MODELING FLOW OF CROWD DURING TAWAF AT MASJID AL-HARAM

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This Study is humbly dedicated to
Allah, the Almighty,
for granting me the opportunity to serve
the believers, those who seek the Truth.

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ABSTRACT

Tawaf is one of the most important rituals of hajj or umrah performed by the Muslim pilgrims in Masjid al-Haram yard, Makkah, Saudi Arabia. It consists of seven counterclockwise circulations around Ka'abah, a building situated in the middle of the yard. Large crowds of pilgrims performing Tawaf during peak seasons need to be investigated towards providing a safe and robust crowd management plan. Although many studies have been reported related to Tawaf, but many of them focused on animation and behavior during Tawaf. There has been limited studies addressing human crowd during Tawaf from queuing system and optimization perspectives. This research modeled the Tawaf activities based on queuing system using discrete-event simulation, Arena. Alternative crowd management policies were studied and their performances were compared using three criteria namely, density, service rate and average time in the system. Important design factors such as pilgrim inter-arrival time, group size, availability of space and switching behavior during Tawaf were investigated. The simulation results suggest that switching lane during Tawaf is the most significant factor in crowd density development and reduce efficiency of the queuing system. The proposed Tawaf model using separation, spiral path and timely scheduled the incoming pilgrims has resulted in the best performance among the investigated models. The techniques used in this study, is potentially applicable to other huge crowd gathering such as in theme parks, public transportation hubs and sports events.

ABSTRAK

Tawaf adalah salah satu ibadat yang paling penting bagi orang islam yang mengerjakan haji atau umrah di Masjid al-Haram, Makkah, Arab Saudi. Ia terdiri daripada tujuh peredaran melawan jam sekitar Ka'abah, iaitu sebuah bangunan yang terletak di tengah-tengah perkarangan masjid. Kesesakan jemaah menunaikan tawaf semasa musim puncak perlu disiasat bagi menyediakan pelan pengurusan kesesakan yang lebih selamat dan teguh. Walaupun banyak kajian telah dilakukan berkaitan dengan tawaf, tetapi kebanyakannya tertumpu kepada kajian animasi dan tingkah laku jemaah semasa tawaf. Kajian ke atas masalah kesesakan semasa tawaf dari perspektif sistem beratur dan pengoptimuman adalah sangat terhad. Penyelidikan ini memberi tumpuan kepada pemodelan aliran jemaah semasa tawaf dengan menggunakan perisian simulasi *discrete-event,* Arena. Beberapa kaedah pengurusan kesesakan orang ramai dikaji dan prestasi model-model dibanding menggunakan tiga kriteria iaitu, ketumpatan, kadar perkhidmatan dan masa purata dalam sistem. Faktor-faktor penting seperti masa antara ketibaan jemaah, saiz kumpulan, kesedian ruang dan tingkah laku jemaah menukar laluan dikaji. Keputusan simulasi menunjukkan bahawa penukaran lorong semasa tawaf adalah faktor yang paling ketara mempengaruhi pembentukan kepadatan jemaah dan ini menjejaskan kecekapan sistem beratur. Model tawaf cadangan berasaskan pemisahan, jalan lingkaran dan kehadiran jemaah secara berjadual memberi prestasi terbaik dikalangan model-model yang dikaji. Teknik yang digunakan dalam kajian ini berpotensi diperluaskan untuk mengkaji masalah lain seperti kesesakan semasa perhimpunan orang ramai di taman tema, hab pengangkutan awam dan acara-acara sukan.

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INTRODUCTION

2.1 Background of the Problem

Tawaf is one of the rituals that Muslim must perform when they enter holy city of Mecca in Saudi Arabia. It consists of seven circumambulate counter clockwise movement around Ka'abah which is a cube structure in the middle of a yard in Masjid al-Haram called Mataf. At certain times of year for example during Hajj and in the holy month of Ramadhan, about 35000 pilgrims gather in Mataf area (Curtis *et al.,* 2011). The time and space limitation cause high density and congestion problems. Proper designing the of the Mataf area and modifying movement of pilgrims according to schedules may lead to reduction of the safety and religious problems that happen as a result of large scale of crowd.

