Hurricane Evacuation Strategy With Public Transportation

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PROJECT SUMMARY

Introduction and motivation

Just before a hurricane is predicted to strike an urban area, millions of people evacuate from impact zones to safer regions. It is to be noted that a sizeable percentage of urban residents do not own vehicles (56% of the households in New York City). This research provides a mass evacuation strategy using road public transportation before the strike of a hurricane.

- The evacuation zones, safety regions, and the time of strike are pre-determined.
- Evacuation operations are to commence when the warnings are issued, and end when the hurricane strike is expected to occur.

Approach

We propose a multi-stage approach.

- At the first stage is the network design problem, where pick-up locations are first determined, and then an initial set of routes is generated along these locations. This is done by weighing each location based on the accumulated demand, and favoring multiple routes to pass through a location with higher demand.
- In the next stage, each route is assigned a trip number such that 1) routes with higher demand require more trips, and 2) two successive trips to a route are spaced evenly.
- A simulation tool is used to model the dispatching of the given number of buses, stochastic arrival of evacuees, queueing effects at the pick-up locations, and the transportation of evacuees to the safety regions.
- The results from the simulation serve as an evaluation tool for a network design, and a local search heuristic is proposed to effect positive changes in the network design. This framework enables a decision maker to make the best possible logistical choices with the available resources.

METHODOLOGY

Pick-up location selection

- Feasible set – current bus stops
- Maximize coverage
- Stochastic demand curve assigned to pick-up locations

Creation of sub networks

- Chosen pick up locations are assigned to the closest shelter
- Each shelter acts as the depot in it's sub network

Dispatch sequence of routes

- Iterative addition of routes to sequence
- Trips per route ∝ Route demand

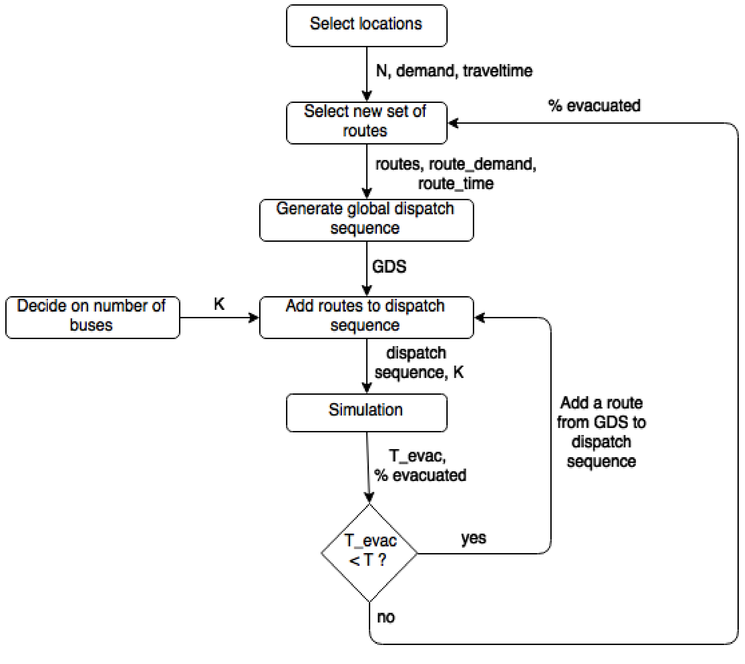
Simulation

- When a bus gets full, it travels directly to the safety location
- Balking, reneging effects at pick-up locations

Route generation

- Initial solution using modified Clark & Wright heuristic
- Local search heuristic based on mixed performances measures

Solution methodology



Network design features

- Heterogeneous bus fleet
- Stop locations
- Shelter locations
- Route set selection
- Road link capacity (congestion)
- Dispatch sequence of routes

Performance measures

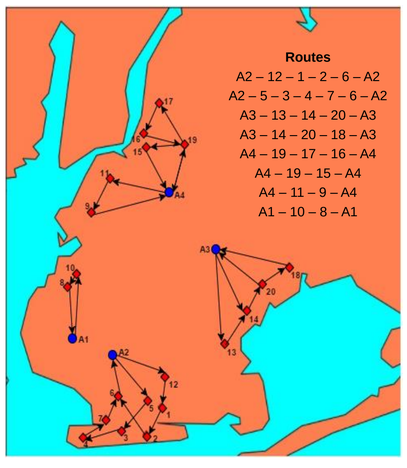
- Percentage of people evacuated
- Waiting time of an average evacuee
- Percentage of dissatisfied evacuees (balked + reneged)
- Accessibility of pick up locations

SIMULATION

Once the design features are set, the discrete-time simulation model represents a real-time hurricane evacuation setup.

1. Each bus dispatched from a shelter along the route in trip-sequence
2. Once a bus reaches the shelter and all the evacuees de-board, is immediately assigned the next route in the sequence.
3. When a bus gets full, it travels directly to the shelter.
4. A percentage of balked and reneged evacuees self-evacuate, which increases the travel time in that link due to congestion.
5. Terminates when the evacuation time window is complete.

Hurricane Sandy - Brooklyn, New York City



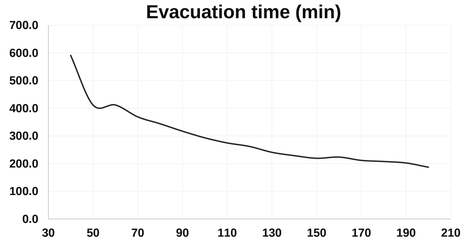
Analysis

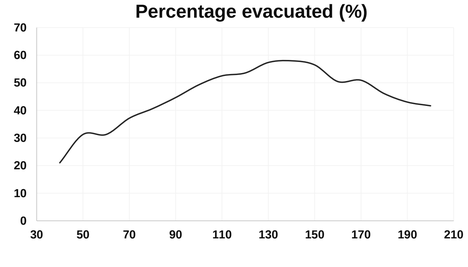
- Capacity of each bus: 56
- 1176 trips needed for 40 buses.
- Optimal number of buses with respect to percentage evacuated can be observed.

Data sources

- Population estimates – NYC Dept. of City Planning (2010)
- Travel time - Google Maps API
- Evacuation zones - NYC Datamine, OEM

Resource sensitivity





Effect of number of buses on performance measures