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A STUDY ON DETERMINANTS OF RFID ADOPTION INTENTION AMONG HAJJ ORGANIZERS IN INDONESIA AND MALAYSIA AND ITS STRATEGIC INFORMATION SYSTEMS PLAN

ABDULLAH HUSSEIN AHMED AL-HASHEDI

UNIVERSITI SAINS MALAYSIA

2013

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by

ABDULLAH HUSSEIN AHMED AL-HASHEDI

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LIST OF ABBREVIATIONS

A	Attitude toward behavior
BI	Behavioral Intention
BSP	Business Systems Planning
CFA	Confirmatory Factor Analysis
CSF	Critical Success Factor
DOI	Diffusion of Innovation
EFA	Exploratory Factor Analysis
EOU	Ease of Use
EPC	Electronic Product Code
EPCIS	EPC Information Services
ICT	Information and Communications Technologies
IE	Information Engineering
IS	Information Systems
IT	Information Technology
KMO	Kaiser-Meyer-Olkin
KSA	Kingdom of Saudi Arabia
ONS	Object Naming Service
RFID	Radio Frequency Identification
RM	Malaysian Ringgit
SCM	Supply Chain Management
SISP	Strategic Information Systems Planning
SN	Subjective Norms
SSP	Strategic Systems Planning
TAM	Technology Acceptance Model
TOE	Technology-Organization-Environment
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action

U	Perceived Usefullness
WORM	Write Once – Read Many

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KAJIAN TERHADAP UNSUR-UNSUR PENENTU DALAM PENERIMAAN HASRAT MENGADAPTASI RFID DALAM KALANGAN PENGELOLA HAJI INDONESIA DAN MALAYSIA DAN PELAN STRATEGIK SISTEM MAKLUMATNYA

ABSTRAK

Setiap tahun, berjuta orang Islam pergi ke Mekah untuk menunaikan Haji. Aktiviti pengurusan haji merupakan tugas yang kompleks bagi pihak berkuasa Arab Saudi dan penganjur Haji kerana bilangan jemaah yang ramai, kawasan georgrafi yang terhad untuk pergerakan jemaah, dan masa mengerjakan Haji yang singkat. Teknologi Pengenalan Frekuensi Radio (RFID) boleh digunakan untuk menyelesaikan masalah dan kesukaran yang timbul semasa musim Haji. Bagaimanapun, sebagai teknologi baru, kegunaan RFID dalam pengurusan haji belum lagi diselidiki sehingga kini. Kajian ini membangunkan satu model teori bagi penerimaan hasrat mengadaptasi RFID untuk penganjur haji dengan menggunakan kerangka teknologi – organisasi – persekitaran. Tujuh pemboleh ubah bebas (kelebihan relatif, kesesuaian, kerumitan, sokongan pengurusan tertinggi, saiz organisasi, sokongan kerajaan dan kesanggupan berkerjasama antara pengelola Haji) dan satu pemboleh ubah penyerdanana (kesediaan organisasi) dicadangkan untuk membantu meramal hasrat mengadaptasi RFID. Pemboleh ubah kesanggupan berkerjasama antara pengelola Haji dan pemboleh ubah kesediaan organisasi bertujuan membantu meramal hasrat mengadaptasi RFID. Pemboleh ubah kesanggupan berkerjasama antara pengelola Haji yang telah diabaikan dalam kajian Sistem Maklumat terdahulu juga telah disertakan dalam kajian ini sebagai faktor penting bagi konteks persekitaran. Kajian ini menguji secara empirikal model cadangan dengan menggunakan saiz sampel organisasi Haji yang mencukupi. Data yang dikumpul daripada 165 penganjur Haji berasal dari Indonesia and Malaysia dan

penyedia perkhidmatan Haji di Arab Saudi diuji ke atas model kajian yang dicadangkan menggunakan regresi berhierarki. Hasil kajian menunjukkan bahawa konteks teknologi (kelebihan relatif, kerumitan), konteks organisasi (sokongan pengurusan tertinggi), dan konteks persekitaran (kesanggupan berkerjasama antara pengelola Haji) mempunyai pengaruh yang signifikant ke atas hasrat mengadaptasi RFID. Di samping itu, kesediaan organisasi (teknologi dan kewangan) sedikit sebanyak memberi kesan kepada hubungan antara pemboleh ubah bebas dan tidak bebas. Keputusan dan implikasi dalam kajian ini meningkatkan kesedaran tentang faktor yang mempengaruhi hasrat mengadaptasi RFID oleh penganjur Haji. Berdasarkan keputusan tersebut, Pelan Sistem Maklumat Strategik dicadangkan bagi melaksanakan teknologi RFID dalam sistem pengurusan Haji. Pelan ini menghasilkan satu pandangan menyeluruh projek tersebut yang merangkumi organisasi Haji yang mungkin menggunakan fungsi yang hampir sama, menghasilkan data yang berulang atau menunjukkan keperluan perkongsian data atau sumber. Ini akan menghasilkan satu garis panduan dalam pelaksanaan teknologi RFID dalam pengurusan Haji.

