

The logistics of household hurricane evacuation

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Abstract Although there is a substantial amount of research on households' hurricane evacuation decision making, there is much less research on the logistical issues involved in implementing those evacuations. The limited research on household evacuation logistics has consistently shown that most evacuees stay in the homes of friends and relatives or in commercial facilities rather than in public shelters. However, evacuation logistics—which can be defined as the activities and associated resources needed to reach a safe location and remain there until it is safe to return—encompasses a much broader range of behaviors than this. The present study extends previous research by reporting data on other aspects of evacuation logistics such as departure timing, vehicle use, evacuation routes, travel distance, shelter type, evacuation duration, and evacuation cost. Hurricane Lili evacuation data at the county level are generally consistent with the data from previous hurricanes, but there is notable variation across counties studied here. There were only modest correlations of demographic and geographic variables with the evacuation logistics variables, a result that indicates further research is needed to better understand what happens between the time an evacuation decision is made and the time re-entry is begun. Moreover, research is needed to understand the logistics of evacuation by special populations such as transients and households with disabled members.

Keywords Hurricanes · Evacuation · Traffic management

1 Introduction

As a hurricane approaches, coastal residents must monitor information from a variety of sources to decide whether and when to evacuate. Research over the past four decades has made considerable strides in identifying the variables that affect this decision (Baker 1991, 2000; Dash and Gladwin 2007; Lindell et al. 2007; Phillips and Morrow 2007). Coastal residents' primary information sources are the news media, authorities, and peers (friends,

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relatives, neighbors, and coworkers); their primary concerns are whether their communities are likely to be struck and, if so, how the hurricane will affect them when it arrives. Although they might also be concerned about looting and storm damage to their homes, such issues deter few households from evacuating.

In addition to deciding whether to evacuate, coastal residents must consider the logistics of evacuation. That is, they must decide when to evacuate, where they will go, what mode of transportation to use, how many vehicles to take, what route to travel, and what type of accommodations to use. They also need to consider where to obtain evacuation route information, how long they will be away from their homes and, thus, how much the evacuation will cost them. Unfortunately, there is substantially less research on these issues than on evacuation decision making. All of these decisions are likely to be affected by people's geographic locations (how far they are inland or along the coast from the point of landfall) and household characteristics—how many people are there in the household, whether they have a functioning vehicle, and especially whether they have enough money to pay for the evacuation expenses.

Evacuation analysts and emergency managers in risk counties need data on evacuation logistics so they can model households' evacuation behavior more accurately (Lindell 2008; Lindell and Prater 2007a). Local emergency managers in host counties need data on evacuees' shelter behavior so they can forecast how many households will need accommodations in congregate care facilities. Finally, planners need data on evacuation durations and costs so they can anticipate when households are likely to return and how the evacuation is likely to affect local business revenues. Such information would also be useful to local officials when they tradeoff the potential costs of false positive (economic costs to government, businesses, and households if there is an evacuation but the storm strikes elsewhere) and false negative (lives lost if a storm strikes a community that has not evacuated) decision errors (Lindell and Prater 2007b).

Unfortunately, only a limited amount of research has attempted to examine issues of *evacuation logistics* that can be defined as the activities and associated resources needed to reach a safe location and remain there until it is safe to return. This definition of evacuation logistics is consistent with the definitions of logistics provided in a variety of textbooks on the topic. For example, “[l]ogistics describes the entire process of materials and products moving into, through, and out of a firm” (Johnson and Wood 1996, p. 4), “[b]usiness logistics is the study and management of goods and service flows and the associated information that sets these into motion” (Ballou 1987, p. 6), and “[l]ogistics is concerned with physical and information flows from raw material through to the final distribution of the finished product” (Rushon et al. 2000, p. 4). Although households sometimes begin their evacuation preparations before they make a final evacuation decision, most of these activities take place between the time a household makes its evacuation decision and the time it arrives at its evacuation destination. Most empirical research on household evacuation logistics has addressed only the very first phase of the process—the time between an evacuation decision and departure from the home (Dixit et al. 2008; Fu and Wilmot 2004, 2006; Fu et al. 2007) and the activities that take place during that time (Kang et al. 2007; Lindell et al. 2005).

Other aspects of evacuation logistics have been examined only as an incidental sequel to households' evacuation decisions. For example, Perry et al. (1981) devoted most of their attention to the antecedents of households' flood evacuation decisions, but also reported some findings regarding evacuation logistics. Specifically, 42% of the evacuees lacked a specific plan that identified a safe route to an appropriate destination, but the possession of a plan did increase the likelihood of evacuation (p. 126). Moreover, 74% used their own

vehicles, 13% caught rides with relatives or friends, and 13% used official transportation. Further, 18% of evacuees used congregate care facilities but this ranged from 3% in the two communities to 26 and 29% in the two other communities.

Baker (2000) summarized the results of his extensive series of hurricane evacuation studies as indicating that it is rare for more than 15% of evacuees to leave before local officials issue a warning, that people prefer to leave during daylight hours, and that non-surge areas leave later than residents closer to the coast. In addition, he reported that evacuees take 65–75% of the registered vehicles, 5% take trailers or recreational vehicles, and only about 5% of evacuating households require assistance—most of whom obtain rides with peers. Finally, consistent with the comprehensive review by Mileti et al. (1992), he reported that only 15% go to public shelters that are primarily occupied by ethnic minorities, the poor, and later departures.

Dash and Morrow (2001) reported evacuation data from the Florida Keys during Hurricane Georges. They estimated that evacuees took 1.7 vehicles per household and that 19% of the evacuating households remained within the Keys despite county officials' order to evacuate to the mainland.

Dow and Cutter (2002) addressed four specific hurricane evacuation logistics issues in their study of the 1999 Hurricane Floyd evacuation—the number of vehicles taken, the timing of evacuation, travel distances, and the availability and use of road maps when selecting specific evacuation routes. They found that about 25% of evacuating households took two or more cars. Moreover, they reported that 5% of their respondents evacuated before any evacuation orders were issued, 61% evacuated on the day of the evacuation orders, and 31% evacuated the day after the evacuation orders. They also found that the majority of respondents carried road maps but just half of them used these maps to determine their evacuation routes. Instead, they relied heavily on the interstate system with which they were most familiar. This produced extreme congestion on I-26 and I-95 during the evacuation, with 9% evacuating in-county, 32% evacuating in-state, and 56% evacuating out-of-state.

