Florida Statewide Regional Evacuation Study Program

Regional Behavioral Analysis

final

report

prepared for

Northeast Florida Regional Planning Council

prepared by

Cambridge Systematics, Inc.

with

University of Central Florida

Whitman, Requardt and Associates, LLP

June 30, 2021

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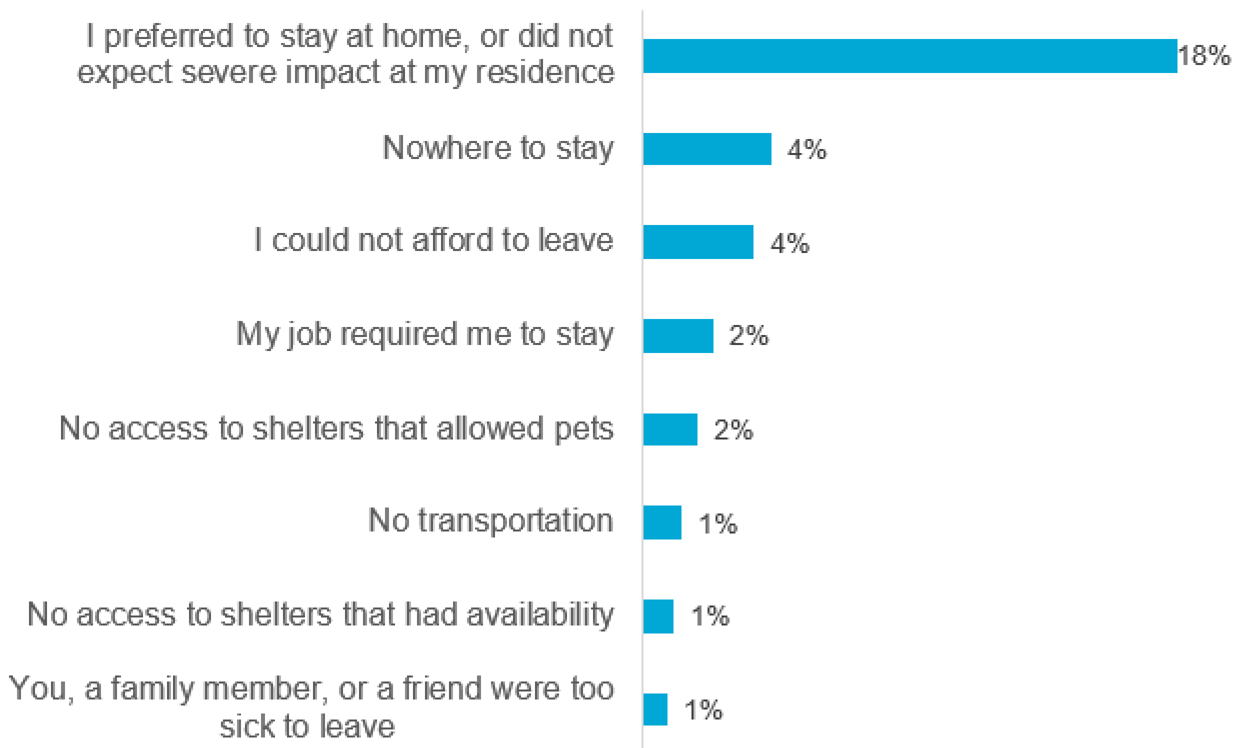
1.0 Introduction

As part of the original Statewide Regional Evacuation Study Program (SRESP) conducted between 2007-2008, a behavioral study was conducted surveying 18,800 Floridians regarding their behavioral response to hurricanes. This information was published in the 2010 Evacuation Studies and utilized in the development of the ground-breaking Transportation Interface for Modeling Evacuations (TIME) software. However, there has been no update to this information since its first publishing. Since that time, Florida has faced numerous hurricanes with the hurricane seasons from 2016 to 2019 being particularly active. Further, from 2008 to 2019, the state has experienced a 17 percent growth in population and this has brought (a) newer residents with limited experience dealing with hurricanes and (b) more housing being built on land that previously might have acted as a barrier to the impacts of hurricanes on life and property.

All these factors make it imperative to collect new data and understand evacuation behavior. A recent survey completed by the project team for the Florida DOT found that 18 percent of coastal county residents did not evacuate since they did not want leave their homes or underestimated the severity of the hurricane. Another eight percent could not afford to leave or had nowhere to stay (Figure 1.1).

Figure 1.1 Responses to the Question – "Reasons for not Evacuating during a Hurricane: from Florida DOT Sponsored Hurricane Evacuation Survey



Source: Cambridge Systematics Analysis of Hurricane Evacuation Survey.

