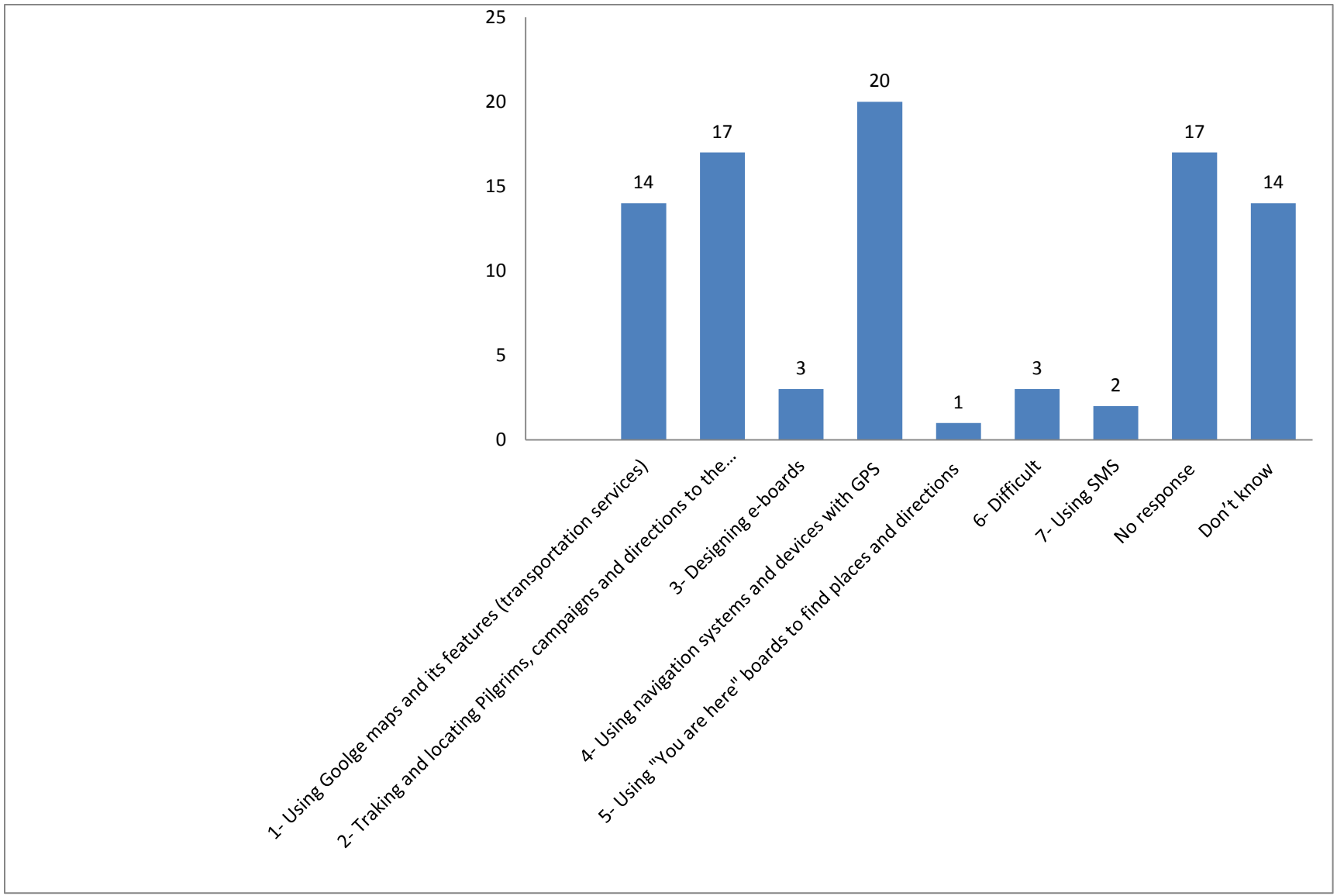
Q.30 Do pilgrims carry with them mobile phones or other communication devices in Hajj? What are they commonly used for? What are the percentage of those pilgrims how are using these devices?