Whitehead (2003) determined that evacuees in Hurricane Bonnie traveled an average of 178 miles, 70.2% stayed with friends or family, 15.7% stayed in hotels or motels, and 5.5% stayed in public shelters. He found that direct costs varied with shelter type; evacuees who stayed in hotels spent an average of \$381 during their evacuations, those who stayed in the homes of friends or family spent an average of \$123, and those who went to public shelters spent an average of \$121.

Most recently, Siebeneck and Cova (2008) reported that 90.5% of their Hurricane Rita evacuees took personal vehicles—averaging 1.5 vehicles per household—and evacuated an average of 198 miles. There was a statistically significant correlation ($r = 0.30$) between evacuation distance and evacuation return date.

In summary, there is extensive evidence regarding some aspects of evacuation logistics such as the primary reliance on the homes of friends and relatives and the low level of utilization of public shelters. However, there is substantially less information available about other aspects of evacuation logistics such as departure timing, distance, duration, and cost. Thus, the purpose of this study is to provide information about additional aspects of evacuation logistics during the Hurricane Lili evacuation. In addition, the study has five research hypotheses and two research questions about the possible predictors of evacuation logistics variables. The research hypotheses are:

H1 Proximity to the coast will be significantly related to departure timing, vehicle use, evacuation route information sources, distance, duration, shelter type, and cost

- H2 Evacuation departure timing will be related to vehicle use, with households that rely on friends/neighbors or official transportation leaving later than those taking their own vehicles
- H3 Evacuation departure timing will be related to evacuation distance, shelter type, evacuation duration, and cost, with households that depart later traveling farther, relying more on commercial facilities, staying away longer, and costing more
- H4 Evacuation distance will be related to evacuation duration and cost, with households that travel farther staying away longer and paying more
- H5 Shelter type will be related to food and lodging cost, with households that stay in commercial facilities paying more

The research questions are:

- RQ1 Are demographic variables related to departure timing, transportation mode, evacuation distance, shelter type, evacuation duration, and evacuation cost?
- RQ2 Do counties differ significantly in evacuation distance, duration and cost?

2 Method

Hurricane Lili originated on September 16, 2002, off the west coast of Africa and moved steadily westward; it struck Jamaica on September 28 as a Tropical Storm. The storm reached hurricane strength by September 30, traveling steadily on a northwest track toward the central Texas coast from September 28 until mid-afternoon on October 2 when it intensified to a Category 4. The National Hurricane Center issued a hurricane watch between St. Louis Pass, Texas and the mouth of the Mississippi River at 4 pm, Central Daylight Time on Tuesday, October 1. They upgraded this to a hurricane warning departure for the coast between High Island, Texas and the mouth of the Mississippi River by 4 am on Wednesday, October 2 (Lindell et al. 2005). The storm made landfall at 1 pm on October 3 as a Category 1 hurricane.

Local officials in Chambers County decided to recommend evacuation for limited areas within their county at 1:30 pm on Wednesday, October 2 (Prater et al. 2004). The population in the recommended evacuation area was less than 1% of the county. Local officials in Jefferson County issued an evacuation recommendation at 6 am on Wednesday, October 2 and Orange County officials also decided to evacuate at the same time. Jefferson and Orange Counties issued countywide evacuation recommendations. Both Cameron and Vermilion Parishes in Louisiana decided to recommend evacuation on Wednesday, October 2. At that time, Louisiana classified evacuations into three types: voluntary, recommended, and mandatory whereas the state of Texas could only issue an evacuation recommendation (Wolshon et al. 2005). Six months after the hurricane, the Texas A&M University Hazard Reduction & Recovery Center began a survey of households in the Louisiana parishes of Vermilion and Cameron and the Texas counties of Orange, Jefferson, and Chambers.

2.1 Sample

As previously reported by Lindell et al. (2005), 200 households in each of the five parishes/counties were selected through a random sampling process. The survey sampling procedure was designed to yield 200 households in each of the five parishes/counties. A list of

randomly sampled names from each ZIP Code was generated to approximate the desired number of households within county. Following Dillman's (1999) procedure, each member of the sample was sent a packet containing a questionnaire and those members of the sample who did not return a completed questionnaire within 3 weeks were sent a second packet. This process was repeated until non-respondents had been sent three packets. There were 507 households that provided usable questionnaires for this research, a gross response rate of 50.5% that exceeds the 31–52% range obtained by Mileti and Fitzpatrick (1993) and is much higher than the response rates obtained in recent HRRC studies of coastal residents (25.8% by Prater et al. 2000; 22.4% by Lindell et al. 2001). However, there was only a modest degree of bias in the demographic characteristics of the sample compared with those of the counties from which they were drawn. The percent married was 68.0 in the sample vs. 57.3 in the population. Other demographic variables were age (46.3 vs. 46.7 years in the sample and population, respectively), female (54.0 vs. 50.8 percent), white (78.0 vs. 80.2 percent), household size (3.0 vs. 2.5 persons), average income (42.5 vs. 49.1 thousand dollars), and home owners (95 vs. 74.5 percent).

