Literature Review of Crowd Management: A Hajj Case Study

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Abstract: Pilgrimage is one of the five pillars of Islam, which is a duty every Muslim should perform once during his lifetime. Over than two millions Muslims from all the world gather in Makkah for one of the world's largest pilgrimages. All those pilgrims are obligated to be accommodated at Hajj ritual sites, which are the Kaaba, Mina, Arafat and Muzdalifah. With this huge number of pilgrims in the holy city, managing the crowd is a complicated task, especially in the geographical area for the movement of pilgrims, the fixed underlying road-network infrastructure between the different worship places, the annually increasing number of pilgrims and also the short duration of Hajj. As a result of this, huge crowd and difficulties in control have led to fatal accidents among the pilgrims. By the last decade, overcrowding management became a big challenge for the Saudi Arabian authorities and Hajj organizers. Scientists have started research projects to provide several methodologies for crowd monitoring and estimation of its density. In this work, we tried to present a literature review about the Hajj in order to help scientists for future contribution and have lots information about this new field of research.

1 INTRODUCTION

Pilgrimage is an important event organized every year to enable Muslims practice one of five pillars of Islam.

In fact, with the increasing numbers of pilgrims, the Saudi authority has faced many problems that lead to hazardous accidents.

Indeed, it's compulsory to ensure the safety of pilgrims from different countries, so it's urgent to adopt strategies for successful crowd management.

Obviously, we have to debate about the problems that face the Saudi authority in the management of the largest event ever: Pilgrimage.

Among these problems we can mention:

▪ *Fixed underlying road-network infrastructure between the different religious places:*

The limited geographical areas in the holy city places (Mina, Arafat and Muzdalifa) are one of the most problems that face the authority Saudi at Hajj event management.

▪ *The lack of respect from the pilgrims to the schedules:*

Some of the pilgrims do not respect the schedules proposed by the authority of Hajj.

▪ *Annually increasing number of pilgrims:*

The increasing number of pilgrims each year and the excessive wait at places of worship inevitably lead to the creation of many disasters because of the inability of the Saudi authority to anticipate these catastrophes.

▪ *Lost pilgrims in Hajj ritual places:*

Every year, thousands of pilgrims got lost or missing, this problem due to the overcrowding at the Hajj holy locations.

In addition, (Amro and Nijem, 2012) illustrated that around 30.000 pilgrims in 2011 got missing during hajj various rituals. This problem occurs especially for the foreign pilgrims and children and the people who do not know any other language of communication other their mother tongue.

▪ *Lack of guidance at Hajj ritual places:*

The lack of directional information is a significant problem. The foreign pilgrims who come for the first time to perform the pilgrimage need the information about the holy sites around Makkah.

In this section we discussed some problems pushed us to study the crowd management for the pilgrimage. In section 2 of this investigation, we present hajj crowd management history. In section 3, we devoted the practical works in this field. Then state of the art studies that contributed to resolve overcrowding management also to avoid the stampede's are depicted in section 4, from which conclusions are drawn in section 5.

2 HAJJ CROWD MANAGEMENT HISTORY

The most accurate description of the terms crowd management and crowd control are introduced by (Fruin, 1993), in which the author defined the term crowd management as a systematic planning for the orderly movement and assembly of members as people. The crowd control is the limitation of crowd behaviour. As an example of the crowd management events, we can note the pilgrimage to Mecca as one of the most visible manifestations of overcrowding.

The pilgrimage is an annual Islamic pilgrimage that takes place on the last month of the Hijri calendar only for five days period, starting on the eighth of the Dhu al-Hijjah and ending on the twelfth of the Dhu al-Hijjah. In these few days, the pilgrims must perform the hajj by practicing all the rituals that Prophet Mohammed (peace be upon him) has formalized. We found in (Feinberg and Alwan, 2008) the activities and dates of pilgrimage which are details in table 1.

The above table shows the acts of worship of pilgrimage and their dates, obviously, the short duration of pilgrimage have a degree of complexity, will usually have an impact on the event management plan.

All hajj activities should be carried out by about 3 million pilgrims which are not only bound to time but also to the place. Indeed, despite the efforts of the Ministry of Hajj and Umrah in the management of pilgrims, the lack of respect for the pilgrims led to many disastrous results of the crowd movement.