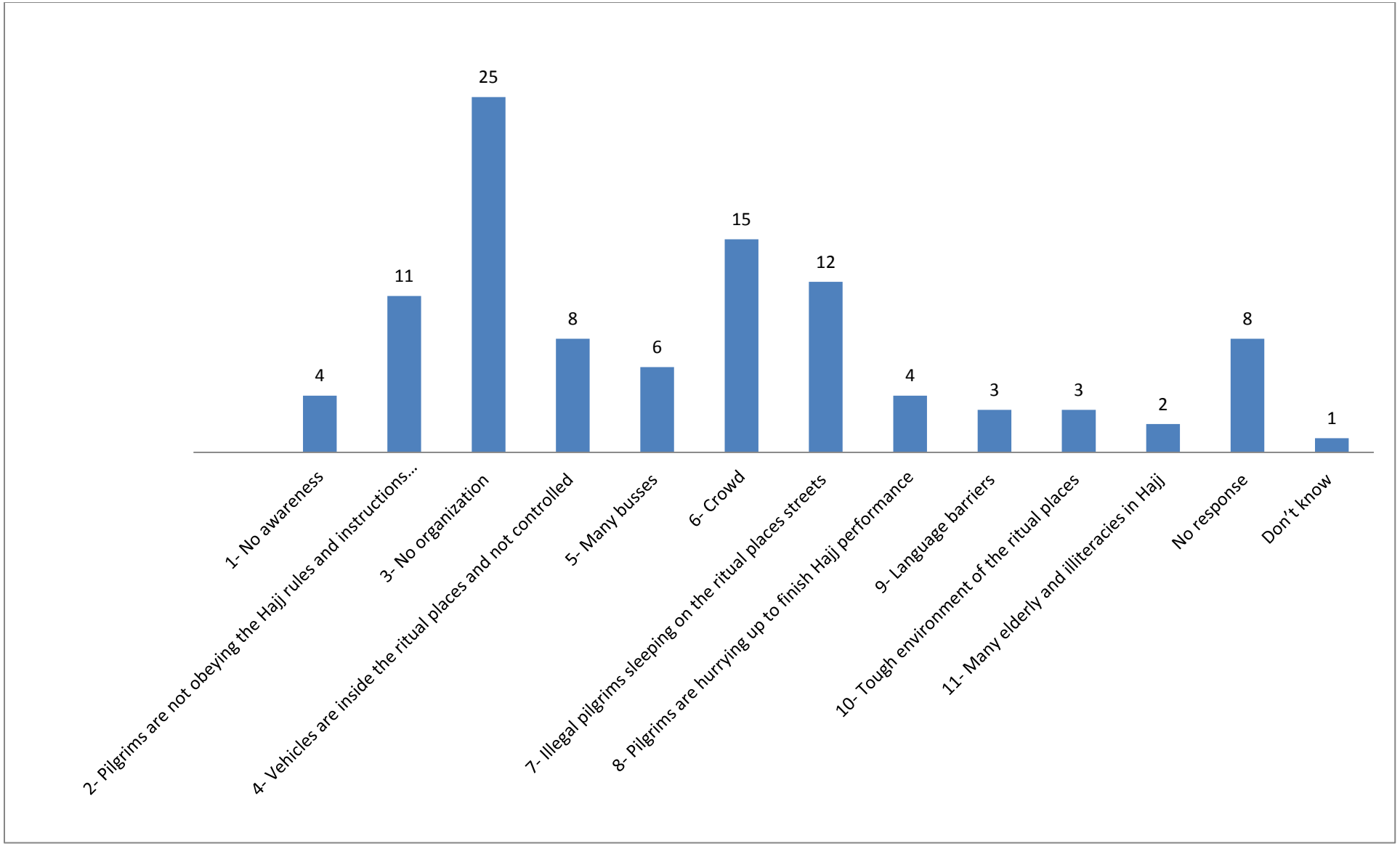
Q31. Could these devices be charged or plugged to the electricity in the Hajj ritual places?



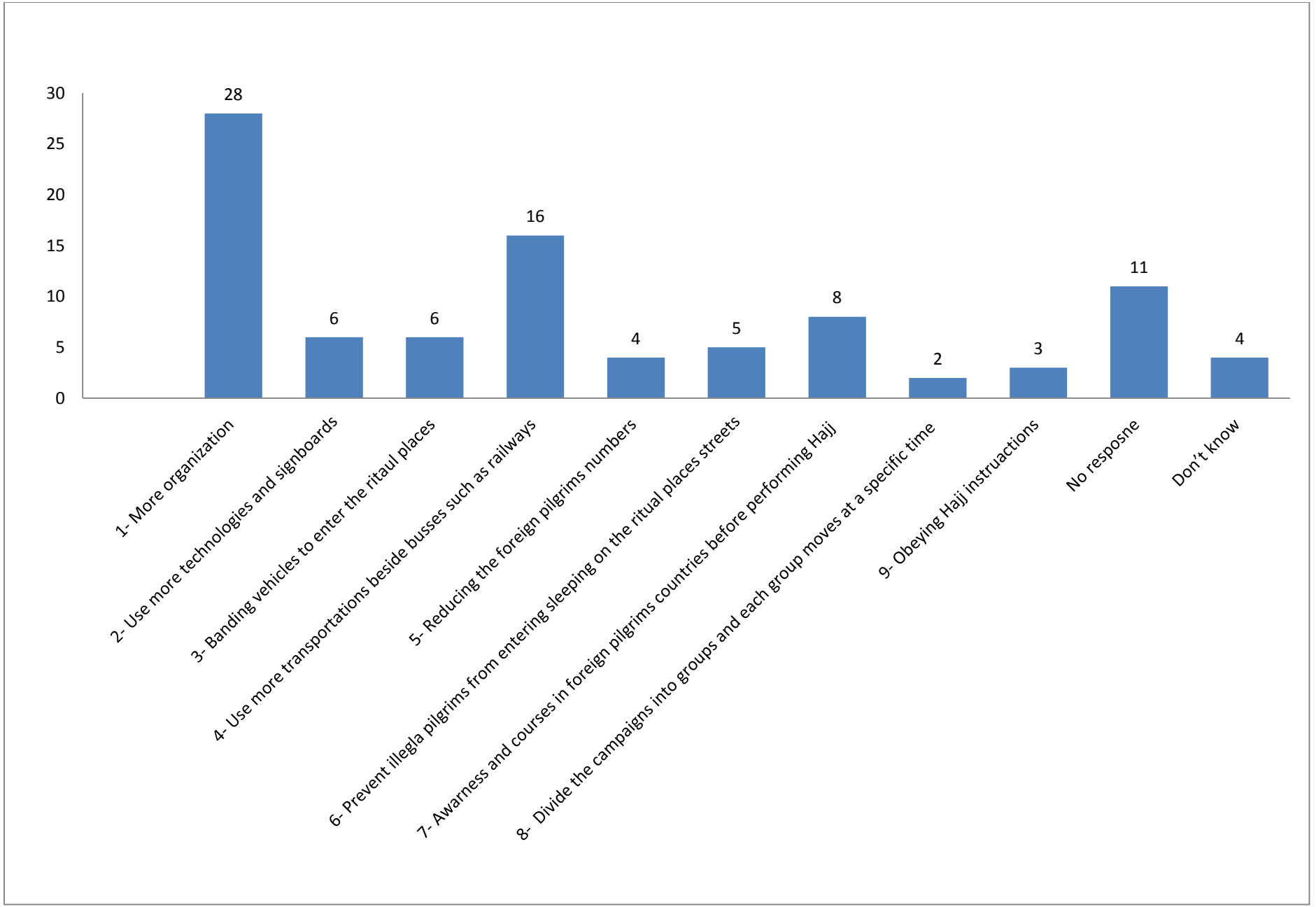
Q32. If any technology is applied e.g. mobile phone or tab devices how it could solve the problem of lost pilgrims?