2.2 Measures

The questionnaire included both open-ended and closed-format questions. Sources of evacuation route information were measured by six items (written materials received before the event; local officials' recommendations during the event; news media recommendations during the event; familiarity with the route based on past experience; and expectation about the relative time, safety, or convenience of the route). Each item was rated on a 1 (=Not at all) to 5 (=Very great extent) scale. The evacuation route used was measured by a free response item asking the respondent to list all highways taken on the way to the evacuation destination. Evacuation transportation was measured using four variables—the first of which was the evacuation transportation mode (personal vehicle, friend's vehicle, or official vehicle). Respondents who indicated using a personal vehicle were asked to indicate their household's number of vehicles taken, number of trailers taken, and whether any high profile vehicles such as recreational vehicles were taken (0 = No; 1 = Yes). The respondent was asked to report the name of their evacuation destination city. Evacuation distance was then determined by employing a Geographical Information System (GIS) to calculate the direct distance between evacuees' origins and destinations as well as the highway distance traveled. Direct distances between evacuees' origins and destinations were calculated based on the 224 respondents who provided information on their destination city. Highway distances were computed using the 133 responses that were provided in response to the evacuation route question. Evacuation shelter type was coded as friend/relative, commercial (hotel/motel), congregate care (public shelter), or other (e.g., second home). Evacuation duration was recorded as the number of days the respondent reported having spent away from home and evacuation cost was the sum of the respondent's entries for transportation cost, food cost, lodging cost, and other cost. Respondents' demographic characteristics included their age, gender, ethnicity (white, black, Hispanic, Asian, and Other), marital status (married, single, widowed, and divorced), and education (grade school, some high school, high school graduate or GED, some college, college graduate, or postgraduate). Demographic characteristics also included the number of persons in the household, the number of children in the household, annual household income (less than \$15,000; \$15,000–24,999; \$25,000–34,999; \$35,000–49,999; more than \$50,000), and home ownership (renter or owner). Households' distances from the coast were calculated using GIS.

3 Results

Table 1 displays the variables' means (M), standard deviations (SDs), and analysis sample sizes (which vary due to item-specific non-response). Among the responding households, 53.6% (263/491 persons) of those surveyed evacuated from Hurricane Lili. There were significant differences by parish/county, with an evacuation rate of 66.1% in Vermilion Parish, 86.8% in Cameron Parish, 55.8% in Orange County, 46.1% in Jefferson County, and 11.7% in Chambers County. Approximately 31% of the respondents left on Tuesday (10/1), 62% left on Wednesday (10/2), and 7% left on Thursday (10/3). When choosing an evacuation route, people tended to consider their familiarity with the route based on past experience ($M = 3.93$) and their expectations about the relative time, safety, or convenience of the route ($M = 3.83$). They relied less on recommendations by peers ($M = 2.79$), the news media ($M = 2.66$), and local officials ($M = 2.48$). Notably, 75.9% of the respondents reported that they did *not* consider written materials distributed before the hurricane; this was the source of information least utilized by evacuees ($M = 1.61$). The overwhelming majority of evacuees (90%) traveled in their own vehicles, whereas 9% rode with peers and less than 1% used public transportation. The average number of vehicles per household was 1.7, the average number of trailers per household was 0.35, and 7% of the households took high profile vehicles.

As indicated by Fig. 1, which displays the frequency of use of different evacuation routes, I-10 was the most frequently used evacuation route, especially the section between Beaumont and Houston. Because of the high evacuation rate in Louisiana parishes, sections of Louisiana State Highways 14 and 27 between Cameron and Lake Charles were used frequently as were some sections of US-69, US-96, SH-82, I-49, and US-171. Lake Charles LA was the most common shelter destination (16/263 = 6.1%), and Houston was the second most common (14/263 = 5.3%), but evacuation destinations varied by state. Over half the evacuees leaving the three Texas coastal counties headed north to cities in East TX. By contrast, 32.3% of Vermilion Parish evacuees went to nearby cities in Southwest LA and 35% of Cameron Parish evacuees went to West Central LA.

The average evacuation distance was 192.50 miles and approximately 54% of the evacuees stayed with friends or relatives, 29% stayed in commercial facilities, and 3% stayed in public shelters. On average, evacuees were away from their homes for 2.33 days, which cost them \$68.35 in transportation costs, \$64.85 in food costs, \$46.90 in lodging costs, and \$28.47 in other costs, for a total of \$228.73 and a daily average of \$111.84.

Table 2 displays a matrix of intercorrelations among all variables, which shows that, with the exception of personal experience, most sources of information about evacuation routes (Variables 12–17) were positively correlated ($0.14 \leq r \leq 0.76$), indicating that those who used any of these sources tended to use multiple sources. Those who chose their route based on familiarity derived from personal experience were no more or less likely to rely on other sources of evacuation route information ($0.04 \leq r \leq 0.10$). In addition, there was a significant tendency for those who took more vehicles to take trailers ($r = 0.57$) and those with trailers to take recreational vehicles or motor homes ($r = 0.20$). Finally, there was a tendency for the different categories of cost (Variables 30–32) to be significantly intercorrelated with each other ($0.38 \leq r \leq 0.58$).

H1 was supported by the significant correlations of coastal proximity with departure timing, evacuation route information sources, vehicle use, but not shelter type. Specifically, those farther from the coast tended to evacuate later ($r = 0.14$) and rely more on the media ($r = 0.12$) and less on personal experience ($r = -0.23$). They also were more likely to

Table 1 Means, standard deviations, and sample sizes

| Variable | M | SD | N |
|----------------|-----------|-----------|-----|
| 1. Age | 46.310 | 21.81 | 261 |
| 2. Female | 0.54 | 0.50 | 261 |
| 3. White | 0.78 | 0.41 | 258 |
| 4. Married | 0.68 | 0.46 | 260 |
| 5. HHsize | 2.98 | 3.08 | 263 |
| 6. Children | 0.79 | 1.12 | 263 |
| 7. Educ | 2.93 | 1.14 | 258 |
| 8. Income | 3.48 | 1.44 | 240 |
| 9. HmOwn | 0.95 | 0.22 | 258 |
| 10. DisCst | 30,573.03 | 15,628.68 | 209 |
| 11. DecDat | 1.68 | 0.66 | 263 |
| 12. WritMat | 1.61 | 1.18 | 241 |
| 13. RecOff | 2.48 | 1.52 | 246 |
| 14. RecMed | 2.66 | 1.55 | 244 |
| 15. RecPeers | 2.79 | 1.50 | 239 |
| 16. PersExp | 3.93 | 1.41 | 247 |
| 17. Expect | 3.83 | 1.40 | 249 |
| 18. OwnVeh | 0.90 | 0.29 | 255 |
| 19. RideOther | 0.09 | 0.29 | 260 |
| 20. VehNum | 1.58 | 1.10 | 263 |
| 21. TrlrNum | 0.35 | 0.86 | 263 |
| 22. RecVeh | 0.07 | 0.24 | 243 |
| 23. EvacDist | 192.50 | 292.89 | 224 |
| 24. FrRelHom | 0.54 | 0.50 | 260 |
| 25. HotelMotel | 0.29 | 0.45 | 260 |
| 26. PubShltr | 0.03 | 0.17 | 258 |
| 27. EvacDays | 2.33 | 1.24 | 263 |
| 28. CostTran | 68.35 | 156.83 | 263 |
| 29. CostFood | 64.85 | 84.11 | 263 |
| 30. CostLodg | 46.90 | 101.69 | 263 |
| 31. CostTotal | 205.60 | 318.31 | 263 |

