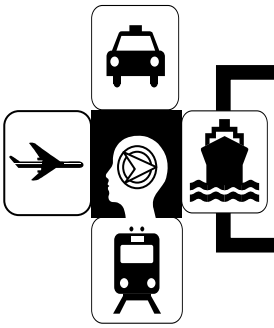
JERSEY DOT'S
"TURNING PROBLEMS INTO SOLUTIONS"



Need a solution?
Think Jersey DOT

Tech Brief

ANALYSIS AND MODELING OF CAPE MAY COUNTY ROADWAY ELEVATIONS AND EVACUATION ROUTES

FHWA-NJ-2005-022 May 2006

SUMMARY

This study determined the evacuation times under varying population, hurricane level, and NJ Routes 47/347 reversal lane operation scenarios for Cape May County, New Jersey. Roadway elevations throughout NJ Routes 47/347 corridor study area were established via a GPS survey to verify whether the roadways are usable in the event of a hurricane. Results of the study show that the current NJ State Police reversal plan is ineffective and needs to be revised as the bottleneck during evacuation would exist south of NJ Route 83, the initiation point of the current reversal plan.

INTRODUCTION & BACKGROUND

Disaster response, to both manmade and natural catastrophes, in the areas of high population density, is centered on evacuating people quickly and efficiently. Being the most densely populated state in the country, New Jersey faces considerable challenges in effectively coordinating and responding to emergencies.

In this project, a microscopic traffic simulation based model was developed to evaluate the effectiveness of the existing State Police "Routes 47/347 Reverse Lane Plan" for Cape May County. This contraflow strategy, also known as lane reversal, was modeled to maximize roadway capacity for the existing network on Routes 47/347. This study determined the evacuation time estimates for various scenarios considering different levels of traffic operations, seasonal area population, hurricane intensity, and behavior response. The behavioral response curves, also called the S-curve models, were applied in this study to approximate behavior responses and to temporally load demand onto the network.

In addition to the traffic analysis of evacuation scenarios, a detailed Global Positioning System (GPS) survey was completed within this project to provide a better estimate of the elevations of the evacuation roadways to determine what roadways will be

inundated under varying storm surge conditions associated with different levels of hurricane strikes.

Results of this study show that the current reversal plan provides very little help in alleviating congestion and reducing evacuation time, as the bottleneck during evacuation occurs south of NJ Route 83, which is the initiation point of the current plan. Consequently, the existing plan is termed ineffective and it is suggested that the plan be revised to extend the contraflow initiation point farther south of NJ Route 83.

RESEARCH APPROACH

The research approach is organized in the following sections:

1. Literature Review

A comprehensive literature review of the previous studies and current practices, development, and implementation work on modeling emergency evacuations was conducted. An evaluation of various behavioral models was also undertaken and the S-curve model was selected to be employed as the loading model in the study.

2. Establishing Roadway Elevations with GPS

In order to identify if the available evacuation routes are passable under the anticipated weather conditions, roadway elevations throughout the Route 47/347 corridor study area were established. It was also necessary to establish the storm surge elevations for various hurricane categories to ascertain the usability of the roads under adverse weather conditions. The establishment of the elevations along the study roadways entailed a detailed GPS survey.

The storm surge elevations for different hurricane categories were obtained from the Philadelphia District of the U.S. Army Corps of Engineers (USACE). A datum conversion from NAVD'88 to NGVD'29 was performed for the GPS surveyed elevations in order to ensure compatibility with the information provided by the USACE. The comparisons that were made between the USACE data and the GPS survey results were localized to maintain accuracy of the predicted water levels under different hurricane categories and to ascertain that only compatible data was compared and analyzed.

In order to evaluate the accuracy of the HES map, the results of the classification of GPS surveyed points were superimposed on the data represented on the HES map. Results of this evaluation affirm that nearly 60% of the GPS surveyed points matched exactly those shown on the HES map and about 40% of the GPS surveyed points were one category removed from the hurricane categories shown on the HES map; usually in the higher (less flood-prone) category than what appears on the map.