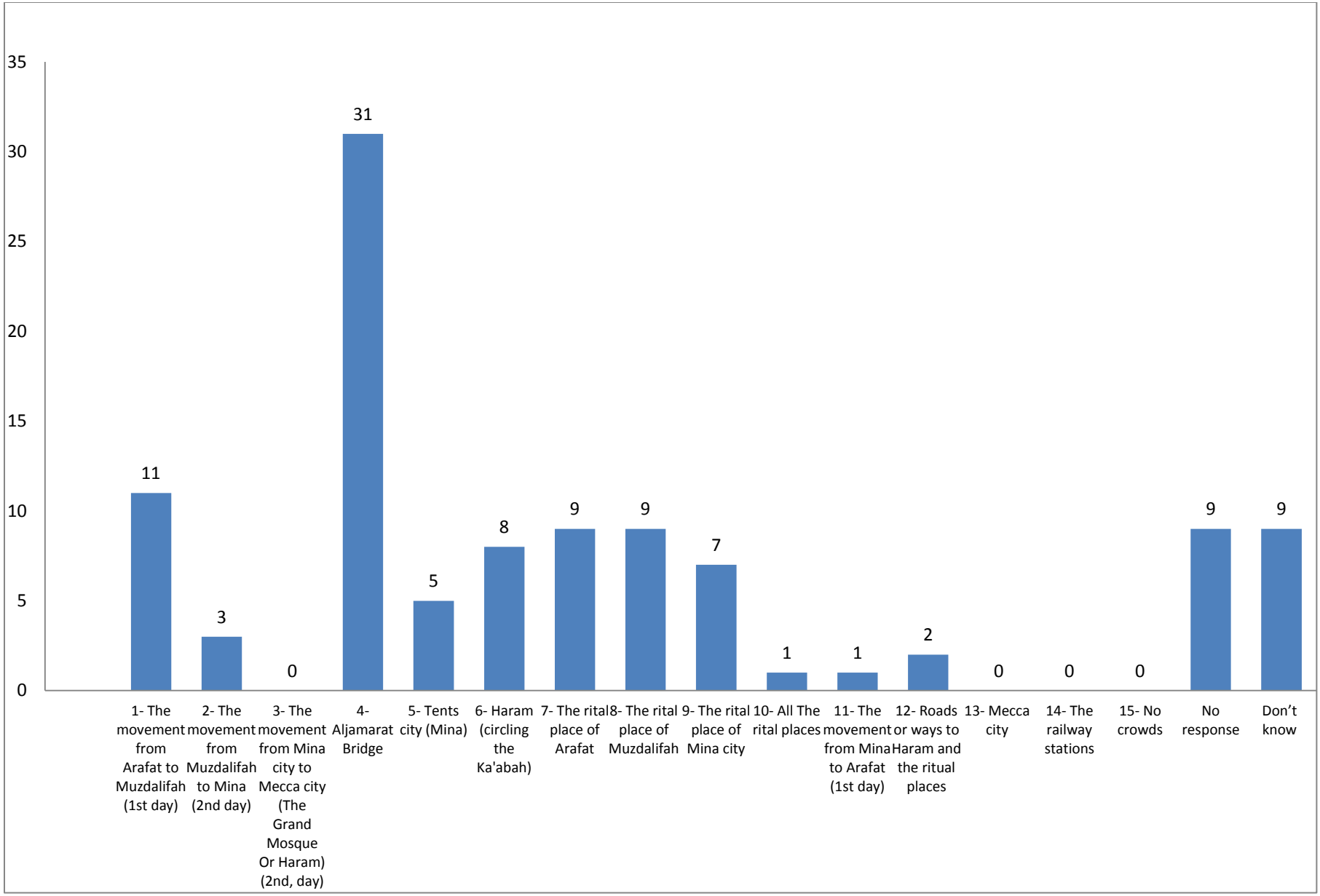
Section 5. Q38. Could you list some problems of congestions in Hajj?



