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Modeling Hurricane Evacuation Traffic: Testing the Gravity and Intervening Opportunity Models as Models of Destination Choice in Hurricane Evacuation

Introduction

Evacuation demand estimation involves if, when, and where evacuation will take place in the case of a hurricane warning. In the context of this report, we at LTRC are specifically concerned with the “where” of the evacuation trip. Assuming we already know which households will evacuate and when they will do so, what determines the locations to which these households will evacuate? In urban transportation planning, this activity is termed “trip distribution.” Several trip distribution models are available in urban transportation planning packages to perform this function. Two of the most popular aggregate trip distribution models, namely the Gravity and Intervening Opportunity Models, are tested in this study to see if they can distribute evacuation trips with sufficient accuracy to warrant their use in evacuation demand modeling.

Objectives

The objectives of this study are to test whether the Gravity and Intervening Opportunity Models (IOM) can successfully reproduce aggregate evacuation destination choice observed in evacuation behavior from Hurricane Floyd, compare the performance of the Gravity and Intervening Opportunity Models in modeling evacuation destination choice, and test the transferability of the Gravity Model by applying the model estimated from the Floyd data to the data from Hurricane Andrew.

Scope

The scope of the research reported in this study is restricted to testing the ability of models commonly used in urban transportation planning to estimate evacuation destination choice at the aggregate level and to test how well a model that is estimated on data from one hurricane can reproduce evacuation behavior in another.

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Principal Investigator:

Chester G. Wilmont

LTRC Contact:
Chester G. Wilmont
Phone (225) 767-9109

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4101 Gourrier Avenue
Baton Rouge, LA 70808-4443
www.ltrc.lsu.edu

Research Approach

The Gravity Model and Intervening Opportunity Model’s ability to model evacuation destination choice was tested by estimating the models on a portion of evacuation data from South Carolina following Hurricane Floyd and then observing how well the models reproduced destination choice at the county level on the remaining data. Because the trip length frequency distribution of households evacuating to friends/relatives or to hotels/motels is different, separate models had to be estimated for each destination type. The Gravity Model predicted evacuation to friends or relatives in 110 different counties with an average error of 1.55 evacuations per county, while the corresponding error for the IOM was 1.64. For evacuation to hotels or motels in 70 different counties, the Gravity Model gave an average error of 1.48 evacuations and the IOM an average error of 1.50. However, when the IOM was modified to make the sequencing of opportunities sensitive to the path of the storm, the modified IOM (termed the extended IOM) performed slightly better than the Gravity Model, with average errors of 1.55 and 1.43 evacuations to friends/relatives and motels/hotels, respectively.

The transferability of the Gravity Model for evacuations to friends/relatives was further tested in this study by applying the model estimated on the Hurricane Floyd data in South Carolina to data from Hurricane Andrew in Louisiana. Transferability was tested by comparing the trip length frequency distributions from the two data sets, the similarity of friction factors from models estimated on each data set, and the ratio of the root-mean-square-error (RMSE) of destination predictions of a locally estimated model to a transferred model on the Andrew data. No significant statistical difference was found between the trip length frequency diagrams or the sets of friction factors at the 95 percent level of significance. The ratio of RMSEs on the Andrew data was 0.67, indicating that the average error of a locally estimated model was 67 percent of that of the transferred model.

Conclusions

The Intervening Opportunity Model, Gravity Model, and Extended Intervening Opportunity Model performed well with relatively little difference in performance among them (less than four percent error in average trip length and less than two percent average error in numbers evacuating to different destinations). If the small differences in performance are taken into account, the extended IOM performed best, followed by the Gravity Model, which is then followed by the IOM. The improvement observed in the extended IOM over the IOM suggests that adjustments to existing models to accommodate features relevant to evacuation can produce improvements in model performance, and should be pursued further. However, the results reported in this study are based on one data set, and the test data set is very similar to the data set on which the models were calibrated. Whether similar studies on other data sets will produce similar results is not known.

When the gravity model calibrated on the Floyd data from South Carolina was transferred to the Andrew data from Louisiana, the transferred model produced an average error in trip distribution (i.e., in origin-destination assignments) that was 50 percent higher than that of a locally-estimated model. The friction factors of the transferred model and the locally-estimated model were not significantly different at the five percent level of significance. Thus, while this is again a single observation of transfer of an evacuation trip distribution model, the results, regarding the inherent transferability of such models are encouraging.

Recommendations

Models of trip distribution that are sensitive to factors commonly influencing destination decisions, such as the location of the destination relative to the projected path of the storm, the level of congestion along the evacuation routes, and the availability of accommodation at the destination, should be developed. In addition, consideration should be given to developing dynamic trip distribution models that are capable of incorporating dynamic conditions on the network and the destination into the distribution process.