A STUDY ON DETERMINANTS OF RFID ADOPTION INTENTION AMONG HAJJ ORGANIZERS IN INDONESIA AND MALAYSIA AND ITS STRATEGIC INFORMATION SYSTEMS PLAN

ABSTRACT

Every year, millions of Muslims go to Makkah to perform the Hajj (Pilgrimage). The management of Hajj activities is a very complex task for Saudi Arabian authorities and Hajj organizers because of the large number of pilgrims, the limited geographical area for pilgrim movement, and the short Hajj period. Radio frequency identification (RFID) technology can be used to provide good solutions for the problems and difficulties that arise during Hajj season. However, as an emerging technology, the use of RFID in Hajj management has not been investigated till date. This study develops a theoretical model for RFID adoption intention in Hajj organizations by using the technology–organization–environment framework. Seven independent variables (relative advantage, compatibility, complexity, top management support, organization size, government support, and willingness to collaborate among partners) and one moderator variable (organizational readiness) are proposed to help predict the RFID adoption intention. The variable of willingness to collaborate among partners, which has been ignored in previous Information Systems literature, is included in this study as an important factor in the environmental context. This study empirically tests the proposed model by using an adequate sample size of Hajj organizations. Data collected from 165 Hajj organizers from Indonesia and Malaysia and their Hajj service provider in Saudi Arabia are tested against the proposed research model using hierarchical regression. Results show that technological context (relative advantage, complexity), organizational context (top management support),

and environmental context (willingness to collaborate among partners) have significant influence on RFID adoption intention. Furthermore, organizational readiness (technological and financial) has a partially moderating effect on the relationship between independent variables and dependent variable. The results and implications included in the study provide increased awareness of the factors that influence RFID adoption intention by Hajj organizers. Based on the results, a Strategic Information Systems Planning to implement RFID technology in the Hajj management system is proposed. This plan produces an overall view of the project across Hajj organizations that may be performing similar functions, generating redundant data, or demonstrating a need to share data or resources. It will form a blueprint for Hajj management authorities and organizers on the adoption and implementation of RFID technology Hajj management.

CHAPTER 1

INTRODUCTION

1.1 Background

Hajj (Pilgrimage) is one of the five pillars of Islam. All able-bodied and financially fit Muslims are required to perform Hajj at least once in their lifetime. Hajj, which occurs yearly, is also considered the largest gathering of Muslims. Millions of Muslims from all over the world go to Makkah (Mecca) in the Kingdom of Saudi Arabia (KSA) to perform Hajj. Hajj authorities in Saudi Arabia are responsible for receiving, housing, serving, and maintaining the safety of pilgrims. The management of Hajj is a very complex task because of the huge number of pilgrims, the limited geographical area for pilgrim movement, and the short Hajj period.

1.2 Research Motivation

The difficulties during Hajj season are very significant. These difficulties include the huge number of pilgrims, short period of Hajj season, limited space for Hajj rituals, and consequent difficulties of pilgrim management. Furthermore, solving the problems of overcrowding and stampedes, loss of pilgrims, pilgrim identification, monitoring and tracking of pilgrim movements from one place to another, and difficulties facing healthcare authorities to provide good services as well the obstacles that hinder the delivery of services have made the situation more complicated. Therefore, solutions should be found for all these problems to mitigate their effects.

RFID is an emerging technology that can be used to identify, monitor, and track objects and people easily without a line of sight or physical contact between a tag and a reader. Applying this technology to the Hajj management system can

significantly improve the quality of the system and provide solutions for Hajj organizers to overcome their commonly encountered problems. RFID technology also provides numerous benefits for Hajj authorities and organizers. By adopting this technology, Hajj authorities and organizers can provide first-class service to pilgrims, reduce the difficulties and problems faced by pilgrims, and enhance the services provided for pilgrims.

Thus, investigating the key factors that may affect the adoption of RFID technology in the Hajj management system by Hajj organizations is necessary, and understanding the potentials of this technology motivates the researcher to conduct this study.

1.3 Problem Statement

RFID technology can provide good solutions for many problems that occur during the Hajj season sucha as overcrowding; delay of pilgrims at airports; difficulty of carrying out identification, monitoring, and tracking of pilgrims in the crowded places, loss of large numbers of pilgrims particularly the elderly; difficulty of obtaining the health record of pilgrim patients; and problem of communication with pilgrims whom speak different languages, through several RFID applications. These RFID applications can positively contribute in mitigating and reducing the effects of these problems. Unfortunately, to date, the complete use of RFID technology has not been adopted by Hajj authorities and organizers.

Hence, this study attempts to address this issue of non-utilization of RFID technology by investigating the factors that influence RFID technology adoption intention by Hajj organizations from the technological, organizational, and environmental perspectives. In doing so, Strategic Information Systems Planning

(SISP) can be developed for RFID system implementation in Hajj, taking into consideration the examined factors, and a set of operational guidelines proposed to assist Hajj management authorities and any related organization wishing to adopt RFID technology.

1.4 Research Objectives

The research has the following objectives:

I. To determine the extent of RFID adoption intention of Hajj organizations.

II. To investigate the factors that influence RFID adoption intention by Hajj organizations from the technological, organizational, and environmental perspectives.

III. To investigate whether organizational readiness (financial and technological) moderates the relationship between technological, organizational, and environmental factors and RFID adoption intention by Hajj organizations.

IV. To develop SISP for the adoption and implementation of RFID technology among all organizers involved in the management of Hajj activities to ensure maximum benefit from this technology adoption.

V. To produce a set of operational guidelines to assist Hajj management authorities and any related organization wishing to adopt RFID technology.

1.5 Research Questions

The present research attempts to answer the following questions:

I. What is the extent of RFID adoption intention by Hajj organizations?

II. What are the most significant factors that influence RFID adoption intention by Hajj organizations from the technological, organizational, and environmental perspectives?

III. Does organizational readiness (financial and technological) moderate the relationship between technological, organizational, and environmental factors and RFID adoption intention by Hajj organizations?