Age respondent age, *Female* respondent gender, *White* respondent ethnicity, *Married* respondent marital status, *HHsize* total number of persons in household, *Children* number of children under 18, *Educ* respondent education, *Income* annual household income, *HmOwn* home owner, *DisCst* straight line distance to coast, *DecDat* date of decision to evacuate, *WritMat* written materials received before the hurricane, *RecOff* officials' recommendations during the hurricane, *RecMed* news media recommendations during the hurricane, *RecPeers* peers' recommendations during the hurricane, *PersExp* personal experience with the route, *Exp* personal expectations about route time, safety, or convenience, *OwnVeh* evacuated in own vehicle, *RideOther* rode with others, *VehNum* number of vehicles taken, *TrlrNum* number of trailers taken, *RecVeh* recreational vehicle taken, *EvacDist* direct distance from home to evacuation destination, *FrRelHome* stayed with friends or relatives, *HotelMotel* stayed in a hotel or motel, *PubShltr* stayed in a public shelter, *EvacDays* number of days evacuated, *CostTran* transportation cost, *CostFood* food cost, *CostLodg* lodging cost, *CostTotal* total evacuation cost

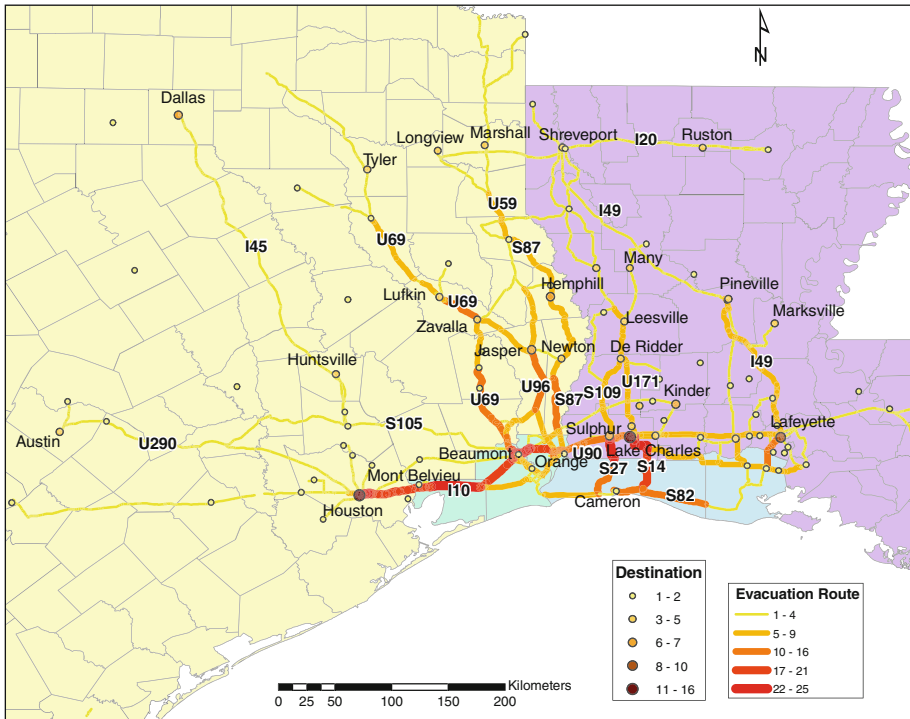


Fig. 1 Primary evacuation routes and destinations

ride with friends or neighbors ($r = 0.15$) and take fewer vehicles ($r = -0.27$) and trailers ($r = -0.47$).

H2 was not supported because the correlation of evacuation decision timing with vehicle use was not statistically significant. Households relying on friends/neighbors for transportation left no later than those taking their own vehicles. Contrary to H3, evacuation decision timing is not significantly related to evacuation distance or shelter type. Moreover, it is significantly negatively ($r = -0.17$)—rather than positively, as hypothesized—related to evacuation duration, with households that depart later staying away for shorter durations. Contrary to H4, evacuation distance was not significantly correlated with evacuation duration or evacuation cost. Nor was it related to shelter type. However, consistent with H5, shelter type was related to evacuation cost; households that stayed with friends and relatives paid less for food ($r = -0.21$), lodging ($r = -0.41$), and total ($r = -0.21$) cost, but not transportation cost ($r = 0.01$).

Analyses related to RQ1 revealed that some demographic variables are significantly related to evacuation logistics. Specifically, older ($r = 0.15$) respondents left earlier but larger households ($r = 0.15$) and those located farther from the coast ($r = 0.16$) tended to leave later. There are seven significant correlations of demographic characteristics with evacuation route information sources. Older respondents and females tended to rely more on recommendations from peers ($r = 0.14$), and whites tended to rely less on the media ($r = -0.12$) and peers ($r = -0.16$) than did other ethnicities. Moreover, those with children tended to rely more on peers ($r = 0.11$), whereas those with higher incomes tended to rely more on personal experience ($r = 0.12$). However, these seven correlations

