

Strategies to Mitigate Disasters at the Hajj Religious Festival Using GIS and Agent Based Modelling

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Abstract : The Hajj religious festival at Mina in Saudi Arabia has always presented the opportunity for injuries or deaths. For example, in 1990, a stampede killed 1426 pilgrims, whilst in 1997, 343 people were killed and 1500 injured due to a fire fuelled by high winds sweeping through the tent city in Mina. Many more minor incidents have occurred since then. It is predicted that 5 million pilgrims will soon perform the ritual at Mina (which is, in effect, a temporary city built each year in the desert), which might lead in the future to severe congestion and accidents unless the research is conducted on actions that contribute positively to improving the management of the crowd and facilitating the flow of pilgrims safely and securely. To help prevent further disasters, it is important to first plan better, more accessible locations for emergency services across Mina to ensure a good service for pilgrims. In this paper, we first use a Location Allocation Model (LAM) within a network GIS to examine the optimal locations for key services in the temporary city of Mina. This has been undertaken in relation to the location and movement of the pilgrims during the six day religious festival. The results of various what-if scenarios have been compared against the current location of services. A major argument is that planners should be flexible and locate facilities at different locations throughout the day and night. The use of location-allocation models in this type of comparative static mode has rarely been operationalised in the literature. Second, we model pilgrim movements and behaviours along with the most crowded parts of the network. This has been modelled using an agent-based model. This model allows planners to understand the key bottlenecks in the network and at what usage levels the paths become critically congested. Thus the paper has important implications and recommendations for future disaster planning strategies. This will enable planners to see at what stage in the movements of pilgrims problems occur in terms of potential crushes and trampling incidents. The main application of this research was only customised for pedestrians as the concentration only for pedestrians who move to Jamarat via foot. Further, the network in the middle of Mina was only dedicated for pedestrians for safety, so no Buses, trains and private cars were allowed in this area to prevent the congestion within this network. Initially, this research focus on Mina city as 'temporary city' and also about service provision in temporary cities, which is not highlighted in literature so far. Further, it is the first study which use the dynamic demand to optimise the services in the case of day and night time. Moreover, it is the first study which link the location allocation model for optimising services with ABM to find out whether or not the service location is located in the proper location in which it's not affecting on crowd movement in mainstream flow where some pilgrims need to have health services.

Keywords : ABM, crowd management, hajj, temporary city

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