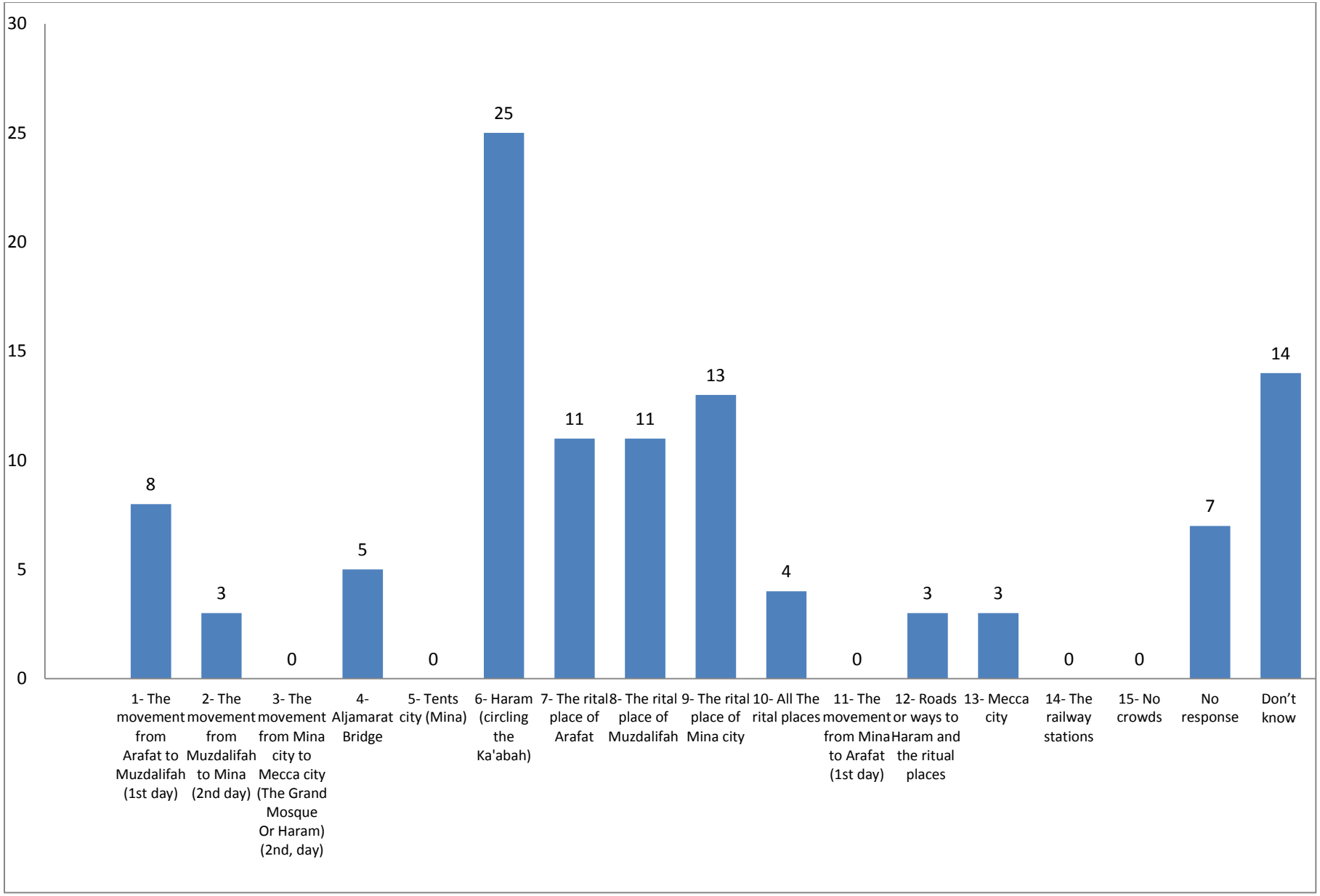
Q.39 What are your suggestions for solving congestions problems in Hajj?



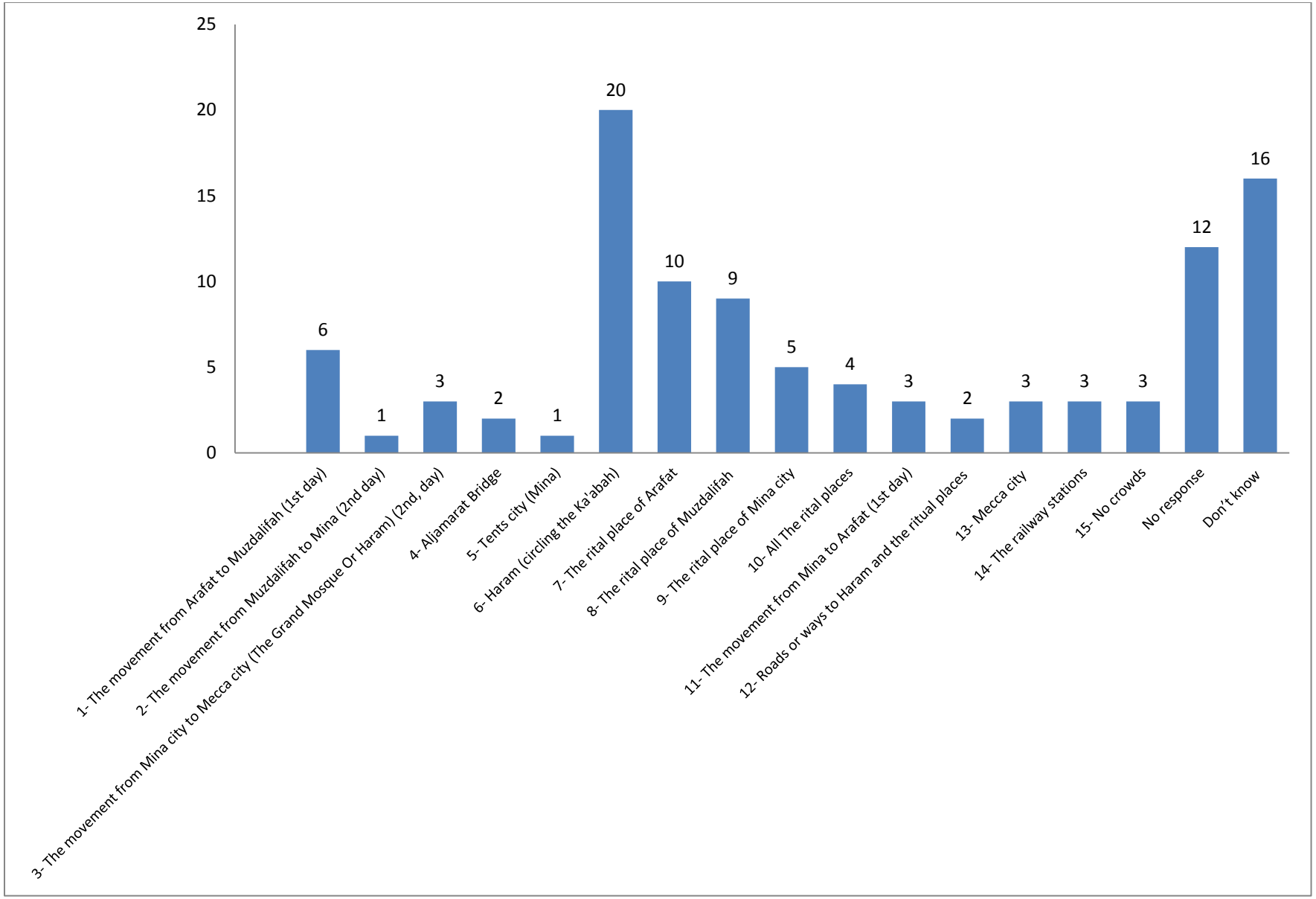
