Activity-Based Modeling and Microsimulation of Emergency Evacuations

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ABSTRACT

Most existing emergency evacuation studies assume evacuees to evacuate from their residence locations. However, depending on the time of day, people’s movements are constrained not only by their workplaces, but also the necessity of picking up family members. Family member interactions, a typical activity during an evacuation, can greatly affect the evacuation process. Activity-based modeling has been applied to estimate daily traffic demand widely. However, only limited research has been reported to incorporate the activity component in examining evacuation processes, particularly for mass evacuations at a micro-scale. Under this context, this study aims to analyze the activity-based travel pattern and its impact on emergency evacuations in the case of a hypothetical emergency evacuation of Galveston Island, Texas. In the study, one typical type of daily trip, picking up school-age children, is considered. All households with school-age children are assumed to pick up their children first in an evacuation. Trip chains are defined to represent the movements from workplaces to schools and then to destinations. This study employs agent-based microsimulation techniques to model the evacuation process at the individual-driver level. The simulation results suggest that the overall evacuation time may not be significantly affected when the trips of picking-up school-age children are considered in the case of Galveston Island. However, the average travel and delay time of individual vehicles may increase dramatically, which suggests the occurrence of considerable congestions during the evacuation. The findings demonstrated the importance of considering activity-based trips in evacuations.

Keywords: Activity-Based Modeling, Emergency Evacuation, Microsimulation, Trip Chain

INTRODUCTION

Emergency evacuations are often necessary when a disaster caused by natural hazards or technological failures poses great threats to a risk area. Ranging from small-area to large-scale evacuations, evacuation studies typically focus on factors that are likely to affect the evacuation process, including evacuation behavior, evacuation response and preparedness, traffic control and management strategies, etc. (Sorensen, 2006). When evacuation movement is under investigation, most existing studies assume evacuees to leave from their residence locations. While this may hold true for evacuations resulting from natural hazards in which
Evacuees receive evacuation notice well in advance, it may not be the case for no-notice evacuations. In no-notice evacuation events, depending on the time of day, the location of the population under risk is highly dynamic. When an emergency evacuation is necessary, people’s movements are constrained not only by their workplaces, but more than often also by the necessity of meeting their family members. Family member interaction, a typical type of activity during an evacuation, can greatly affect the evacuation process.

Activity-based modeling has been applied to estimate daily traffic demand widely and has been credited as a more reasonable approach to transportation planning because it considers travel behaviors of people and the temporal aspect of travel patterns (Miller & Shaw, 2001). Although activity-based travel behavior has attracted attention in emergency studies, only limited research has been reported to incorporate the activity component in examining evacuation processes, particularly for mass evacuations at a micro-scale. Under this context, this study aims to analyze the activity-based travel pattern and its impact on emergency evacuations in the case of a hypothetical emergency evacuation of Galveston Island, Texas using microsimulation techniques.

In reality, accurately predicting the type of activities (e.g., working, shopping) that people make with regard to location and time in a day is a great challenge, needless to say in an emergency situation. However, it is possible to include some typical activities that could be less subject to uncertainties. In this study, one typical type of daily trip, picking up school-age children, is considered. All households with school-age children are assumed to pick up their children first at the beginning of an evacuation. This study defines the trip chains as the movements from workplaces to schools and then to the destinations. Although it is ideal to include more types of trip activities in the study, the findings could still shed some light on how such type of trip chain movement could potentially affect the evacuation process. This study also employs agent-based microsimulation techniques to model the evacuation process. Microsimulation is capable of modeling the evacuation at the individual-driver level. Therefore, it could help better represent the nature of activity-based models, as well as the dynamics and interactions in evacuations comparing to a traditional static modeling approach.

The remainder of the paper is organized as follows. The second section reviews the studies related to activity-based modeling and its applications in emergency evacuations. The third section describes the study area and research methods. The fourth section discusses the results and findings. The last section concludes the paper with discussions of the findings and future work.

RELATED WORK

Activity-based modeling is built upon the assumption that transportation is a derived demand and travel decisions are resulted from individual activities and needs or wishes of interactions (Hensher & Button, 2000). Its theoretical foundation is linked to the pioneering work of Hagerstrand’s time geography (Hagerstrand, 1970). Chapin (1974) and Fried et al. (1977) also contributed to the intellectual foundation of activity analysis (McNally & Rindt, 2008). The time-geography framework emphasizes that an individual’s activity choice is subject to space and time constrains. The classic four-step transportation modeling framework assumes that there are no linkages among trip generation (trip origins), trip distribution (choice of destinations), modal split (choice of transportation modes), and trip assignment (choice of routes) (Miller & Shaw, 2001). Unlike the classic four-step transportation modeling framework, activity-based models attempt to address the spatial and temporal interconnectivity inherent in travel behavior. Therefore, the activity-based modeling approach captures the dynamic and behavioral aspects of transportation, which are largely overlooked in the traditional modeling system.
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