Traffic Flow Simulation Model for Neighborhood Hurricane Evacuation

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Abstract: Neighborhood evacuation is one of the main issues in hurricane emergency management planning. Many studies have focused on predicting evacuation along major highways and freeways with no consideration to local streets. This study investigated a new concept for hurricane evacuation (similar to fluid flow in pipelines) using local streets with speed limits (less than 30 mph) in an urban setting. .

1 Introduction

Hurricanes are one of the most catastrophic events resulting in loss of life and property damage. The magnitude of devastation was evident from the aftermath of hurricanes in the Gulf coast in the past few years. Emergency management planning teams play a major role in safeguarding the lives of people in endangered areas by evacuating them to safer locations as efficiently as possible. An evacuation plan is an essential component of an emergency plan. Most of the models do not address the limitations of local streets but focus on major highways and freeways. By observing the past emergency evacuations, it was visible that people (vehicle)had many traffic flow problems along local streets to enter in to a major highway or a freeway. Considering this issue, It was necessary to develop a new model to address the issues related to evacuation along local streets. .

2 Objectives

The objective of this study was to develop a new model to guide the evacuation along local streets with speed limits. The model introduces a new concept of traffic impedance to guide the traffic flow.

3 Modeling Background

The development of traffic assignment models and algorithms have increased during the last decades because of the natural disaster evacuations such as hurricane, flooding, fire and, tsunami. Traffic assignment is the process of searching the equilibrium flow pattern over a given road network. Knight(1924) gave an early description of an equilibrium process through a traffic network. Wardrop (1952) put forward the user-equilibrium (UE) principle and system optimization (SO).

4 Modeling Concepts

This model was developed for the purpose of hurricane evacuation so as to minimize the travel-time during emergency evacuation period. Traffic flow equation is given by:

$$q = ku \qquad (1)$$

Where, q, k, u are traffic flow (veh/hr), traffic density(veh/mile), velocity (mile/hr) respectively.
Assuming that there is no accumulation of vehicles at any junction this can be represented by the following equation:

$$q_{in} - q_{out} = q_{ext} \qquad (2)$$

Where, q_{in} , q_{out} and q_{ext} are traffic flow into the junction, traffic flow out from junction and additional vehicles entering the system or current vehicles existing the system respectively. Also for a closed traffic loop (TL) (coming back to the same point; equivalent to not moving), total impedance to flow will be equal to zero and represented mathematically as:

$$\sum_{TL} I_{im} = 0 \qquad (3)$$

Where, I_j is the impedance of j^{th} link (street) of a closed traffic loop of having n number of links. This tells that for a traffic closed loop network, impedance of links must be equal while considering the optimization of the network by minimizing the travel-time. In this model, it assigns impedance level for each junction depending on the network pattern and the impedance of the network links. That impedance level is called as I_i for every node. The impedance of every link also calculated by given formula, this is derived by literature review and calibration of models.

$$I_{im} = I_i - I_m = R_j q_j^2 \quad (4)$$

Where I_j, R_j and q_j are impedance of j^{th} link, flow resistance coefficient of j^{th} link and flow on the j^{th} link. Here flow resistance coefficient R is given by the following equation:

$$R_j = c_j \left(\frac{L_j}{N_j}\right)^n \quad (5)$$

Here c_j, L_j, N_j, and n are coefficient of impedance (which mainly depends on the pavement condition, parking block factor, shoulder lane, gradient of road), length of the road (link), number of lanes and Network complexity number respectively.

5 Results and Analysis

A typical neighborhood network (Fig. 1) was studied to predict the flow rate on a typical road net work (total of 6 stations and 9 streets (links). There was 1000 vehicles to be evacuated from station #1 to Station #6. The speed was limited to 30 mph. The length of the all the streets (link) were assumed to be 2 miles.In order to determine the flow along each street, 15 simultaneous equations (total of 6 nodes (Eqn. 2) and 9 links (Eqn. 4)) were solved. . The travel time was also calculated for each pathway from staring point (Station #1) to the destination (Station #6). The average travel time for vehicle to evacuate from this zone was approximately between 10-18 min with an average value of 13 min. This model gives reasonable values for travel time. The fastest route (connecting the nodes) was 1-2-7-6 or 1-4-5-6.

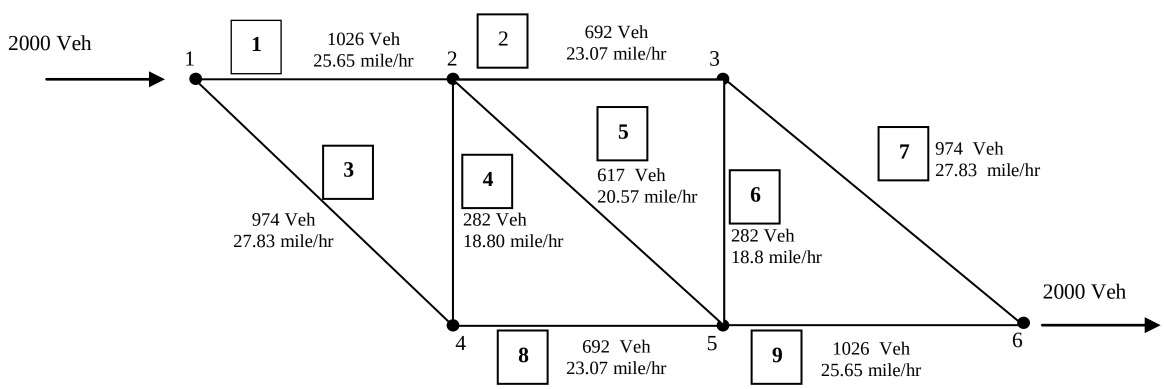

Fig. 1 Typical road network and traffic flow

6 Conclusions

The new model (similar to fluid flow in pipelines), with speed limits, can be used for evacuation of a neighborhood.The impedance paramenter could be used to guide the traffic, higher the impedenace along a street the greater will be the delay.

7 Acknowledgements

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8 References

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