3. Development of Studied Simulation Network

Figure 1 shows the simulated study area in green and the secondary study regions (areas within Cape May County but not included in the simulation network) in pink. The lane reversal section begins at the junction of Route 83 in the south and continues

along NJ 47 and NJ 347 to the north, ending at the junction of Route 55 and NJ 47. The simulation software Paramics was selected for modeling the studied evacuation region based on a review of previous studies and current practices of widely used traffic simulation tools.

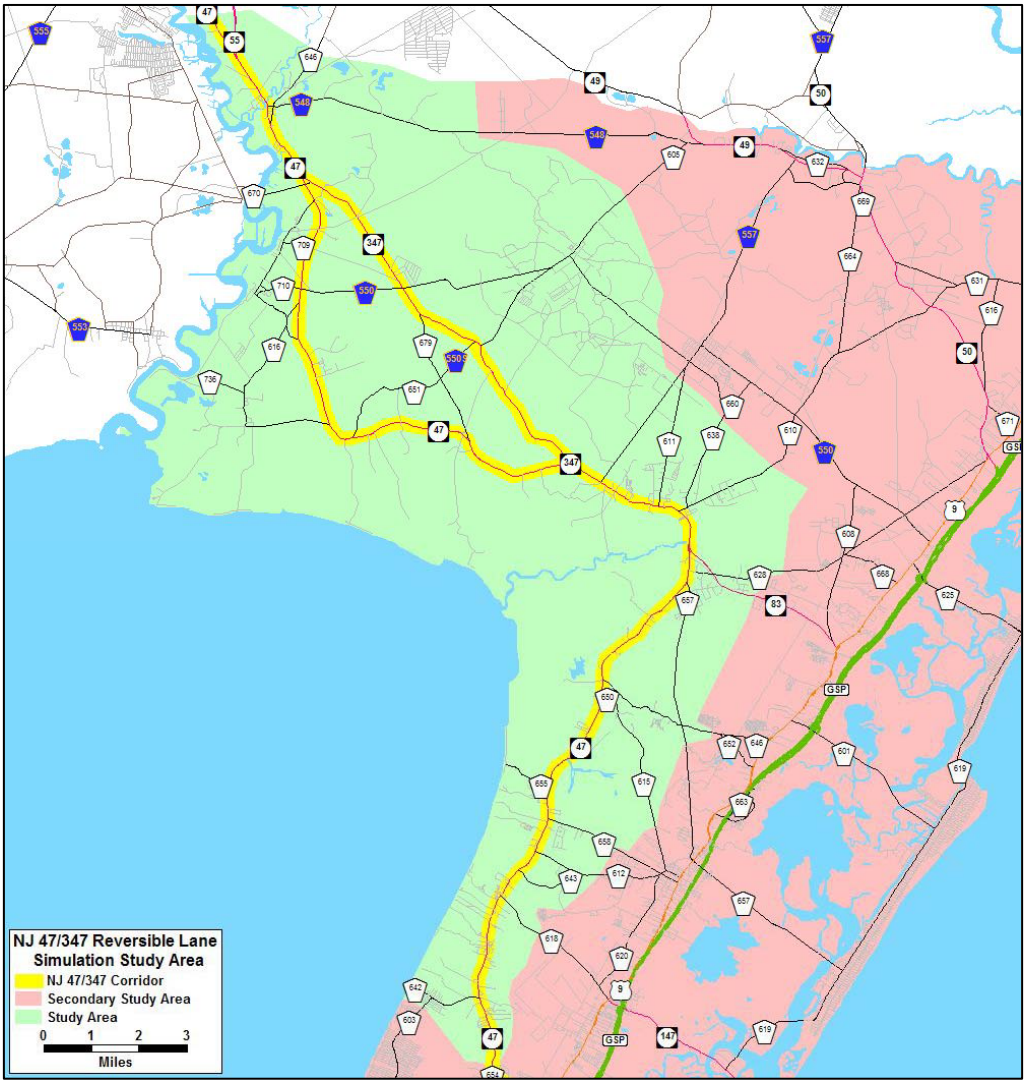


Figure 1. Simulation Study Area

4. Evacuation Demand Generation

The population that needs to be evacuated was determined by estimating the affected population, the evacuee participation rates, and evacuee routings, and distributions.