Table 2 Intercorrelations among variables

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1. Age | – | | | | | | | | | | | | | | |
| 2. Female | –07 | – | | | | | | | | | | | | | |
| 3. White | 03 | –08 | – | | | | | | | | | | | | |
| 4. Married | –13 | –28 | 18 | – | | | | | | | | | | | |
| 5. HHsize | –21 | 02 | 09 | 34 | – | | | | | | | | | | |
| 6. Children | –22 | 09 | 01 | 12 | 46 | – | | | | | | | | | |
| 7. Educ | –05 | –10 | 07 | 00 | –12 | –09 | – | | | | | | | | |
| 8. Income | –15 | –23 | 31 | 55 | 02 | 10 | 26 | – | | | | | | | |
| 9. HmOwn | 02 | –05 | 33 | 15 | 04 | –04 | 12 | 36 | – | | | | | | |
| 10. DistCst | 07 | 02 | 03 | –13 | –04 | –05 | 03 | –06 | –01 | – | | | | | |
| 11. DecDat | –12 | –04 | 06 | 07 | 15 | 09 | 00 | 02 | 04 | 14 | – | | | | |
| 12. WritMat | 01 | –04 | 00 | 09 | –06 | –10 | 02 | 01 | 06 | –05 | –02 | – | | | |
| 13. RecOff | –07 | 08 | –05 | –02 | –04 | 03 | –01 | 01 | 09 | –01 | –06 | 43 | – | | |
| 14. RecMed | –16 | 09 | –12 | –02 | 08 | 04 | –03 | –02 | 03 | 12 | 07 | 36 | 76 | – | |
| 15. RecPeers | –15 | 14 | –16 | –10 | 10 | 11 | –02 | –09 | –09 | 07 | –01 | 16 | 33 | 47 | – |
| 16. PerExp | –06 | –01 | 05 | 07 | 09 | 05 | 05 | 12 | 08 | –23 | –08 | 10 | –02 | –03 | –04 |
| 17. Expect | –09 | 06 | –04 | –04 | –01 | –03 | 12 | 04 | 07 | –05 | –08 | 14 | 18 | 23 | 18 |
| 18. OwnVeh | –19 | –15 | 15 | 35 | 15 | 16 | 13 | 36 | 28 | –15 | 05 | 06 | 05 | 07 | –08 |
| 19. RideOther | 18 | 15 | –15 | –35 | –15 | –16 | –13 | –36 | –27 | 15 | –05 | –06 | –05 | –07 | 08 |
| 20. VehNum | –17 | –02 | 09 | 29 | 17 | 32 | –02 | 29 | 08 | –27 | –05 | 01 | 04 | –05 | –01 |
| 21. TrlrNum | –12 | –06 | 12 | 22 | 18 | 29 | –12 | 19 | 06 | –47 | –05 | 00 | –05 | –09 | –06 |
| 22. RecVeh | –01 | –08 | 05 | 06 | 03 | 09 | 01 | 12 | 06 | –09 | –08 | 04 | 03 | –06 | –05 |
| 23. EvacDist | 08 | –08 | 07 | –04 | –05 | –07 | 04 | 07 | –01 | 25 | –07 | –03 | –07 | –02 | –07 |
| 24. FrRelHom | –01 | –03 | 06 | 01 | 03 | –06 | 01 | 03 | 02 | 09 | 01 | –10 | –13 | –09 | –08 |
| 25. HotlMotl | –02 | 03 | –07 | –04 | –04 | –01 | 02 | –01 | 00 | 02 | 00 | 05 | 13 | 10 | 10 |
| 26. PubShltr | 01 | 03 | –20 | –02 | –01 | 05 | –03 | –14 | –15 | –05 | –05 | 06 | 03 | 02 | 15 |
| 27. EvacDays | 13 | 14 | –10 | –30 | –07 | –05 | –01 | –25 | –11 | 03 | –17 | 08 | –03 | –05 | 11 |
| 28. CostTran | 01 | –07 | 00 | 04 | 09 | 06 | 01 | –01 | –06 | –16 | –06 | 08 | 06 | 03 | 02 |
| 29. CostFood | –14 | 02 | –04 | 01 | 14 | 22 | 00 | –01 | –10 | –07 | –04 | 01 | –06 | 01 | 08 |
| 30. CostLodg | –08 | 09 | –08 | –05 | 04 | 07 | 02 | –08 | –05 | –05 | –09 | 07 | 03 | 04 | 12 |
| 31. CostTotal | –08 | –03 | –03 | 03 | 09 | 20 | 04 | –01 | –11 | –16 | –09 | 09 | 03 | 04 | 08 |

| Variable | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|-------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1. Age | | | | | | | | | | | | | | | |
| 2. Female | | | | | | | | | | | | | | | |
| 3. White | | | | | | | | | | | | | | | |
| 4. Married | | | | | | | | | | | | | | | |
| 5. HHsize | | | | | | | | | | | | | | | |
| 6. Children | | | | | | | | | | | | | | | |
| 7. Educ | | | | | | | | | | | | | | | |
| 8. Income | | | | | | | | | | | | | | | |
| 9. HmOwn | | | | | | | | | | | | | | | |
| 10. DistCst | | | | | | | | | | | | | | | |

Table 2 continued

| Variable | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---------------|------|------|------|------|------|------|------|------|------|------|------|-----|-----|-----|-----|
| 11. DecDat | | | | | | | | | | | | | | | |
| 12. WritMat | | | | | | | | | | | | | | | |
| 13. RecOff | | | | | | | | | | | | | | | |
| 14. RecMed | | | | | | | | | | | | | | | |
| 15. RecPeers | | | | | | | | | | | | | | | |
| 16. PerExp | – | | | | | | | | | | | | | | |
| 17. Expect | .52 | – | | | | | | | | | | | | | |
| 18. OwnVeh | .19 | .08 | – | | | | | | | | | | | | |
| 19. RideOther | –.19 | –.08 | –.99 | – | | | | | | | | | | | |
| 20. VehNum | .23 | .08 | .34 | –.33 | – | | | | | | | | | | |
| 21. TrlrNum | .13 | –.04 | .14 | –.14 | .57 | – | | | | | | | | | |
| 22. RecVeh | .07 | .06 | .07 | –.07 | .05 | .20 | – | | | | | | | | |
| 23. EvacDist | –.01 | .00 | –.01 | .01 | –.13 | –.13 | –.08 | – | | | | | | | |
| 24. FrRelHom | .09 | –.03 | .02 | –.01 | –.07 | –.05 | –.04 | .03 | – | | | | | | |
| 25. HotlMotl | –.11 | .01 | –.08 | .08 | .10 | .02 | –.05 | .00 | –.69 | – | | | | | |
| 26. PubShltr | –.13 | –.01 | –.02 | .02 | –.04 | –.02 | –.04 | .03 | –.19 | –.12 | – | | | | |
| 27. EvacDays | .02 | .04 | –.17 | .16 | –.15 | –.09 | .02 | .05 | .02 | –.05 | .10 | – | | | |
| 28. CostTran | .03 | .08 | .09 | –.09 | .15 | .16 | .08 | –.05 | .01 | –.02 | –.01 | .17 | – | | |
| 29. CostFood | .03 | .01 | –.01 | .01 | .29 | .23 | .05 | –.07 | –.21 | .17 | .05 | .29 | .38 | – | |
| 30. CostLodg | –.07 | .00 | –.05 | .05 | .16 | .10 | –.07 | –.02 | –.41 | .48 | –.01 | .16 | .41 | .58 | – |
| 31. CostTotal | .01 | .03 | .05 | –.05 | .27 | .23 | .04 | –.07 | –.21 | .18 | .00 | .21 | .74 | .72 | .69 |