Authors (Al-Nuaim and Al-Masry 2012) have summarized disasters that happened at Hajj events in the two last decades due to the human bottlenecks, crowd of pilgrims and unsuccessful Hajj management (Table 2). In fact, we update the

"History of Hajj tragedies" by adding some new information.

Table 1: Schedule of Hajj.

* Hijri date	No of days	Activities
12/8 or before	Varies	a. Bathe and wear a 2 piece white garment. b. Verbal declaration of intending to perform Hajj. c. Perform the Tawaf **
12/8	1 day	a. Travel at dawn to Arafat. b. Travel to Muzdalifah after sunset and collect 70 pebbles (optional).
12/9	1 day	a. Travel at the dawn to Mina. b. Visit Makkah to perform the Tawaf **and the Sa'y. c. Return to Mina.
12/11 to 12/13	2 to 3 day	a. Sleep in Mina for 2 to 3 nights. b. Stone the symbol of Satan. c. Sacrifice an animal. d. Return to Makkah e. Perform the Farewell Tawaf**.

*__Hijri calendar:__ Islamic lunar calendar, which is comprised of 12 months, with 354 days per year.

**__Tawaf:__ is one of the Islamic rituals of pilgrimage. During this ritual, Muslims going round Al-Kaaba seven times in a counterclockwise direction.

Table 2: A history of Hajj tragedies.

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	
2001		Death of 35 pilgrims	
2003		Death of 14 pilgrims	
2004		Death of 251 pilgrims	
2006		Death of 346 pilgrims	
2015		Death of 2,411pilgrims	Mina.

In view of the multiplicity of causes of overcrowding in the Hajj, the Saudi authorities are called upon to find practical solutions to overcome these problems. Therefore, we find in the next part some of the concrete works to overcome the disasters facing the pilgrims when performing the rituals of Hajj and especially the problem of overcrowding.

3 PRACTICAL WORKS

The annual Islamic Pilgrimage is the biggest gathering of its kind in the world. In this annual event, millions of Muslims from around the globe gather in the same place to perform a set of acts of worship in Makkah. Managing crowd is a complex task for the Saudi Arabian government. In fact, the number of pilgrims rose each year, which make the problem got worse. For example, the planning of the movement of pilgrims from one holy site to another during the course of Hajj is a big challenge that faces the authority, especially with the increasing number of pilgrims from the globe and with the movement of mass (vehicle, pedestrian) more problems continually arise. The Saudi authority has broad responsibility for the protection of the area's visitors. In reaction to past crowding problems and this forecast growth, the local authorities have made a set of steps to increase the content of the holy places in and around Makkah.

Recently, scientists have begun working on research project to improve the mass movement that helps in the crowd management. For example, the authority hasn't allowed the small cars to enter Makkah environs during peak periods. As for the management of the transportation of pilgrims to Mina, Arafat and Muzdalifah, Saudi Arabia undertook to expand a railway network by the construction of a monorail "Al Mashaaer Al Mugaddassah Metro Line" to solve the problem of heavy bottleneck congestion traffic and to improve the antiquated logistics infrastructure. The line was opened in November 2010 and became fully operational in November 2011 (Reffat, 2012).

For instance, (Sheffi and Mahmassani, 1981) proposed a model, one of the first of its kind, to study how masses of people behaved in certain situations.

As such Dr Felemban's centre is developing a bracelet for tracking the pilgrims and to provide guidance at Hajj ritual places and an electronic health record.

Moreover, there are approximately 800 surveillance cameras have been installed to ensure the safety of pilgrims.

Given the fact that the number of pilgrims is growing, the pilgrimage authorities work so hard to ensure the safety of the crowds.

Recently, many scientists have proposed making structural refinements to the geometry of sacred sites (Algadhi et al., 2002) organizing crowds streets in holy sites (Al-Abideen, 2005).

This proposal has been implemented as indicated (Pin et al., 2010) in its work.

The Jamaraat Bridge was rebuilt with a new design in order to improve the infrastructure and accommodate the largest amount of pilgrims in the stoning of the devil ritual of the Hajj on the bridge. The idea of this new design is to increase the number of visitors by adding multiple floors that made it a multi-level design.

In the next section, we will describe the empirical studies which done to contribute to the resolution of the crowd management problems related the pilgrimage.

4 LITERATURE REVIEW

4.1 A Hajj Case Study

Many researchers discussed the situation of crowd management in Mecca, and many efforts by the authorities have been made to provide safety to pilgrims during this crowded event. Indeed, (Khozium et al., 2012) studied the crowd management of pilgrims using the thermography. The proposed system is based on two main components: the information management component, and the decision support system module.