The affected population was determined from data from Census 2000, an extensive estimation by the USACE of vulnerable housing units, and an inventory of campground sites in Cape May County. The number of affected housing units was then converted into the number of vehicles that would be evacuating on the roadways. The vehicles per housing unit factor varied by the type of housing unit (permanent, seasonal, hotel/motel, and campground) and ranged from 1 to 1.54 vehicles per housing unit. Day

trip volume to the Cape May County region during the peak summer season was not included in the evacuation demand, under the assumption that these persons would stay home if a major storm to Cape May was predicted.

The evacuee participation rates vary by area of inundation, category of storm, and type of housing unit. For lack of information specific to Cape May, the participation rates estimated from the recently completed Delmarva Evacuation Study were used in determining the number of evacuating vehicles from areas under different levels of inundation (Categories 1 to 4).

After estimating the demand originating from each evacuation district, the districts were subdivided in to smaller zones in the primary study area (origin zones for simulation model) on the basis of the density of the roadway network and housing density to be used as the origin traffic assignment zones in the simulation model. The routing of the evacuating traffic was determined on a district by district basis, based on the roadway network available for the evacuating traffic, the assumed police intervention to force routing of evacuees (barricades, detours, etc.), the ultimate destination of the evacuating traffic, and the presumed traffic loadings outside of the study area.

5. Modeling Behavioral Response

A response curve (loading curve) portrays the assumed departure time distribution of evacuees. After a comprehensive research of existing behavioral models, the behavioral response curves or S-curve model was deemed suitable for loading traffic temporally to the simulation network. Three types of responses were simulated; fast, medium, and slow. The response rate signifies how readily the evacuees are expected to respond to an order to evacuate.

6. Formulation of Evacuation Scenarios

24 scenarios for analysis in the study were considered based on the combinations of the following parameters:

1. Traffic Operations - 2 Alternatives: Normal operations (no reversal) and Lane Reversal (current NJ State Police plan)
2. Area Population - 2 Alternatives: Peak Season (estimated as Labor Day weekend) and Off-Peak Season (estimated late September)
3. Hurricane Intensity - 2 Alternatives: Category 1 and Category 2 or higher
4. Behavior Response - 3 Alternatives: Fast, Medium, and Slow Response Rates

7. Calculation of Evacuation Times

After the evaluation of all the scenario parameters were decided upon and calculated, the running of the computer simulations was conducted. Due to the limitation of the Paramics software and the fact that most of the evacuation scenarios required more than 24 hours of simulation time to complete evacuation, the simulations were needed to run in 24 hour segments, or a day 1 simulation and an day 2 simulation. In an attempt to minimize statistical variability between runs, several simulation runs for one scenario, identical in all inputs and parameters except for a random seed were

conducted. The end result of all scenario combinations and random seed iterations required a total of 210 individual simulation runs. Following these runs, the data was then processed with custom processing scripts to extract and calculate the needed performance measures (evacuation time, percentage cumulative demand evacuated with time) for each scenario to allow for the comparison of the results between all scenarios.

The estimated total evacuation time required to completely evacuate the Cape May County area varies between approximately 16.5 and 24.5 after the call for evacuation. In most cases, congestion from insufficient capacity did not dramatically lengthen the time to evacuate, and for most scenarios, the total time to evacuate was determined by the response rate assumed. The only scenarios tested that resulted in significant delays due to congestion were those with the heaviest demand combination of a category 2+ hurricane striking during the peak tourist season. This does not mean that congestion and delay are not experienced during a category 1 hurricane or off-peak evacuation, but implies that any congestion delay and queue buildups that are experienced during the evacuation midpoint when the heaviest demands are experienced are dissipated before the last vehicle to evacuate leaves home.