Italics correlations are statistically significant at $p < 0.05$

represent only 12.9% of the 54 correlations in this section of the matrix, which is not that much larger than the 5% that would be expected by chance.

There are many more significant correlations of demographic variables with vehicle use ($33/45 = 73.3\%$). All demographic characteristics were significantly correlated with use of a personal vehicle. Older females were less likely, whereas white, married home owners with larger household sizes, as well as higher educations and incomes were more likely to take their own cars (correlations range from 0.13 to 0.36 in absolute value). In addition, younger evacuees who were married and had larger households with children and higher incomes tended to take more vehicles (correlations range from 0.17 to 0.32 in absolute value) and were more likely to take a trailer (correlations range from 0.12 to 0.29 in absolute value).

There were many fewer significant correlations of demographic variables with shelter type ($3/27 = 11.1\%$). Whites were less likely to use public shelters ($r = -0.20$) as were those with higher incomes ($r = -0.13$) and home owners ($r = -0.15$). However, there were many significant correlations of demographic variables with evacuation duration. Older ($r = 0.13$) and female ($r = 0.14$) evacuees tended to be away longer, whereas married ($r = -0.27$) and higher income ($r = 0.23$) respondents tended to have shorter evacuations. There were no significant correlations of demographic variables with transportation costs, but older ($r = -0.14$) evacuees had lower food costs, whereas large households ($r = 0.14$), especially those with children ($r = 0.22$), had higher food costs. Females ($r = 0.14$) reported higher, but white ($r = -0.22$) and married ($r = -0.14$)

evacuees reported lower, lodging costs. Overall, evacuees with children reported higher ($r = 0.20$) and home owners reported lower ($r = -.11$) total costs.

Analyses related to RQ2 revealed some significant differences among counties in evacuation vehicle types, distances, durations, and costs. As indicated in Table 3, Column 1, households in Cameron Parish had the highest rate of personal vehicle use ($M = 95\%$), whereas Jefferson County had the lowest (81.0%). Moreover, as indicated in Column 2, Cameron Parish evacuees took the largest number ($M = 2.15$) and Chambers County evacuees took the smallest number ($M = 1.10$) of vehicles per household. Columns 3 and 4 indicate that evacuees from Cameron Parish took many more ($M = 1.08$) trailers than evacuees from other jurisdictions ($0.07 \leq M \leq 0.09$ except Chambers County, which had zero trailers) and also took more high profile vehicles (11.4% than the other parishes/counties ($4.4\% \leq M \leq 9.4\%$) except Jefferson and Chambers counties, which had zero high profile vehicles). The large number of trailers arose from farmers evacuating their livestock to safer locations inland (Prater et al. 2004).

Columns 5 and 6 show the evacuation distances by parish/county. Evacuees from Orange County traveled the longest direct and highway distances—212.11 km (131.80 mi) and 241.68 km (150.17 mi), respectively, whereas those from Cameron Parish went the shortest distances—108.11 km (67.18 mi) and 165.25 km (102.68 mi), respectively. Columns 7 and 8 indicate that Chambers County (63.6%) had the highest and Jefferson County (42.9%) had the lowest percentage of evacuees who stayed with friends and relatives. Conversely, Chambers County (9.1%) had the lowest and Jefferson County (42.9%) had the highest percentage of evacuees who stayed in commercial facilities. As Column 9 indicates, respondents in Vermilion Parish had the longest evacuations ($M = 2.84$ days) and those from Chambers County had the shortest ones ($M = 1.73$ days). This result is readily explained by the fact that Vermilion Parish is closest to, and Chambers County was farthest from, Lili's point of landfall. However, Column 10 indicates that it was evacuees from Jefferson County that spent the most money—averaging \$425.14—whereas the estimated cost for respondents from Chambers County is the lowest (\$119.38), as would be expected from the short evacuation durations.

Finally, as Table 4 indicates, evacuees who stayed in a hotel or motel (\$319.11) spent over five times as much as people who went to a friend's or relative's house (\$160.75). However, part of this disparity is attributable to differences in the number of days spent in evacuation. The average evacuation cost per day of evacuees who went to a hotel or motel was \$153.84, but people who stayed in their friend or relative's house spent \$70.31 per day—a little over half as much. Those who stayed in public shelters incurred total costs of \$277.17, an average of \$111.92 per day.