Section 6. Q46. Which place(s) was/were dangerously crowded in the past?



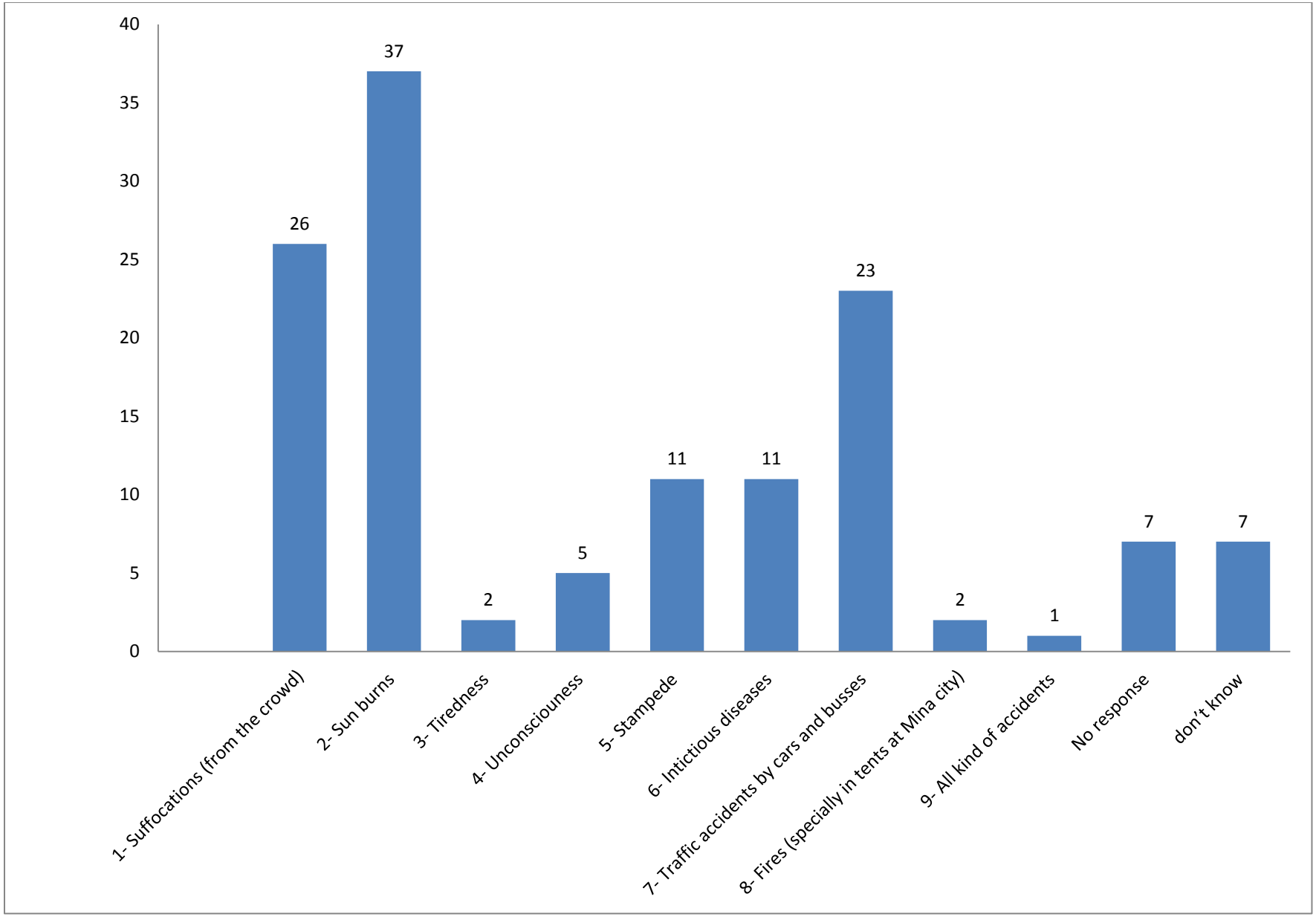
Q47. Which place(s) is crowded in present?