IV. How can RFID technology be adopted and implemented by all organizations involved in the management of Hajj activities to ensure maximum benefit from this technology?

V. What are the operational guidelines required to assist Hajj management authorities and any related Hajj organization wishing to adopt RFID technology?

1.6 Research Scope

There are a lot of technologies that can be used in Hajj management system for a variety of purposes. RFID as an emerging technology introduces several potential applications in Hajj which contribute to reduce the effects of some of the problems that appear during the Hajj season. For example, RFID technology can be used for identification, tracking, and monitoring of pilgrims, luggage, and vehicles; monitoring crowded places; used as E-passport; indoor tracking; medical services; among others. Although other technologies such as barcode and GPS can be used in Hajj in specific applications, RFID has advantages over these technologies. For example, RFID eliminates the need for line of sight to read objects that is required in barcode as well as ensures greater scanning distances. Furthermore, RFID technology required low cost requirements comparing with GPS which required GPS

receiver such as smart phone consumer applications or navigator device. In addition, GPS can be used only in an open area unlike RFID that can be used on both open and closed areas. In addition to the foregoing, RFID is an easy-to-use technology and has multipurpose uses compared with other technologies.

Thus, there is a need to study this emerging technology in Hajj management system to discover its potential capabilities and then to gain more knowledge and benefits from its adoption in Hajj.

This study focuses only on RFID technology to investigate the key factors that influence its adoption intention by Hajj organizers in Indonesia and Malaysia. This is because of the difficulty to collect data from all Muslim countries. The reasons why the researcher select Indonesia and Malaysia is because, first, the author is well connected with these two countries since he lives in Malaysia. Second, Indonesia and Malaysia represent a significant portion of the total number of Muslims worldwide particularly Indonesia which is the largest Muslim country. Third, Malaysia is more advanced in the field of IT than other Muslim countries.

Besides, this study focuses only on the adoption intention at organizational level not individual level because RFID so far not adopted in Hajj management and the first stage in its adoption will be on organizational level. After the complete use and maturity of RFID technology in Hajj by the pilgrims, the study of factors affecting pilgrims to accept use RFID will become very important and this is one of the recommendations of this study.

1.7 Research Limitations

This study poses several limitations that form new directions for future work. First, the study sample covers only Hajj organizers from just two Muslim countries, namely, Indonesia and Malaysia. This may not be sufficient to generalize the whole population of Hajj organizers from all Muslims countries. This limitation is because of the impossibility to collect data from all Hajj organizers over all Muslim countries.

Second, this study addresses RFID adoption intention on the organizational level and does not take the user level into consideration. This limitation is due to the stage of technology adoption which consists of two stages called primary adoption and secondary adoption. Primary adoption refers to the organizational-level decision and secondary adoption refers to the individual-level decision (Zaltman et al., 1973). In case of RFID adoption in Hajj, the majority, if not all of Hajj organizations, have not yet effectively adopted RFID technology. Therefore, it is an important to, first, investigate the factors that influce their intention to adopt this technology since they form the first stage of the adoption. Second and after the complete adoption of RFID technology by Hajj organizations as well as the maturity of this technology, it will be very important to investigate the factors that influence the use of RFID technology by end users, namely, pilgrims themselves. For this reason, model of this study does not include any factor related to the end user. Investigating end user factors forms new directions for future work.

1.8 Research Significance

The significance of this study lies in its novelty, contributions, and usefulness. With regards to the novelty, this study earns novelty from being the first study that studies

the factors affecting the adoption intention of RFID technology in the field of Hajj management.

Regarding the contribution of the study, this study empirically validates and supports the applicability of the TOE framework in understanding organizational RFID adoption in Hajj management by Hajj organizers. It found several key findings and implications on the factors affecting RFID adoption intention in the Hajj organizers. Furthermore, it investigated a new environmental variable of RFID adoption intention, namely, willingness to collaborate among partners that was ignored in IS literature and found it significant in predicting RFID adoption intention. In addition, this study, investigated the moderating effect of organizational readiness on the relationship between technological, organizational, and environmental factors and RFID adoption intention by Hajj organizers. The factor found to have a partial moderating effect. From the practical context, this study produced Strategic Information Systems Plan (SISP) for RFID based Hajj management system. This SISP forms blueprint for Hajj authorities and organizers on how they can participate and collaborate in an RFID system implementation project.

In other words, this study is useful for Hajj authorities and organizers as it provides them with required knowledge for the adoption decision through determining the most significant factors that influence the adoption process. Thus, ensuring maximum benefits from this technology adoption.

Moreover, SISP helps Hajj authorities and organizers to determine the main processes and data classes in RFID-based Hajj management systems and, in turn, determine the main systems that can be implemented. SISP also shows the main partners who participate in the implementation process for each system. Furthermore,

the plan describes the appropriate mechanisms for storing and sharing RFID data, communicating between Hajj partners, and installing the infrastructure required for the project, as well as the role of each party in the project.

1.9 Definitions of Variables

Intention to adopt RFID is defined as the degree to which Hajj‟s organizers intend to acquire and use RFID technology in the management of Hajj‟s activities.

Relative advantage is defined the degree to which RFID technology is perceived by Hajj organizers as being better than the technology and idea it supersedes (Rogers, 1983).

Compatibility is defined as the degree to which RFID technology is perceived as consistent with the existing values, past experiences, and needs of Hajj organizers (Rogers, 1983).

Complexity is defined as the degree to which RFID technology is perceived as relatively difficult to understand and use by Hajj organizers (Rogers, 1983).