The information management component includes data acquisition module via using of several thermal cameras deployed at critical points on the target route. It is divided into two modules: the thermography module and the fuzzy logic module.

The decision support system module generates different alternatives showing the closed roads, road priorities, and which group should move through which road. It is divided into two modules: the operations research module and the expert system module. Intelligent agents have been used to treat this problem by (Mulyana and Gunawan, 2010). Their system was able to demonstrate more realistic pilgrims' behavior for three Hajj rituals, thawaf, sa'i and jumrah. The three Hajj rituals are modeled in the form of finite state machine. To compare the real word data with the simulation result, the authors based on the replicative validity type.

Negative aspects of intelligent agent research included about lack of the number of agents to simulate that can be mitigated by using a more powerful computer.

The negative aspect about using intelligent agent is the big numbers of communication between agents which can provide a time response problem.
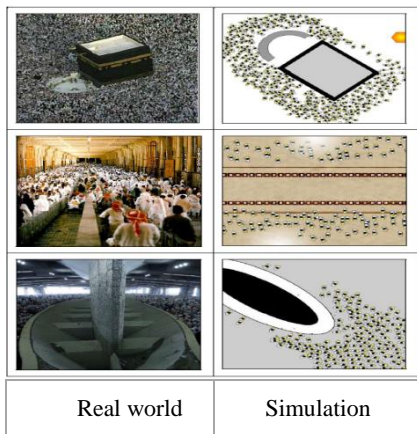
| Real world | Simulation |

Figure 1: Replicative validation result.

(Pin et al, 2011), have shown that applying TRIZ principles in crowd management can be used to solve the problem. TRIZ was introduced by Genrich Altshuller and his colleagues in1946. It is the Russian" Theory of Inventive Problem Solving" (Mann and Domb, 1999). A fundamental concept in TRIZ is that a problem is defined by contradictions. In the case of study of Hajj, the contradiction is based on the increasing crowd capacity in a relatively small area, leads to overcrowding; it is one of the common contradictions in crowd management. In fact, the research aims to apply the theory of the resolution of invention-related tasks.

The authors found the contradictions that arise in the context of crowd management based on a selection from the 40 principles. They applied three principles:

a) Principle 1 Segmentation:

- Divide an object into independent parts
- Make an object easy to disassemble
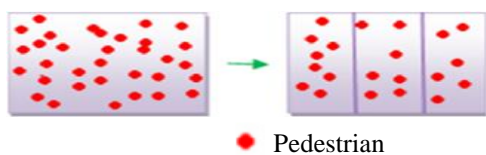- Increase the degree of fragmentation or segmentation

Figure 2: Illustration of pedestrians' segmentation.

b) Principle 7 Nested doll:
- Place one object inside another; place each object, in turn, inside the other
- Make one part pass through a cavity in the other.

c) Principle 17 Another dimension:

- To move an object in two- or three-dimensional space
- Use a multi-story arrangement of objects instead of a single-story arrangement
- Tilt or re-orient the object, lay it on its side
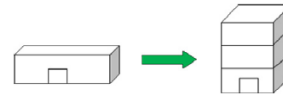- Use 'another side' of a given area.

Figure 3: Illustration of changing building's dimension.

(Maciej et al., 2011) has proposed an approach based on optical flow data. In this work, the authors has introduced a concept of crowd management system that consider two threads, the analysis of crowd behavior to detect atypical or dangerous situations and the second focus on detecting a hold-ups in the door.

In the same context, we also attached importance to the bottlenecks congestion traffic that can be occurred on the roads interconnecting the holy city places.

(Omar et al., 2014), the objective of author's proposal is to evaluate congestive bottleneck areas in the Mecca road network interconnecting holy sites during the pilgrimage period through the use of computational modeling and computer networking techniques. However, in this work, the authors made several assumptions to evaluate the movement of the pilgrims' traffic.

To sum up, a queue/polling model was proposed to the traffic control that uses an adaptive control algorithm that calculates traffic decisions in response to real-time variable congestion levels.

It is also possible to take advantage of the following researches, which are related to solving bottlenecks congestion traffic, that it is possible to inspire from it.