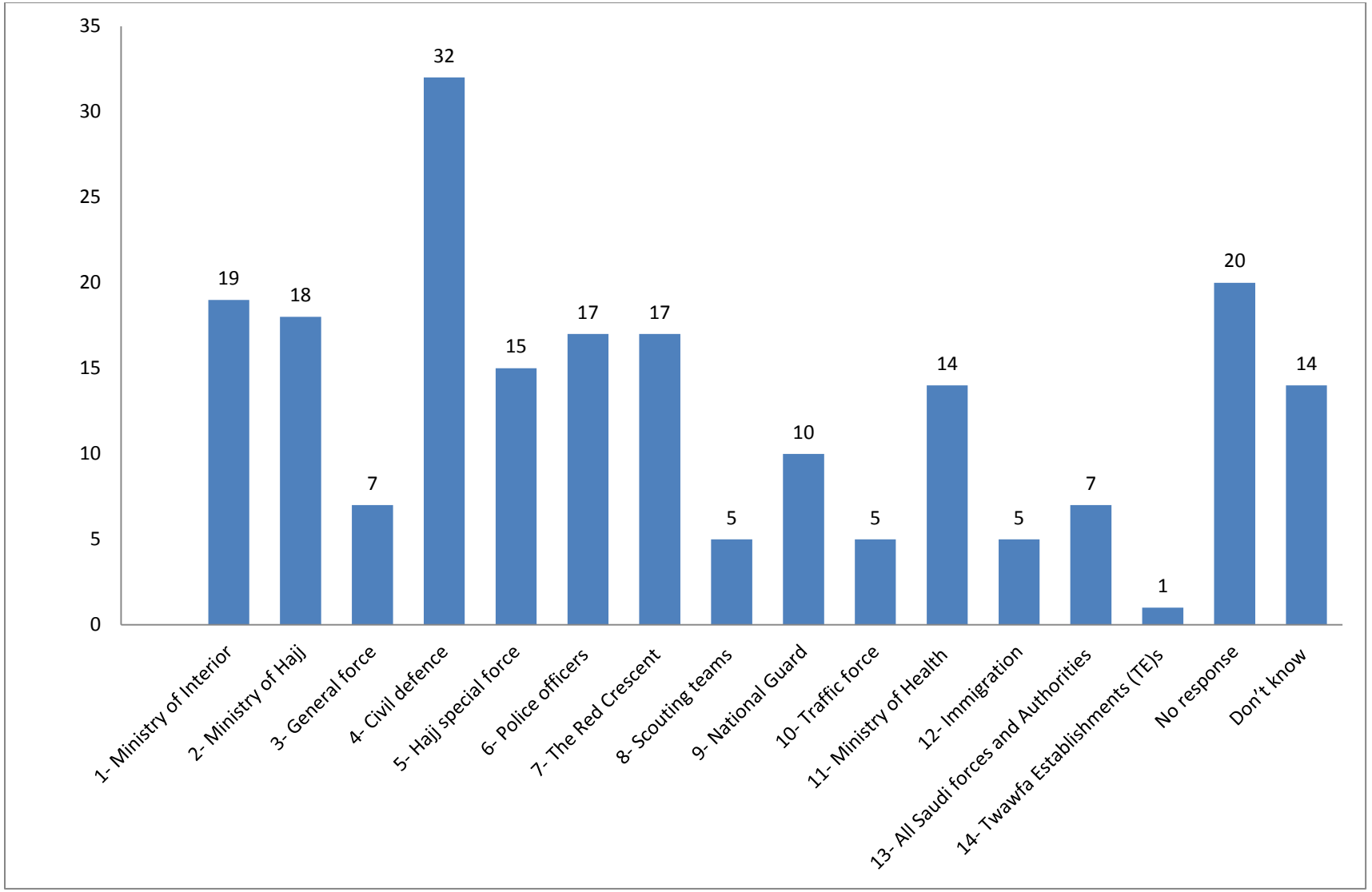
Q48. Which place(s) will expect to be crowded in the future?