Top management support is defined as the extent to which top managers in Hajj organizations provide direction, authority, encouragement, and resources during and after the acquisitions of RFID technology (Ifinedo, 2008).

Organization size refers to the number of employees in the organization, as well as the organization‟s annual revenue.

Organization readiness is defined as level of sophistication of the technological resources and availability of financial resources of the Hajj organizations which is required to cover the costs of purchasing, implementation, and maintenance of RFID technology (Iacovou et al., 1995).

Government support is defined as any support (e.g. financial incentives, policies, regulations, initiatives, facilities, etc) that can be provided by government for the Hajj organizations to help them in RFID technology adoption.

Willingness to collaborate among partners is defined as the willingness of the Hajj organizers to cooperate, to coordinate, to share infromation, and to participate with other Hajj partners in the adoption of RFID technology.

1.10 Research Organization

The rest of this thesis is organized as follows:

Chapter 2 reviews the theories that provide the theoretical basis for this study, including Technology Acceptance Model (TAM), Diffusion of Innovation (DOI) theory, and Technology-Organization-Environment (TOE) framework. The chapter also reviews the literature of RFID adoption using the TOE framework.

Chapter 3 proposes the theoretical model of the study based on the previous literature and then develops testable hypotheses.

Chapter 4 describes the methodology used to test the hypotheses which include research design, unit of analysis, research method, research strategy, research time dimension, sampling procedure, and data collection method.

Chapter 5 discusses the data analysis and results. It presents the profile of respondents, factor analysis, reliability analysis, descriptive statistics for variables, correlation analysis, and regression analysis.

Chapter 6 discusses the findings of the study comparing with prior studies.

Chapter 7 proposes SISP for RFID adoption and system implementation.

Chapter 8 provides conclusion and discusses the limitations, implications, and future research directions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the background of RFID technology and related works. It also explains the basic concepts of innovation adoption and reviews the three adoption theories described in the literature namely, TRA, TAM, and DOI theory as well as TOE framework. Moreover, a brief description of organizational IT and RFID adoption are presented. Section 2.2 describes the background of the study. In Section 2.3, the related works of IT and RFID adoption are reviewed. Besides, it provides describtion for SISP and explains the most popular methodeologies as well as proposes the SISP model for RFID-based Hajj management systems.

2.2 Background

The following subsections provide detail background about difficulties and problems during Hajj, organizational hierarchy of Hajj organizaers, Radio Frequency Identification (RFID) technology, and potential RFID applications in Hajj, concepts of innovation, theoretical foundation of adoption models, and selection of research model.

2.2.1 Number of Pilgrims

Every year, a large number of Muslims who wish to perform Hajj gather at Makkah in Saudi Arabia. This number is continuously increasing. According to recent statistics from the website of the Central Department of Statistics and Information in the KSA, the number of pilgrims who perform Hajj in the kingdom increases annually (Figure 2.1).

In general, the total number of pilgrim arrivals from outside or inside Saudi Arabia increases yearly (Table 2.1).

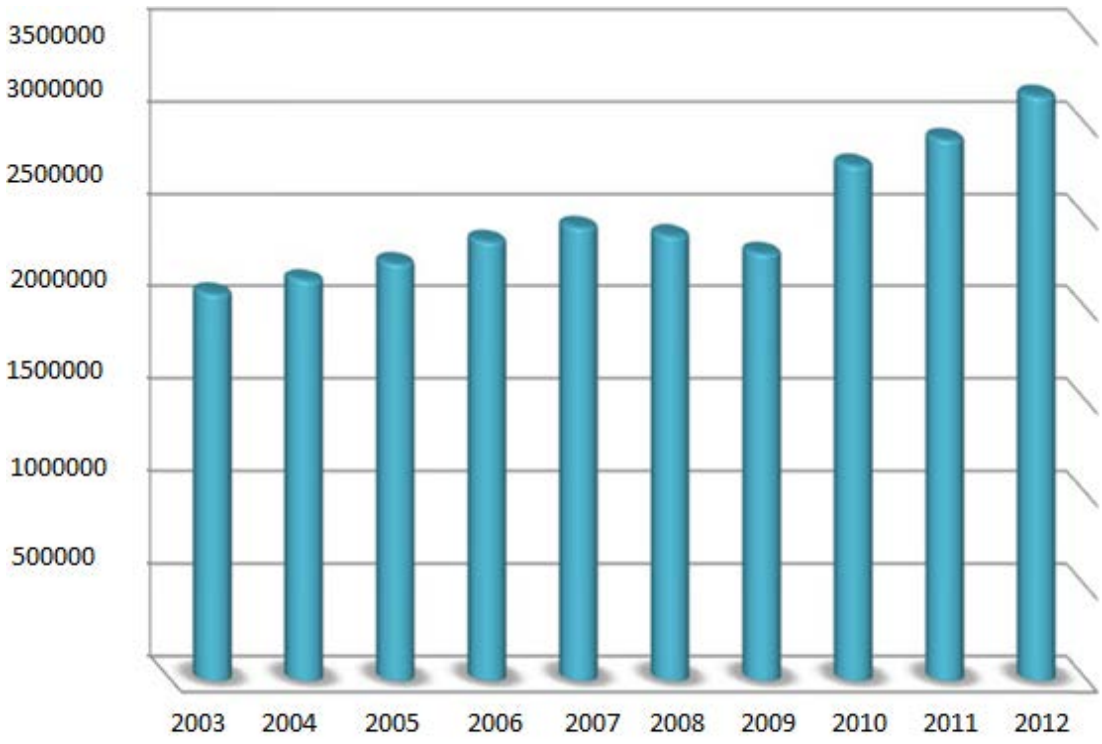

Figure 2.1: The number of pilgrims for the years from 2003 to 2012. (Central Department of Statistics & Information in the Kingdom of Saudi Arabia, 2012)

The growing number of pilgrims causes numerous problems for Hajj authorities and organizers. Overcrowding is the most prominent problem because it, in turn, causes other problems such as the entry delay of a large number of pilgrims at main ports, where they endure long queues for several hours, sometimes up to a full day, for immigration processing.

