Modeling transit-assisted hurricane evacuation through socio-spatial networks

Supplementary File

1. Construction of home-workplace-neighborhood social network among households

Each synthetic household was assigned a total number of *n* social links. *n* is drawn from a Poisson distribution with a parameter λ that indicates the average number of links in the network. Among the *n* links, a uniformly distributed random integer *k* was then generated between 0 and *n* to simulate the household's workplace connections. From the synthetic workplaces of household members, *k* colleagues were selected at random and the colleagues' households were linked to the household. The rest of *n*-*k* social links were randomly wired to other households in the same block group as their residential neighbors. These procedures were repeated for every household, which completed a home-workplace social network of the study area (Yang, et al. 2019).

To find the best estimator for λ (the average number of links per household), it was varied from 2 to 8 with an increment of 1 to construct different network scenarios. We simulated evacuation curves for different λs and checked which λ produced results closest to the actual observation. We found that the network structure with an average of four social links (λ = 4) produced an evacuation rate of 53.2% (95% CI: [52.6, 54.3]), the closest to the empirical evacuation rate of 53% (Dash, 2002). Thus, this social network with λ = 4 was selected to further explore the spatial dynamics of evacuation behavior and simulate evacuation traffic for evaluation (Yang, et al. 2019).

2. Setting households' evacuation thresholds

Surveys conducted after major hurricane events were used to estimate households' evacuation thresholds. First, a logistic regression was run on the basis of survey data collected by Irwin and Hurlbert (1995) to identify household characteristics contributing to evacuation from Hurricane Andrew in 1992. The dependent variable indicated whether each of 466 households in southwestern Louisiana evacuated from Hurricane Andrew, following the analysis by Wilmot & Mei (2004). Independent variables included household type (mobile home, single family house, multi-family building, and others), ownership (owned or rented), size of household members, marital status, age, race, gender of householder, and presence of children. In addition, a binary independent variable was included to indicate whether a mandatory evacuation order was issued or not. The significant results from this logistic regression model are shown in Table S1, with a corresponding R^2 of 35%. For example, as a reflection of the vulnerability context associated with a household's risk perception, living in a mobile home has a significant and strong positive effect on the likelihood of evacuation. In contrast, less vulnerable households living in a single-family home were less likely to evacuate.

Table S1. Household characteristics that significantly contribute to evacuation tendency

Variable	**Coefficient**	**Significance**
Intercept	-0.8000	0.0769
Living in a mobile home	2.3613	0.0002
Living in a single-family house	-0.8580	0.0474
Evacuation order given	1.2346	<0.0001
Presence of children	0.6186	0.0127
Female householder	0.3424	0.0029
Senior householder (Age > 65)	-0.9791	0.0369

Second, the results of this logistic regression model were applied to estimate the evacuation tendency of every household in the Florida Keys as a value ranging from 0-100%, as presented in Table S2. Overall, the model predicted a 53% evacuation rate of households in the

Florida Keys, which is consistent with the observed rate during Hurricane Georges (Dash 2002, Dash and Morrow 2000).

Table S2. Assignment of household evacuation thresholds based on evacuation tendency*

Evacuation tendency	Evacuation threshold T_i	% of households	Supporting sources
0-0.37	Stayer (decline to evacuate)	12.5	Dash (2002)
0.37-0.38	1	10.9	
0.38-0.4	0.8	12.3	
0.4-0.5	0.5	9.9	Equal interval assignment
0.5-0.6	0.4	8.3	
0.6-0.7	0.3	21.6	
0.7-0.8	0.2	4.1	
0.8-0.9	0.1	5.3	
0.9-1	0	15.2	Horney (2009)

*****(Yang et al. 2019)

Based on the predicted evacuation tendency from this regression model, each household in the agent-based model was assigned an evacuation threshold, assuming that households with lower tendency to evacuate would have higher thresholds. The distribution of evacuation threshold assignments for the Florida Keys presented in Table S2 was estimated using the regression model with Census data for the Florida Keys. The estimated proportions were partially validated with results of evacuation surveys for Hurricane Isabel (Horney 2009) and Hurricane Georges (Dash 2002). On one hand, the survey of 2003 Hurricane Isabel indicated 12.5% of residents in the affected area of North Carolina chose to evacuate even though none of their neighbors did (Horney 2009). To approximate this observed rate, households with the highest evacuation tendency (> 0.9) were assigned a threshold value of zero; these accounted for 15.2% of households in the Florida Keys study area. On the other hand, the survey of Hurricane Georges showed about 35% of respondents would “only consider what is best for them no matter what authorities say” (Dash, 2002), and those households were reluctant to evacuate. To approximate this rate, households with an extremely low evacuation tendency (< 0.4) were either designated as stayers or assigned extremely high thresholds (0.8 and 1.0). As indicated in Table 3, these three categories accounted for a total of 35.2% of households in the study area. Thresholds for the rest of the households were assigned using an equal interval method.