4 Discussion

The estimates of central tendency for evacuation logistics data from Hurricane Lili are generally consistent with those from previous hurricanes and the tests of the relationships of the evacuation logistics variables with other variables contribute some new findings to the disaster research literature. Consistent with Baker's (2000) conclusion, most households left on the day of the evacuation warning or the day after. However, a significant percentage of those who did leave on the day of the warning did so before authorities issued a warning (see Lindell et al. 2005, for further discussion). Consistent with Perry et al. (1981) and Baker (2000), the overwhelming majority of evacuating households took their own vehicles (90%) and almost all of the remainder caught rides with friends or

Table 3 Evacuation logistics data, by county

| County | Private vehicle | Vehicles/ house hold | Trailers/ house hold | HPVs*/ house hold | Direct distance (Km) | Highway distance (Km) | Friend/ relative | Hotel/ motel | Evacuation days | Evacuation cost |
|-----------|-----------------|-------------------------|-------------------------|----------------------|-------------------------|--------------------------|---------------------|-----------------|--------------------|--------------------|
| Vermilion | 62 (84.9) | 1.47 | 0.09 | .04 | 150.76 | 198.54 | 44 (60.3%) | 19 (26.0%) | 2.84 | 234.06 |
| Cameron | 76 (95%) | 2.15 | 1.08 | .11 | 108.11 | 165.25 | 42 (52.5%) | 24 (30.0%) | 2.13 | 276.79 |
| Orange | 53 (89.8%) | 1.39 | 0.07 | .09 | 212.11 | 241.68 | 30 (51.7%) | 17 (29.3%) | 2.31 | 186.67 |
| Jefferson | 34 (81.0%) | 1.78 | 0.08 | .00 | 199.50 | 222.81 | 18 (42.9%) | 18 (42.9%) | 2.15 | 425.14 |
| Chambers | 10 (90.9%) | 1.10 | 0.00 | .00 | 127.66 | 173.82 | 7 (63.6%) | 1 (9.1%) | 1.73 | 119.38 |

* High profile vehicles

Table 4 Evacuation cost by shelter type

| Shelter type | Transportation cost | Food cost | Lodging cost | Other cost | Total cost | Cost/day |
|---------------------|---------------------|--------------------------|----------------------------|----------------|--------------------------|---------------------------|
| Friend/ relative | 78.21 | 54.68 | 9.56 | 18.29 | 160.75 | 70.31 |
| Hotel/ motel | 68.79 | 94.45 | 132.73 | 23.14 | 319.11 | 153.84 |
| Public shelter | 77.50 | 119.17 | 54.17 | 26.33 | 277.17 | 111.92 |
| Other | 83.18 | 82.27 | 40.79 | 78.79 | 285.03 | 180.06 |
| | $F = .07, ns$ | $F = 4.26,$ $p < .01$ | $F = 27.49,$ $p < .001$ | $F = 1.51, ns$ | $F = 4.12,$ $p < .01$ | $F = 6.04,$ $p < .001$ |

relatives (9%). Consistent with the studies by Baker (2000) and Dow and Cutter (2002), households generally took more than one car when evacuating. More precisely, the data from the present study are consistent with the average number of evacuating vehicles per household (vph) reported by Dash and Morrow (2001)—1.7 vph—and Siebeneck and Cova (2008)—1.5 vph. However, the breakdown by county in Table 3 goes beyond these previous studies in showing that there can be significant variation by county (1.10–2.15 vph). This problem of excess vehicles is compounded by the percentage of households taking trailers, which ranged from 0 to 8% across the five counties—a range that overlaps Baker’s report of 5–13%. These vehicle loads clearly present a major issue for evacuation managers.

The evacuation distance data, which varied substantially across counties, are all somewhat shorter than those of Whitehead (2003)—286 km—and Siebeneck and Cova (2008)—319 km. These differences in evacuation distances are probably due to differences in the size and intensity of the storms, as well as the population densities of the projected impact areas—all of which affect the demand for safe places to stay. In addition, the differences in evacuation distances are probably also due to differences in the proximity of safe places to stay. Thus, the greater the demand and the smaller the local supply, the farther some evacuees will need to travel. The fact that evacuation distance was not significantly correlated with evacuation date or shelter type (e.g., hotel/motel) suggests that some evacuees made reservations before they left home. Early reservations would allow evacuees to leave late, yet still stay relatively close to home. No data were collected on the timing of hotel/motel reservations, so this hypothesis must be tested in future research.

Consistent with the conclusions of the Mileti et al. (1992) literature review and the findings from more recent hurricane studies (Whitehead 2003), the overwhelming majority of Hurricane Lili evacuees stayed with friends and relatives (54%) or in commercial facilities such as hotels and motels (29%) and only 3% stayed in public shelters. The consistency of these results indicates that local officials in host counties need not be overly concerned about demand for public shelters except in the very largest hurricane evacuations. In an evacuation of 2,000,000 people, even a public shelter percentage as low as 3% still yields 60,000 people. Moreover, a hurricane evacuation this large is likely to increase the percentage of people seeking public shelters because the 29% of the evacuees who would ordinarily seek accommodations in commercial facilities will yield 580,000 persons—requiring almost 200,000 rooms. Such demand is likely to create additional demand for shelter space in the short term before households can move farther inland in their search for hotel or motel rooms.

Indeed, such a pattern of multiple types of accommodations is likely to explain why those respondents who reported staying in public shelters, as well as those who reported staying with friends and relatives, did not also report a zero cost for evacuation lodgings. It is likely that they spent most of their time in the location they reported (either friend/relative's home or public shelter) but also spent part of their time in commercial facilities. In any event, the average total household evacuation costs for Hurricane Lili—approximately \$319 for commercial facilities and \$161 for friend/relative's home—were generally consistent with those reported by Whitehead (2003)—approximately \$381 for commercial facilities and \$123 for friends/relatives. However, there is a significant disparity between the \$277 for public shelters in Hurricane Lili and the \$121 for public shelters in Hurricane Bonnie. Most of the difference was in food cost, but there was also a notable difference in lodging cost. Further research will be needed to determine if such differences are due to some systematic factors or simply reflect sampling fluctuations.

The result of evacuees' higher dependence on previous experience and familiarity with the evacuation route than on recommendations by officials are likely to be problematic for analysts who try to forecast (Lindell and Prater 2007a), and transportation officials who attempt to regulate (Wolshon et al. 2005), evacuation traffic flows. Planners typically assume that they should provide hurricane hazard awareness information, as especially evacuation route information, before hurricane season. These data, together with those of Zhang et al. (2004), seem to indicate that pre-season hurricane information has limited value and that the most important method of controlling evacuation traffic is for local officials and the media to provide evacuation route information during a hurricane's approach.