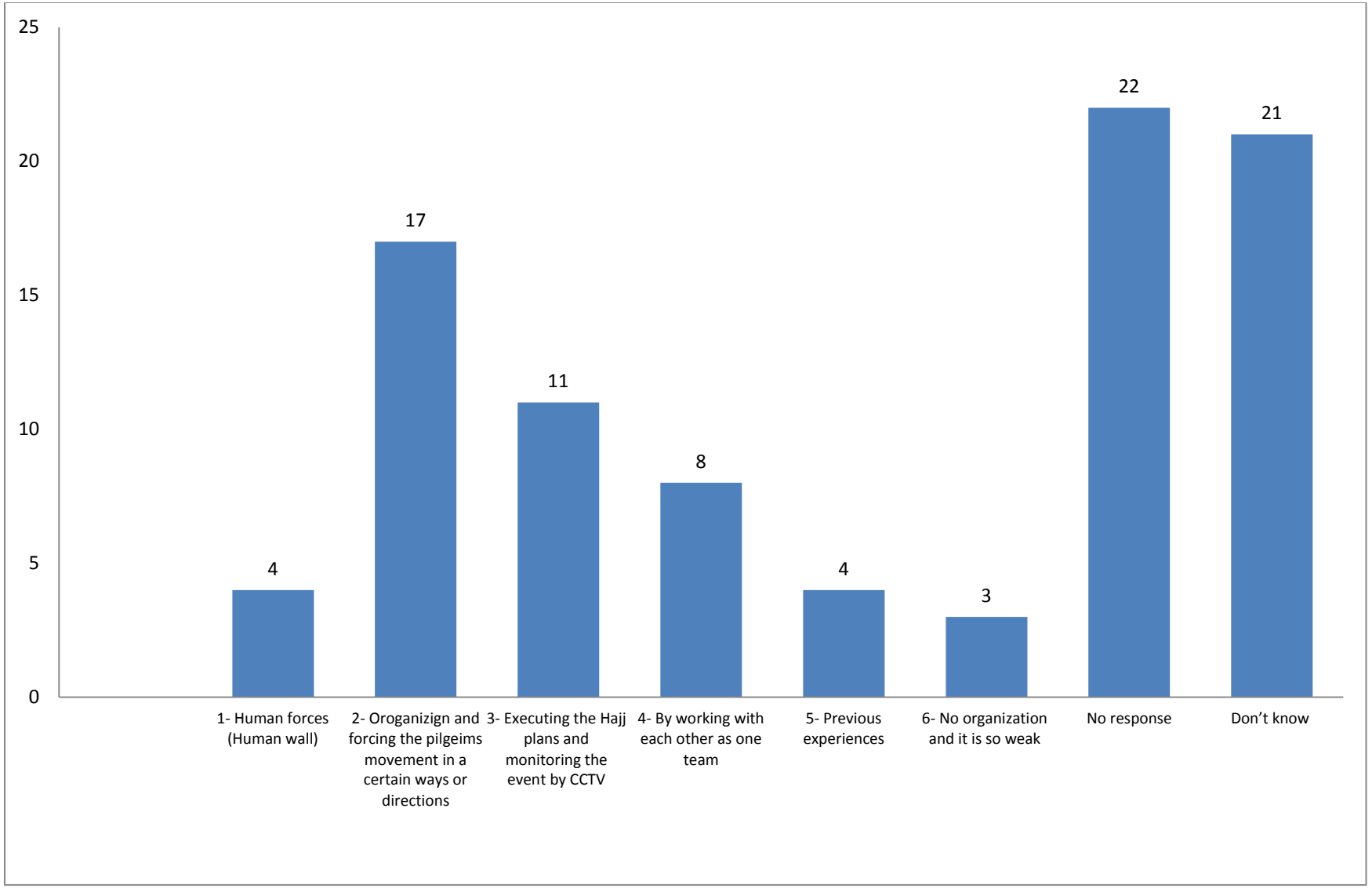
Q49. What kind of incidents that pilgrims could face them in Hajj season?



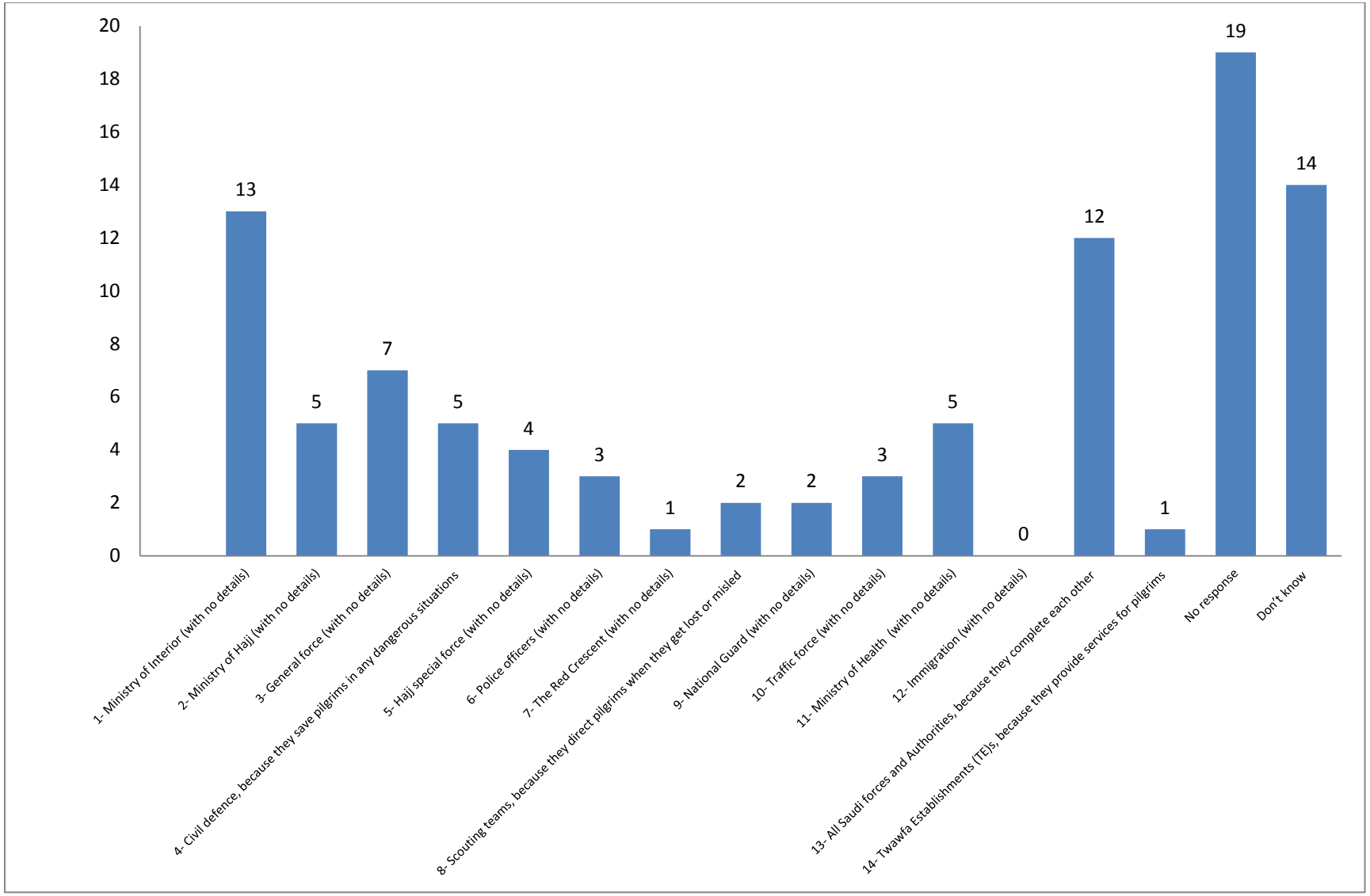
Section 7. Q50. Could you list the Saudi authorities and forces, which participate in Hajj season?