The identification, monitoring, and tracking of pilgrims are also difficult to carry out in crowded places at the holy sites, particularly when a natural disaster occurs and causes injury and even death. Furthermore, amid the huge number of pilgrims, a large number, particularly the elderly, get lost, causing additional burden on the Hajj authorities who will have to search for them and guide them back to their camps.

Table 2.1: The number of pilgrims for the years from 1416H (1995G) to 1433H (2012G). (Central Department of Statistics & Information in the Kingdom of Saudi Arabia, 2012)

Year	From Inside The Kingdom	From Outside The Kingdom	Total
1416H (1995)	784,769	1,080,465	1,865,234
1417H (1996)	774,260	1,168,591	1,942,851
1418H (1997)	699,770	1,132,344	1,832,114
1419H (1998)	775,268	1,056,730	1,831,998
1420H (1999)	571,599	1,267,555	1,839,154
1421H (2000)	549,271	1,363,992	1,913,263
1422H (2001)	590,576	1,354,184	1,944,760
1423H (2002)	610,117	1,431,012	2,041,129
1424H (2003)	592,368	1,419,706	2,012,074
1425H (2004)	629,710	1,534,769	2,164,479
1426H (2005)	700,603	1,557,447	2,258,050
1427H (2006)	724,229	1,654,407	2,378,636
1428H (2007)	746,511	1,707,814	2,454,325
1429H (2008)	679,008	1,729,841	2,408,849
1430H (2009)	699,313	1,613,965	2,313,278
1431H (2010)	989,798	1,799,601	2,789,399
1432H (2011)	1,099,522	1,828,195	2,927,717
1433H (2012)	1,408,641	1,752,932	3,161,573

Health authorities also face the difficulty of obtaining the health record of pilgrim patients because of the large number of patients who arrive at health centers around the clock. The task becomes more challenging when these patients do not have records or documents that show their health status and their diseases, particularly their chronic illnesses. Difficulty in communication is another problem that arises because the pilgrims speak different and multiple languages, compounding the misery of both health authorities and patients.

2.2.2 The Duration of Hajj

The second issue that contributes to the complexity of Hajj management is the short duration of Hajj, which is around one week from 8 to 13 Zil-Hijjah, an Islamic lunar month. During this short period, the huge number of pilgrims must perform specific

rituals at specific times in specific places. This situation consequently increases the incidence of overcrowding and stampedes, where pilgrim crowds move at the same moment as well as settle in the same place and at the same time. The followings are the common rituals performed by pilgrims:

2.2.2.1 Rituals During Day One

Pilgrims visit Al-Masjid Al-Haram (Holy Mosque) in Makkah and perform the welcome Tawaf, which is the act of circumambulating seven times around Ka'bah. Then, the pilgrims perform the Saʿy, which is walking between the hills of Al-Safa and Al-Marwah seven times back and forth. Next, they go to Mina to stay for one day (the eighth of Zil-Hijjah) and perform five prayers.

2.2.2.2 Rituals During Day Two

In the morning, the pilgrims leave Mina to go to Arafat, about seven miles southeast of Mina. In Arafat, pilgrims stay all day (Wuquf) until sunset, and then leave to go to Muzdalifah, where they stay under the open sky. Pilgrims offer the evening prayers (Maghrib and Isha) and stay overnight. In addition, they collect the pebbles they will need for the "stoning" ritual (Ramy). At dawn, they offer Fajr (the dawn prayer), and then depart to Mina again before sunrise.

2.2.2.3 Rituals During Day Three

Pilgrims perform the Stoning (Ramy) of the Devil Site, conduct rituals, go to Al-Masjid Al-Haram in Makkah to perform Tawaf Al-Ifadha, and then return to Mina.

2.2.2.4 Rituals During Days Four Through Six

Pilgrims repeat the Stoning of the Devil Site. They conclude the Hajj by performing the farewell Tawaf at Al-Masjid Al-Haram in Makkah.

2.2.3 Limited Space

During Hajj season, pilgrims are mandated to perform specific rituals in specific places. These rituals are stipulated for specific time durations and cannot be performed beyond their boundaries. This situation leads to the concentration of population density in specific places, which result in overcrowding, stampedes, and slow pilgrim movement from one place to another. Some of these critical Hajj places are listed below:

AL-Masa'a: Al Masa'a is the place where pilgrims perform Sa"y during Hajj and Umrah. Sa'y is one of Hajj and Umrah"s rituals. It requires pilgrims to walk seven times back and forth between the two hills of Al-Safa and Al-Marwah (Figure 2.2). Al-Masa"a consists of three floors, each having an area of 16,700 m^2 and capable of accommodating 16,000 pilgrims at a time. The daily average is around 600,000 pilgrims (Al-Rakeiba, 1999).

