Using GIS to Develop Evacuation Bus Routes for Transit-Dependent Population

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Some hazardous situations require the evacuation of the general public away from the incident location. Some members of the population may not have access to a personal vehicle at the time an evacuation is ordered. These people are considered to be transit-dependent. Local emergency organizations/departments of transportation may need to provide transportation for this population group.
Several questions need to be asked:

- How many transit-dependent people live within our jurisdiction?
- Where do the transit-dependent people live?
- Do we have enough transportation resources to evacuate them?
- Do we have a location to transport transit-dependents to?
Data Collection

- **Transportation Resources**
  - Location of vehicle depots
  - Inventory of vehicles by depot location
  - Stated capacities of each vehicle

- **Reception Centers**
  - Location of evacuee reception centers
  - Capacity of each reception center

- **Census Data**
  - Population
  - Households
  - Vehicle availability\(^{(1)}\)

\(^{(1)}\) Data may need to be supplemented
Data Analysis [1]

- Transportation Capacity Analysis
  - During an emergency, capacities may need to be adjusted, considering residents may evacuate with their belongings (clothing, medication, pets, etc.)
  - For the purpose of this presentation, an evacuation capacity of 50% of the stated capacity will be used.

- Population Analysis
  - Number of households and household size is available through U.S. Census data
  - Vehicles tenured by household was previously available in the 2000 Census data and is now part of the American Community Survey only.
  - Transit-dependents may be calculated using the above information.
Data Analysis [2]

- Survey data (i.e., vehicle availability) is not available at the census block level.
- This data needs to be spatially joined with census block level data.
Data Analysis [3]

- Average Household (HH) Size can be calculated as follows:

\[
\frac{\text{Population}}{\text{Occupied Households}} = \text{Average HH Size}
\]

- Transit-Dependent Population can be calculated as follows:

\[
\text{No. of HH} \times \sum_{i=0}^{n} \{(% \text{HH with } i \text{ vehicles}) \times [(\text{Average HH Size}) - i]\} \times A^i B^i
\]

Where, 
A = Percent of Households with commuters 
B = Percent of Households in which the commuter will not return home prior to an evacuation
Data Analysis [4]
Data Analysis [6]

• Transit-Dependents: 4,551

• Transportation Resources:
  • Depot A: 35 Buses
  • Depot B: 55 Buses
  • Depot C: 75 Buses
  • Total Transit Capacity: 4,950

• Reception Centers:
  • Reception Center A: 2,500
  • Reception Center B: 500
  • Reception Center C: 2,000
  • Total Reception Center Capacity: 5,000

• It’s important to ensure that enough transit resources exist to evacuate transit-dependents, and there is sufficient capacity at reception centers to accommodate all transit-dependents.
Methodology [1]

- Local planning departments may require special considerations be taken when designing transit-dependent bus routes:
  - Maximum walking distance for transit-dependents to bus stops\(^{(1)}\)
  - Vehicle height and weight restrictions on local roads
  - Additional stops at special facilities (senior communities, nursing homes, etc…)

- For the purposes of this study:
  - A ¼ mile walking distance will be used
  - Vehicle dimensions of 8′-6″ \( \times \) 40′-0″ \( \times \) 10′-9″ H\(^{(2)}\)
  - Vehicle loaded weight of 20 tons\(^{(2)}\)
  - A transit bus capacity of 60 (30 when applying 50% evacuation capacity reduction)

\(^{(1)}\) The American with Disabilities Act (ADA) has no specifications about walking distance from a person’s home to a bus stop.

\(^{(2)}\) 2000 Highway Capacity Manual
Methodology [2]
Methodology [3]
Methodology [4]
Methodology [5]

- Using a pre-screening tool, like the one available through New York State DOT, bridges, tunnels and roadway segments that cannot accommodate a transit bus, can be avoided.

- If a tool is not available, local planning departments may have this information, or a road survey of local roads may be necessary to document vehicle restriction signage.
Methodology [6]

• Census Block centroids can be selected spatially within a ¼ mile distance of a selected bus stop.

• Fine tuning your selection may be required, as a spatial selection is a linear distance, not walking distance.
**Methodology [7]**

- Transit-Dependent Bus Stops should be given specific attributes, such as location, a unique bus stop identifier and anticipated transit-dependent utilization.
- Census Block Centroids should be given assigned bus stop ID numbers.
  - This allows the opportunity for cross-referencing and
  - Guards against double counting of transit-dependent persons
Methodology [8]
Methodology [9]

- Bus stops are linked to create bus routes.
- Bus routes are designed to begin at bus depots and end at reception centers.
- Bus routes should generally maintain an outward direction from the incident location once transit-dependents board the bus.
- Bus routes should be given specific attributes such as, bus depot, reception center, a unique route identifier and anticipated transit-dependent utilization.
Methodology [10]

- Bus stop transit dependent utilization can be summed along a bus route to estimate an anticipated bus route utilization.
- The anticipated number of buses can be calculated as follows\(^{(1)}\):

\[
\frac{Transit \ Dependent \ Utilization}{Evacuation \ Bus \ Capacity} = No. \ of \ Buses
\]

\(^{(1)}\) It is important to round this number up to nearest whole number.
Results [1]
Results [2]
Summary [1]

- Accurate record keeping ensures a realistic allocation of resources.
  - 34 Buses are needed from Depot A (35 Available)
  - 51 Buses are needed from Depot B (55 Available)
  - 73 Buses are needed from Depot C (75 Available)
- A total of 158 Buses were needed, with a total evacuation capacity of 4,740 (96% occupancy rate)
  - It is practically impossible to achieve a 100% bus occupancy rate due to the spatial distribution of transit-dependent population, and other requirements deemed appropriate by local planning departments.
  - Different combinations of bus stops can achieve higher bus occupancy rates. Several iterations may be needed.
Accurate record keeping ensures transit-dependent population are sent to reception centers with sufficient capacity.

- 2,355 transit-dependents are sent to Reception Center A
  - (Capacity of 2,500)
- 221 transit-dependents are sent to Reception Center B
  - (Capacity of 500)
- 1,975 transit-dependents are sent to Reception Center C
  - (Capacity of 2,000)
Summary [3]

- Because an evacuation requires the movement of a large group of people, bus routes are going to require multiple buses to accommodate everyone.

- Planners should take into account the severity and nature of an emergency to determine bus headways for each route.
  - Forecasted emergencies have the benefit of allowing residents to pack belongings and secure their home in advance. Therefore, buses could be dispatched with longer headways.
  - Fast-breaking emergencies that would require the immediate evacuation of the general public need to have buses dispatched as soon as they are available.
Summary [5]

- It should also be noted that most transit-dependent persons may choose to rideshare with a neighbor or friend. Local planners may decide on a rideshare factor to apply to the transit-dependent population that would reduce the transportation resources necessary for evacuation.
Applications

- GIS files of the bus routes and applicable data can serve many useful purposes:
  - Route turn sheets can be developed for the drivers to use in the event of an emergency.
  - If a roadway segment becomes impassable during an emergency, a bus dispatcher can easily identify which bus routes are affected. Dispatchers could then reroute the affected bus routes.
  - GIS gives dynamic flexibility to local planners depending on the varying nature of the emergency.
  - Local planners could update transit-dependent estimates annually based upon population growth rates, and quickly update emergency plans based upon the updated data.
  - Web mapping could be made available to the general public so they can easily identify which bus stop is closest to their home.
Questions???

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