3. TRANSIMS simulation setting

Table S3. Parameters for Traffic Simulation*

Parameter	Value
WALK_SPEED	1.34 m/s
LEFT_TURN_PENALTY	15
RIGHT_TURN_PENALTY	5
UTURN_PENALTY	20
MAX_CIRCUITY_DISTANCE*	50000 meter
DISTANCE_VALUE	1
VEHICLE_TIME_VALUE	1

*MAX_CIRCUITY_DISTANCE – a parameter used by the path-building algorithm to determine if a node path is out of range. For example, this parameter will limit the trip distance to 50,000 meters longer than the straight-line distance between the origin and destination (USDOT 2009)

4. Optimized pick-up locations for bus evacuation

Table S4. Sequence of 24 Optimized Pick-Up Locations on the Bus Evacuation Route

Stop	Facility Name	Stop	Facility Name
1	St Peter's Episcopal Church	13	Key Colony Beach City Hall
2	Monroe County Senior Ctr	14	Whispering Pines Trailer Park
3	Impact Community Church	15	Layton City Hall
4	American Red Cross US Navy	16	Bay Harbour Condominium
5	American Red Cross	17	First Baptist Church
6	United Pentecostal Church	18	Treasure Village Montessori
7	Sugarloaf Lodge	19	San Pedro Catholic Church
8	Transfer Station-Cudjoe	20	Montessori Island School
9	Dallas Mc Donald Senior Ctr	21	Dolphin Children's Montessori
10	Wesley House Family Svc	22	Odyssey Healthcare Inc
11	St Columba Episcopal Church	23	Key Largo School
12	ABC Day School	24	Pumpkin Cay Condominium

5. Car-based evacuation traffic: Simulated vs. Observed

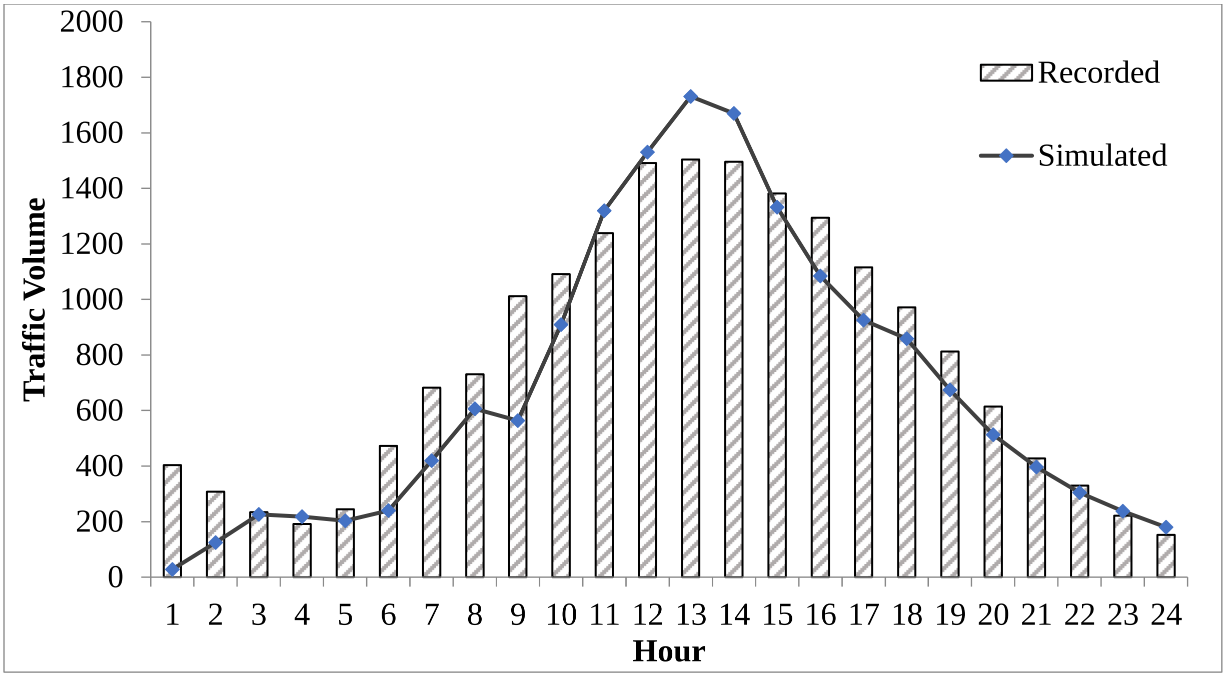

Figure S1. Simulated and recorded hourly traffic volume on September 23, 1998. The Y axis represents the traffic volume per hour; X axis represents the 24 hours of a day. Hour 1 represents 1:00, and so on (adopted from Yang, et al. 2019).

References

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