Most of the catastrophic accidents are due to crowd density, distribution problem, congesting panic, non-adaptive behavior and late time to take an action (Hamizan, 2008). The number of casualties and victims brings many researchers concern to investigate if there is any effort that can be done to prevent the accident or reduce the casualties and victims.

The large number of pedestrians will cause crowd congestion and may cause disasters as pedestrians push into each other. Elderly pilgrims and women face

difficulties in completing the seven rounds. Secondly, entry into the Tawaf area is unlimited, which causes pilgrims to flow in from various directions at the same time.

Safety is one of the most important issues when dealing with such a large crowd. According to Still (2012), three steps should be taken to develop safer crowd, which is crowd modeling, crowd monitoring and crowd management. Crowd Modeling investigate how, where, when and why crowds arrive, move around and leave an event/venue. Crowd monitoring is monitoring of the arrival flow rates, how the queues build up, areas of high crowd density and different types of crowd behavior, both normal and emergency. Crowd modeling and crowd monitoring are both essential to develop a safe and robust crowd management plan.

Several crowd simulation models are available for either the simulation of the evacuation or the normal movements of the crowd. However based on Sarmadi *et al*. (2007) studies, none of the previous software was able to simulate circular movements in Tawaf area with enough accuracy and details. Besides, existing software normally can handle relatively small crowds. The huge crowd of 32000 pilgrims in the court area cannot easily be simulated using the existing software.

In previous researches, crowd during Tawaf was studied from diverse points of view (Widyarto, 2008; Sarmady *et al*., 2011; Zarita *et al.*, 2009; Kamareddine and Hughes, 2011). Our literature review only able to locate Al-Haboubi and Selim (1997) addressed crowd during Tawaf from safety and queuing efficiency aspects. Most of the other researches from computer science and mathematics schools, conducted studies with the purpose of density estimation and developing virtual representation of crowd behaviors.

1.2 Statement of the Problem

The large crowd of pilgrims attending Masjid al-Haram, “Muslim Holy Mosque”, makes it one of the most significant and complicated existing crowd management challenges. Some major crowd problems in Tawaf are high density, low service rate and lengthy delays. The time and space limitation as well as large crowd of people, make crowd management a challenging task.

There is lack of studies on flow of pilgrims during Tawaf from queuing theory perspective. This project presents investigation to evaluate the effect of various crowd formation factors and their interaction in congestion development towards improving the flow and reducing the congestion. The study is limited to crowd movement in the main court of Masjid- Al-Haram.

1.3 Objectives of the Study

The research objectives are listed as below:

i. To identify significant factors affecting the flow of pilgrims during Tawaf.

ii. To evaluate the effect of alternative crowd management procedures.

1.4 Scope of the Study

The scope of study covers the followings:

i. Data modeling for incoming, in-process and out-going crowd are based on published literatures.

ii. The outcomes of the study are limited to proposals for improvement in Mataf and procedures in crowd management.

iii. The variation of different Islamic ruling (fatwa) is not included.

1.5 Significance and Contribution of the Study

In this research a statistical discrete-event approach was used to simulate the pedestrians' actions and a manufacturing software called ARENA was to simulate their movements. This study approach can contribute in establishing specific Tawaf performance measures, providing useful findings to the new Mataf design team, retesting possible modifications, continuous process/improvements, evaluating Tawaf schedules and predicting the flow rate values in the presence of various future circumstances.

1.6 Organization of the Report

This report is organized into seven chapters. Chapter 1 serves as an essential introduction to the research. Chapter 2 provides background information and review of related literature that leads to formulation of research problem. Chapter 3 describes the research methodology and its rationale. Chapter 4 describes basic model development. In Chapter 5, alternative improved models and their performance are elaborated. Chapter 6 provides an overall conclusion and suggestion for future research.

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