(Koushik et al., 2011) proposed an intelligent traffic congestion monitoring and measurement system called TrafficMonitor to monitor and measure traffic congestion using the probe vehicle. The congestion detection algorithm introduced in this investigation based on the calculation of the vehicle speed on a section of road and the average waiting time of road vehicles.

RFID and GSM based system was adopted for detect and manage automatically the congestion on any road leading to a junction in real time. This system was proposed by (Siuli et al., 2010). Nevertheless, the RFID reader used in this work to calculate the number of vehicles and to determine

the congestion volume helps only to find the conjunction but doesn't give any indication for it.

The authors (Stefania Bandini, Fabietti, Pomello, Manzoni, Vizzari, Manenti, Sartori, Bonomi, Lembo, Nishinari, Ohtsuka, Shimura, Koshak, Gutub, Al Azzony) have been involved in the Crystals Project. Crystals project is a joint research effort between the Complex Systems and Artificial Intelligence Research Center of the University of Milano Bicocca, the Centre of Research Excellence in Hajj and Omrah and the Research Center for Advanced Science and Technology of the University of Tokyo. This project aims to establish an agent-based pedestrian and crowd modeling approach to survey the relationship between the contributions of anthropology and the empirical works of the research on crowd dynamics. Also, investigate the influence of heterogeneous groups in the emergent dynamics.

The objective of Reffat's (Reffat, 2012) proposal is to develop a framework an intelligent computational real-time virtual environment model for efficient crowd management, especially the vehicles traffic movement and the movement of pedestrians from Arafat to Muzdalifah, by using diverse optimization methods and simulation.

Indeed, the limit of the proposed framework is that the 3D virtual model does not intend for optimization.

(Stefania et al., 2007) proposed a multi-agent approach to crowd modeling and simulation, the guidelines for its adoption to model crowds and some relevant elements of a simulation infrastructure for crowd simulation.

(Sonia and Mohamed, 2015), have shown that Wireless Sensor Network deployment model can be used to monitor pilgrims and help them in the case of evacuation process. The proposed model determines anchor positions within the worship areas that facilities the evacuation process and ensures the survival of persons.

In the next section, we will describe methods and proposed works concerning other cases of study.

4.2 Other Case Studies

Recently, there have been inherent dangers associated with every large public gathering. Thousands of people have perished in stampedes, fires and other incidents resulting from the overpopulation and mismanagement.

By digging more in the literature, we found another cases of study in the field of crowd management.

(Bisojit et al., 2016) have proposed a sensor system to sense level of occupancy in each train compartment. In the system, the level of occupancy will be shown on a large indicator on the platform before the train arrives on station via ZIGBEE.

(Andrew et al., 2015) have used an agent-based modeling and simulation (ABMS) technique for developing a decision support system called "SimCrowdControl".

The decision support system uses a realistic crowd model developed based on social science research studies. It employs a heterogeneous crowd model with 3 kinds of agents: Instigator agent, susceptible agent and Guardian agent.

In this investigation, we have studied the problem of hajj crowd management. Actually, the above approaches of several technologies addressing the problem of crowd management provided auspicious potentials of utilizing diverse systems as means for improving the pilgrims movements and decreasing the crowd congestion will be accordingly enhanced. Therefore, technological solutions can be useful to control the crowds, but also it has a negative impact if that is used in a standalone mode as almost in the case of religious gatherings.

5 CONCLUSIONS

Managing crowd is a substantial challenge, especially when religious perceptions take into consideration. However the disasters like the one which took place at Datia district in Madhya Pradesh in India in 2013 hundreds of people killed (Local Authorities, Administrators and Organizers, 2014). Also in 2015, many people were crushed and trampled to death in the Saudi Arabia hajj stampede (G. Keith Still). Given the difficulties of this problem, we have addressed this issue in this investigation.

The literature review of this study presented the problem of crowd management in human and industrial standpoint in which we have mentioned the most famous overcrowding event in Makkah (Pilgrimage) experiences in order to clarify the proposed objectives. With thus use of technologies discussed in this article could be deployed to overcome Hajj problems.

Despite, with the empirical point of view in which we have analyzed the research works that contributed to solving the problem of crowd incidents such as overcrowding and bottleneck, we conclude that the majority of research works has dealt with the problem in a static context (offline)

using resolution methods that are either exact or approximate. This does not reflect the reality.

So, the problem of crowd management must be studied in such a way to get closer to the reality and in order to create decision support systems.

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