Figure 2.2: Al-Masa"a

Holy Mosque in Makkah: The Holy Mosque (Al-Masjid Al-Haram) in Makkah is the largest and holiest mosque for Muslims in the world. It is the Ka'bah (the house of Allah) to which Muslims from over the world turn toward during their prayers. Al-Masjid Al-Haram is also commonly known as the Haram or Haram Sharif (Figure 2.3). Al-Haram has an area of 361,000 m^2 and can accommodate 730,000 worshipers. However, during Hajj and peak periods, this number increases and people pray in surrounding streets (Al-Rakeiba, 1999).

Figure 2.3: Panoramic view of Al-Haram in Makkah

Mount Arafat: Mount Arafat is a granite hill east of the Holy City of Makkah, 20 km southeast of Al-Haram. It covers 13.9 km^2 (1390 hectares), of which about 0.27 km^2 (27 hectares) are built areas. The density of pilgrims is 1,500 per hectare (Al-Rakeiba, 1999). All the pilgrims are required to stay in Arafat on the ninth day of Zil-Hijjah (Figure 2.4).

Figure 2.4: Al-Rahmah Mountain in Arafat

Muzdalifah: Muzdalifah is a valley located between Mina and Arafat where pilgrims spend the night in the open after their arrival from Arafat (Figure 2.5). Muzdalifah is 9.25 km^2 (925 hectares), of which only 6.7 km^2 (670 hectares) are used by pilgrims while the rest are built areas. Muzdalifah can accommodate 3.4 million pilgrims, with a density reaching 5,000 persons per hectare (Al-Rakeiba, 1999).

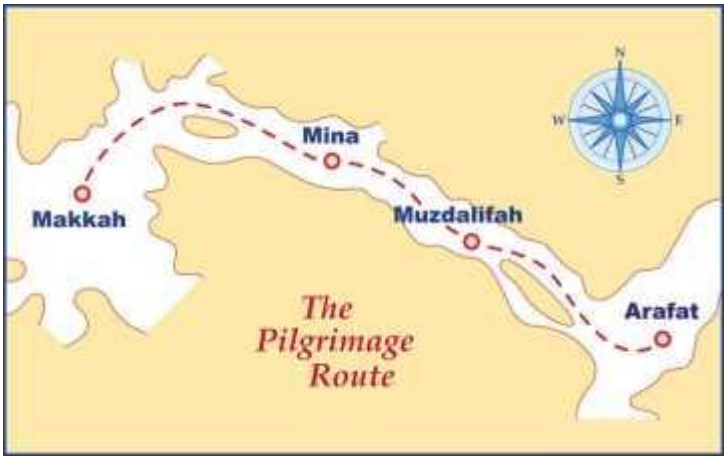

Figure 2.5: Hajj route (website of Ministry of Hajj, Kingdom of Saudi Arabia)

Mina: This place lies between the Holy City of Makkah and Muzdalifah (Figure 2.6). It has a total area of 7.8 km^2, 3 km^2 of which are mountainous, and only 49% of the remaining area (4.8 km^2) can be used to accommodate pilgrims (Al-Rakeiba, 1999). Mina"s capacity can be improved to accommodate 1.7 to 2.2 million pilgrims, with a density reaching 5,000 persons per hectare by adding new camps and building new housing units.

Figure 2.6: City of tents, Mina

2.2.4 Organizational Hierarchy for Hajj Organizers

Figure 2.7 shows the organizational hierarchy of Hajj organizers responsible for the management of Hajj. The Ministry of Hajj at KSA is the authority that is concerned with the implementation of public policies related to Hajj, Umrah, and pilgrims. It is the government authority that coordinates with other authorities and sectors from inside and outside of KSA in respect of the organization and arrangements of performing Hajj and Umrah. The National Tawafa Establishments for Hajj Affairs is responsible of receiving, housing, transporting, serving, and maintaining pilgrims. While Hajj agents which come at the low level of the hierarchy is responsible of the registration of pilgrims, facilitating the procedures for their traveling to Saudi Arabia, provision of housing, healthcare, transportation for pilgrims in coordination with The National Tawafa Establishments as well as supervision of pilgrims while they perform their rituals until they return back to their home countries.