Although the central tendency data of the evacuation logistics variables confirm findings from previous studies, the tests of the relationships of the evacuation logistics variables with other variables contribute some new findings to the disaster research literature. Unfortunately, the tests of the correlational hypotheses were mixed at best. H5 was completely supported, and H1 was partially supported, but H2, H3, and H4 were not supported. With regard to H5, the findings regarding the costs of different shelter types contribute to the development of systematic procedures for estimating evacuation costs. In turn, accurate cost estimates can provide local officials with a basis for understanding the true economic impact of an evacuation (Lindell and Prater 2007b). As Whitehead (2003) has indicated, a "million dollars a mile" seems to be the prevailing rule of thumb. However, this estimate is logically absurd because it implies that the cost of evacuating Kenedy County Texas (population 400) would be approximately the same as the cost of evacuating Miami-Dade County Florida (population 2.4 million). Even though there are differences between the Hurricane Bonnie and Hurricane Lili studies in some of their evacuation cost estimates, both studies support Whitehead's contention that a "million dollars a mile" is simply not a credible estimate for the cost of a hurricane evacuation. To get better estimates of evacuation costs, future research will need to continue to collect data on household expenses but will also need to collect data on the costs of an evacuation to local businesses and government agencies—a topic that has been completely ignored by empirical research to date.

With regard to H1, the identification of effects of coastal proximity on evacuation logistics is significant in three ways. First, the finding that inland residents tend to evacuate later confirms previous reports by Baker (2000). This result, combined with the fact that larger households (which tend to take more cars) also tend to leave later, suggests that traffic jams will form inland from the coast as late evacuees from those locations converge with earlier evacuees from coastal areas. This is consistent with observations of the

Hurricane Rita evacuations, in which there were massive traffic jams that formed north of the city of Houston—well inland from the areas exposed to coastal surge. Second, however, the fact that inland residents tend to rely more on the media and less on personal experience suggests that such evacuees will be more likely to comply with the evacuation management efforts of local transportation officials. This might help in diverting demand to less congested evacuation routes. However, the local authorities and the news media will need to take care in presenting any risk area maps because of the difficulties many residents have in interpreting them (Arlikatti et al. 2006; Zhang et al. 2004).

Finally, the finding that inland residents are more likely to ride with friends rather than take their own cars might seem to indicate that residents of these areas would add less demand to the evacuation route system. However, the fact that reliance on friends and relatives for evacuation transportation was significantly correlated with income suggests that this finding will not generalize to other political jurisdictions unless they also have lower income households located inland from the coast. Of course, coastal property generally is more expensive than inland property, so there might well be many jurisdictions where these results do apply. Moreover, the experience in Hurricane Katrina showed that reliance on friends or relatives for evacuation assistance can be a major problem in communities where entire neighborhoods depend on public transportation. In such cases, friends and relatives will themselves be in need of transportation assistance. Thus, such communities need to make special efforts to provide public transportation to those in need.

The county level data on evacuation logistics are useful because they indicate that there can be significant differences among jurisdictions in the utilization of private vehicles as well as the number of cars, trailers, and motor homes per household. All of these variables can have significant effects on the resources needed to implement an evacuation, as well as the time it takes to clear the risk area. In addition, there can be significant differences among jurisdictions in households' evacuation durations and costs. Both of these variables are likely to affect the economic impact of a hurricane evacuation because many households are likely to compensate for evacuation expenses by disproportionately reducing different categories of their household budgets. For example, they might absorb a small cost by reducing their entertainment budget but need to also reduce their food budget if there is a large evacuation cost. Thus, there is likely to be a disproportionate effect on different sectors of the local economy in the aftermath of an evacuation even if the hurricane causes no physical damage. Such effects have not been examined in previous studies so they will need to be addressed in future research.

Despite its contributions, this study did have some limitations. First, the data come from only one storm and, to the degree that evacuation behavior differs as a function of the characteristics of the storm and the affected population, the results of future studies may differ from those obtained here. Indeed, the county level data presented here suggest that researchers should not only expect variation from one study to another, they should expect (and report) variation from county to county within their samples and seek to identify the variables that determine this variation.

Second, the response rate was only about 50%. Though this is a relatively high response rate compared to other mail surveys of environmental hazards, the overrepresentation of married home owners with larger families and higher incomes raises questions about the degree to which the conclusions apply to other demographic categories such as younger single renters. However, overrepresentation of some demographic categories will produce significant bias in the evacuation logistics variables only to the degree that the bias in the demographic variables is significant and the demographic variables are substantially correlated with the evacuation logistics variables. However, there was only modest bias in our

sample's demographic characteristics, and the correlations of the demographic characteristics (other than marital status and income) with the evacuation logistics variables were also small (see Table 2). More generally, reports by Curtin et al. (2000), Keeter et al. (2000), and Lindell and Perry (2000) indicate low response rates do not appear to bias central tendency estimates such as means and proportions, and Lindell and Perry (2000) presented psychometric reasons for believing low response rates are very unlikely to affect correlations.

Third, as noted earlier, the data on evacuation distances suggest that people might have made hotel/motel reservations before they left, and the data on evacuation costs for those reporting having used public shelters suggest that people used multiple types of accommodations. Thus, future studies should ask about advance reservations and the number of days spent in each of the three types of shelter rather than which type of shelter was used.

In addition, future research should examine hurricane evacuation logistics for households other than the general population. Specifically, as noted by others (Drabek 1994; Phillips and Morrow 2007), there continues to be a need to study transient populations. Lindell (2008) and Lindell and Prater (2007a) have contended that evacuation logistics are likely to be simpler for most transients than for residents because they lack property to protect and they can easily remove their important belongings because they packed them to bring them into the risk area. However, empirical research is needed to confirm these propositions. By contrast, the logistics of evacuating households with disabled members are likely to be distinctly more complex than for the general population. Finally, future studies should examine the logistics of local government support for evacuation management. Wolshon and his colleagues (Wolshon et al. 2005a, b) have made a valuable contribution to this topic, but more work is needed to bridge the gap between social science and transportation engineering.

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