CONCLUSIONS AND RECOMMENDATIONS

The following summarizes the conclusions and recommendations that were derived from the analysis completed during this study.

Elevation Survey:

The objective of this part of the project was to evaluate the usability of the Route 47/347 corridor for the evacuation of Cape May in an event of a hurricane ranging from category 1 to category 4. Assuming that the storm surge calculations are correct, it was found that the evacuation plans can reasonably rely on the information provided on the Cape May HES map. Sections of the NJ Routes 47/347 corridor that are shown to be inundated on the HES maps for a given level of hurricane should not be used for evacuations if a hurricane of that category should occur.

Evacuation Simulations:

The objective of this part of the project was to estimate the total time required to evacuate the affected population during several combinations of hurricane strike levels, seasonal population, and traffic operation plans under different behavioral response possibilities. Based on simulation runs of the considered scenarios, an evacuation of the Cape May County area for a hurricane strike would require between 16 and 25 hours to complete after the order to evacuate is given. The primary factor affecting the duration of the evacuation was determined to be the assumed behavior responses. The analyzed scenarios showed that the current reversal plan for the Route 47/347 corridor is ineffective in helping evacuate the region. The reasoning behind the ineffectiveness of the reversal plan is that the majority of the traffic that will be evacuated via the Route 47/347 corridor was assumed to enter the corridor at the southern end of the corridor. This is well to the south of the beginning of the planned contraflow section at Route 83.

Therefore, while the addition of capacity in the northern section of the corridor aids the evacuation of those residing near Route 83 and further north, the majority of the evacuating traffic must still utilize the existing one northbound lane (whose flow is limited by the bottleneck caused due to congestion) on the southern section of the corridor to reach the additional capacity provided by the reversed lane.

Short of permanently adding capacity to roadways exiting Cape May County, a revised reversal plan is required to reduce evacuation times. Expanding the work effort beyond the current scope to include an investigation of new reversal plans within the NJ Routes 47/347 evacuation corridor would not require extensive efforts. The human costs that could be incurred should an evacuation not be successful almost demand that these additional simulations be undertaken. An expanded version of this study could be undertaken to extend the simulation study network to include other major roadways in the area, predominantly US Route 9 and the Garden State Parkway. Considering the apparent ineffectiveness of the existing reversible lane plan, investigations into using this corridor to evacuate vehicles from the populated southern areas of Cape May County should be completed. In addition to adding the Route 9 / GSP corridor to the simulation study network, extending the network scope further to the north could address the possible conflicts between evacuees from Cape May with the large evacuating population of Atlantic City. While this would be a significant undertaking, it would provide a much greater understanding of what could happen during a hurricane evacuation across South Jersey and would provide a good tool for State Police and NJDOT to develop new and modify existing evacuation plans. Further work could also be done to determine the effectiveness of a staged evacuation for the Cape May County area. This effort would also require an investigation into the logistics and human behavioral factors that would be encountered in planning and implementing a staged evacuation plan.

FOR MORE INFORMATION CONTACT:	
NJDOT PROJECT MANAGER:	Vincent Nichnadowicz
PHONE NO.	609-530-5963
e-mail	vincent.nichnadowicz@dot.state.nj.us
UNIVERSITY PRINCIPAL INVESTIGATOR	Steven I-Jy Chien, PhD.
UNIVERSITY:	New Jersey Institute of Technology
PHONE NO.	973-596-6083
e-mail	chien@njit.edu

A final report is available online at http://www.state.nj.us/transportation/refdata/research/

If you would like a copy of the full report, please FAX the NJDOT, Bureau of Research, Technology Transfer Group at (609) 530-3722 or send an e-mail to Research.Bureau@dot.state.nj.us and ask for:

Report Title: Analysis and Modeling of Cape May County Roadway Elevations and Evacuation Routes

NJDOT Research Report No: FHWA-NJ-2005-022