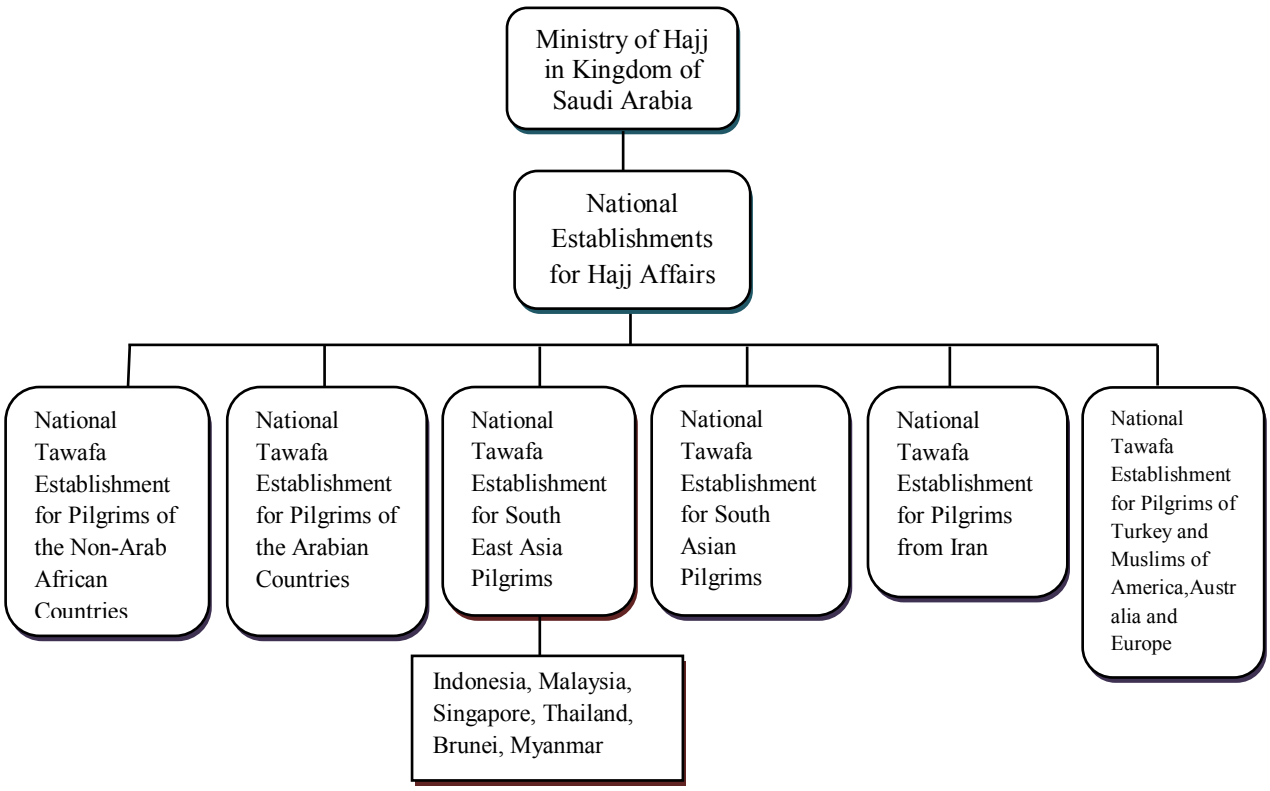

Figure 2.7: The organizational hierarchy for Hajj organizers

2.2.5 Radio Frequency Identification (RFID) Technology

RFID is an emerging technology used to identify, track, and trace objects, people, transactions, or events. RFID wirelessly transfers the unique serial number (the identity) and data of an object via radio waves. All RFID data can be sent directly to a computer system, thus eliminating human intervention errors that occur during the execution of operational tasks and business analyses (Sectoral e-Business Watch, 2008). This information can then be used by other internal or external computer systems.

RFID data are stored on an electronic device called tag, which can be attached to objects, people, and animals, among others. Data are exchanged between the tag and the reader device without a physical connection (Khan, 2008).

2.2.6 Architecture of RFID Systems

Figure 2.8 shows the RFID system architecture, in which data are exchanged between the different layers where system and application functions are arranged.

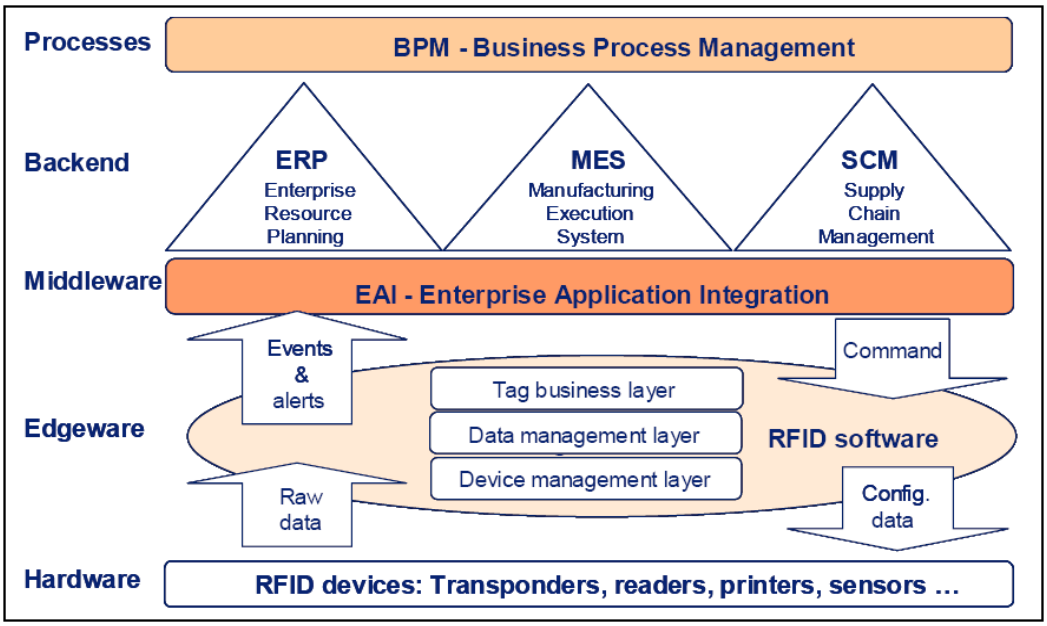

Figure 2.8: System architecture for RFID applications (BITKOM, 2005)

2.2.6.1 RFID Hardware

The main components of RFID hardware are the tag and reader. They are described as follows:

2.2.6.1.1 Tag (Transponder)

An RFID tag is a tiny silicon microchip composed of an antenna, memory, an encapsulating material, and a small processing unit (optional) (Khan, 2008). The tag is combined with an antenna in a compact inlay (Figure 2.9). The antenna returns and receives signal to and from an RFID reader device. These signals are the data with a unique serial number. RFID tags come in various sizes and shapes. Depending on the application, sometimes a metal tag and durable high-temperature tag (Figure 2.10) are constructed to avoid failure in a harsh environment. The most commonly deployed tags are housed in paper, polypropylene, or polycarbonate material because of cost issues. Manufacturers used to put human readable code, barcode magnetic strips, and RFID inlay together to produce a barcode RFID tag (Figure 2.11) that shares the same data string so that the information can be retained even if one of the codes is lost (Mohd-Yasin et al., 2006).