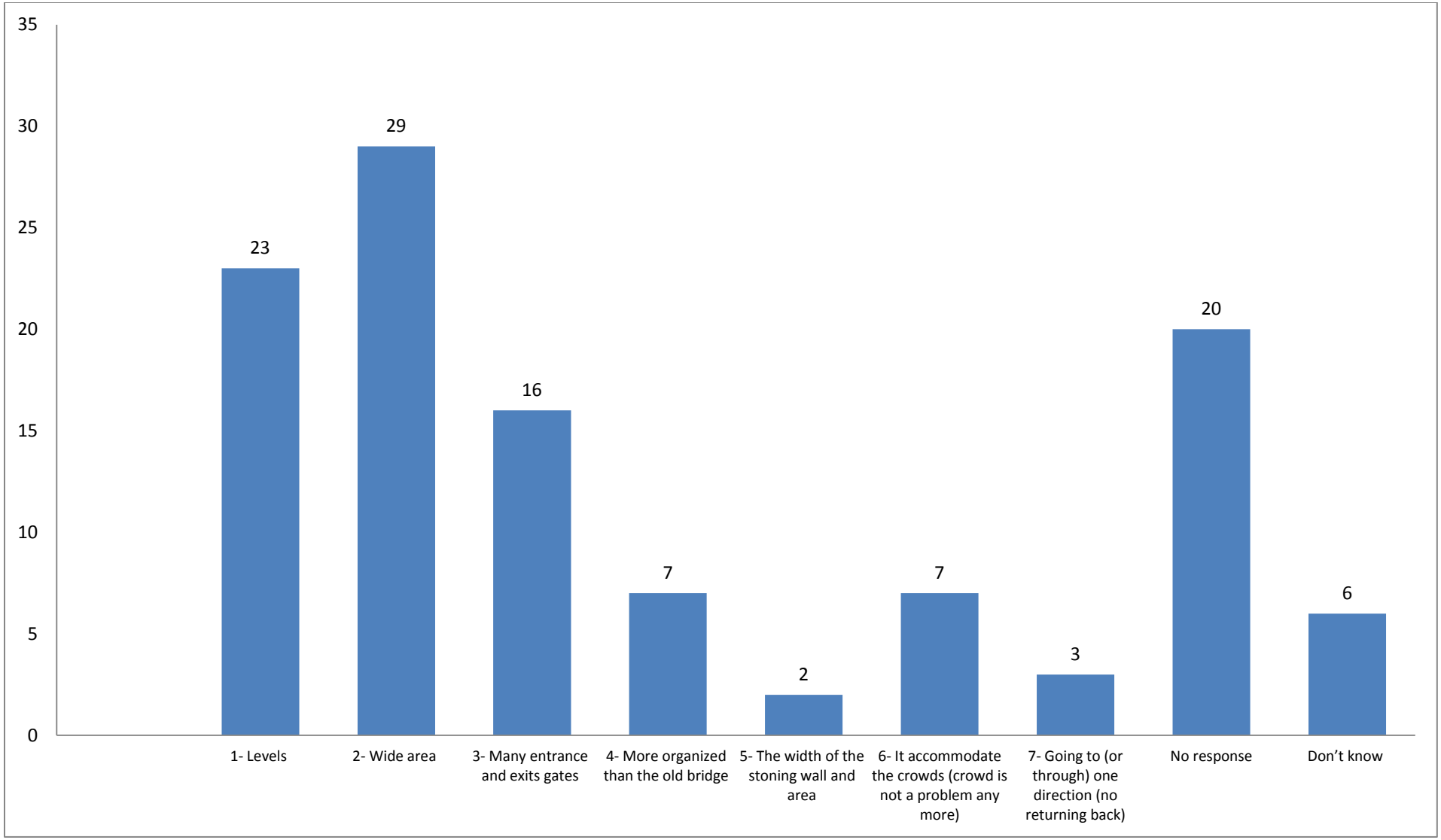
Q56. How Saudi authorities deal with crowd pilgrims and organize them?



Q57. Which authority is the most efficient in Hajj? Why?



Section 8. Q63. Could you explain the features of the new Jamarat Bridge?



Q64. What are the reasons of not executing any infrastructure projects other ritual place (Arafat & Muzdalifah)?