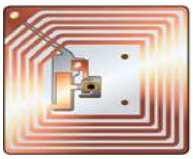

Figure 2.9: RFID inlay

Figure 2.10: Metal tag

Figure 2.11: RFID and barcode tag

I. Types of RFID Tags

RFID has three types of tags:

a) Passive tags

This type of RFID tag does not have an internal power source (e.g., battery) and requires an external power source to initiate communication. Its power source comes from the signal sent by the reader in which the antenna of passive tags receives this signal and then sends it to the integrated circuits to power them up. The powered integrated circuits in turn process the reader signal and send the response.

b) Active tags

Active RFID tags have their own power source or an internal battery that runs the circuitry and initiates the communication with the reader by sending their own signals. Active tags do not need an activation call from the reader. Active RFID tags generally ensure a longer read range than passive tags and are more expensive. The batteries must be replaced periodically.

c) Semi-passive tags

Semi-passive tags have their own power sources such as batteries, which are used only to maintain memory in the tag or to power the tag circuitry, but not to initiate communication with the reader. The signal sent by the reader activates the tag and the tag sends a response to the reader.

II. RFID Tag Classification

RFID tags are also classified based on the write/read capability into the following classifications:

a) Read-only tags

This is a passive tag that is already programmed with a unique identifier (EPC number) during manufacturing. This identifier cannot be changed by overwriting the identifier or adding additional data.

b) WORM (write once – read many) tags

This is a passive tag that has memory with no data written into it during manufacturing. However, the data can be written once into the memory by the user in the field and can be read unlimited times.

c) Read/write tags

This tag is an active read and rewritable tag that allows the user to manipulate the data without limitations. The unique identifier from the manufacturer remains in this tag, but the user can add data to the tag chip. This kind of tag is more expensive than other RFID tags because of its capability to both read and write.

2.2.6.1.2 RFID Reader (Interrogator)

An RFID reader is an electronic device that collects the tag‟s information and sends it to the back end system. The reader generates and receives RF signals to and from RFID tags through its own antenna. The core part of the reader includes a microprocessor embedded on an electronic circuit. Depending on their type and the application for which they are designed, RFID readers can have multiple functions and capabilities such as communication with the tags and back end systems, as well

as operational capabilities such as firmware upgrade, graphical user interface, and I/O capability (Moore and Benbasat, 1991). There are many types of RFID readers with different purposes and ambient conditions.

I. **Fixed Readers:** This reader is mounted in specific locations where the tagged objects are expected to pass. It can be installed on walls and doors or integrated with other devices such as manufacturing lines, conveyors, door portals, and others. A fixed reader needs an external power source, contains multiple antennas, and can be connected to a hardwired or wireless local area network. Figure 2.12 shows the fixed reader.

Figure 2.12: Fixed readers

II. **Handheld (Portable) Readers:** Handheld readers are portable readers that contain all reader elements, including an antenna and application software. They can be either wireless or wired. They are much smaller compared with fixed readers and usually come in the form of a gun or a tablet. They have the same capabilities as fixed readers. However, handheld readers are more flexible than fixed readers because they can be brought close to the tagged object to collect information. They are designed with near-field read/write capabilities. On the other hand, the read range for handheld readers is less than that of fixed readers. Figure 2.13 shows an example of a portable reader.

Figure 2.13: Portable Reader

III. **Plug Play Readers:** These readers come in different forms. They can be integrated into desktops, laptops, Palms, PDAs, or smart phones through their interface ports such as a compact flash, SD, PCMCIA, and USB ports. Figure 2.14 shows an example of a plug-and-play reader.

Figure 2.14: Plug play reader

2.2.6.2 Middleware

An Information Technology (IT) system requires a middleware layer, which can be one or more special functional layers, to identify the data transmitted by the antenna. In the middleware layer, the data are cleaned from a single reading or multiple reading of errors and then buffered in a database. In accordance with the business process, the data are filtered and then transferred to back end systems in real-time because the back end systems may have to trigger other actions as responses. Once the data are buffered, they become available for further analysis or review (BITKOM, 2005).

2.2.6.3 Back end systems

The back end system layer, which is the highest layer in the RFID system architecture, includes IT systems from different standard software producers such as Microsoft, SAP, Petek, Oracle, and possibly other individually programmed systems. Back end systems use received data to support business processes. Such systems have an umbrella term called enterprise resource planning. Complementary systems such as a supply chain management (SCM) and a manufacturing execution system can act as covers for the application-specific aspects (BITKOM, 2005).

2.2.7 RFID Advantages and Disadvantages

RFID technology as an emerging technology has many advantages and disadvantages.

2.2.7.1 RFID Advantages

According to McCathie (2004), RFID has several advantages:

1. RFID technology does not require line of sight to read RFID tags like barcodes.
2. Simultaneous automatic reading for many RFID tags can be performed.
3. Less manpower is required to do the task of orientating objects to scan their barcodes.
4. The system provides enhanced visibility because of the capability of RFID to read tags without line of sight, which allows for continuous monitoring of objects.
5. Item-level tracking maximizes the potential benefits of RFID, such as theft detection and automatic monitoring of shelves.