1.1 Data Description

The question to be addressed is how to collect new data in this day and age of diminished response rates and unwillingness of citizens to participate in data collection efforts. Anonymized cellphone data, i.e. location-based services (LBS) data provide one potential avenue to overcome this shortcoming by providing information on when and where people evacuate to and respond to hurricane evacuation information.

- Collecting LBS data can potentially overcome weaknesses in behavioral surveys that rely on respondent memories by measuring population movements through LBS and can help accurately locate evacuees relative to evacuation zones.
- Further, collecting these data will help provide precise location data on evacuation destinations and these could help further enhance TIME with respect to the evacuation trip distribution.
- LBS data can also help with future enhancements of TIME to improve evacuation routing in the model by better understanding evacuee route choice.
- Finally, these new data provide much needed updates to model participation rates and response curves including recalibrating pre-evacuation and overnight plateauing.

The potential of these data to provide richer information about where and when people travel motivated the Regional Planning Councils to investigate the use of LBS data to obtain behavioral rates for the hurricane seasons from 2016 to 2020The focus of this analysis is on the big three hurricanes that struck Florida during this period (Matthew (2016), Irma (2017), and Michael (2018)). The other hurricanes (Hermine (2016), Nate (2017), Sally (2020), and Eta (2020)) were also considered but due to their very localized nature and availability of data for the 2020 hurricane season just coming online the focus of the analysis was on these big three hurricanes. The LBS data used for analysis is derived from number of unique devices (including visitors to the county) is shown in Table 1.1. The study period is two months pivoting around the date of landfall.

1.1.1 How is Data Collected

The increased penetration of smartphones and apps have provided a wealth of data that is useful for evacuation analysis. The way the data is collected is as follows. Every time, a cellphone is used for any purpose, a ping indicating location and timestamp is transmitted via Global Positioning System (GPS) to a central database. These data are then anonymized to remove any personal identifying information (PII) and then shared by the data vendor. Once the data is obtained, home locations are identified after observing where the devices spend their night over a one month period. For the hurricanes being studied, five days before the recorded landfall, the devices were observed (based on location and duration) to identify how they were moving through the system. Observing these devices over a period of time (given their persistent ids) allows identification of device movement over time and space during the evacuation period. These individual device data are aggregated to provide a more complete picture about evacuation behavior. Details about the methodology are provided in section two.

Table 1.1 Unique Devices Sighted by County During Study Period

County	Population (2018)	Matthew	Irma	Michael
Alachua	263,148	31,979	139,298	96,591
Baker	27,785	7,040	16,410	17,136
Bay	182,482	29,597	98,837	463,458
Bradford	26,979	6,224	18,105	12,109
Brevard	576,808	55,097	199,887	59,828
Broward	1,909,151	197,502	754,001	108,405
Calhoun	14,444	1,314	5,246	37,513
Charlotte	176,954	15,354	82,915	14,796
Citrus	143,087	11,264	60,328	22,842
Clay	207,291	42,266	96,497	43,175
Collier	363,922	25,792	137,002	25,365
Columbia	69,105	15,072	50,696	56,265
DeSoto	36,399	3,378	15,387	4,494
Dixie	16,437	1,625	8,201	11,378
Duval	924,229	150,468	342,092	169,087
Escambia	311,522	46,851	132,209	603,626
Flagler	107,139	12,818	49,263	19,839
Franklin	11,736	2,266	10,129	45,963
Gadsden	46,017	7,033	24,222	114,996
Gilchrist	17,615	2,163	9,655	8,787
Glades	13,363	1,762	8,442	3,516
Gulf	16,055	2,263	8,927	56,807
Hamilton	14,269	5,191	16,917	18,538
Hardee	27,228	2,427	10,936	3,129
Hendry	40,127	4,462	18,011	5,345
Hernando	182,696	16,461	72,936	25,395
Highlands	102,101	7,471	33,045	11,030
Hillsborough	1,378,883	117,057	482,545	134,829
Holmes	19,430	3,112	9,839	60,917
Indian River	150,984	15,922	66,448	14,848
Jackson	48,472	8,148	28,017	143,573
Jefferson	14,105	2,866	11,274	51,586
Lafayette	8,744	890	3,760	5,745
Lake	335,362	40,066	158,292	71,659

County	Population (2018)	Matthew	Irma	Michael
Lee	718,679	46,467	235,975	40,831
Leon	288,102	25,105	109,648	503,199
Levy	39,961	5,004	25,908	18,273
Liberty	8,365	793	3,186	25,344
Madison	18,474	4,571	15,926	44,403
Manatee	373,853	30,653	144,413	30,160
Marion	348,371	37,704	158,472	96,503
Martin	157,581	21,459	93,279	18,388
Miami-Dade	2,715,516	219,277	881,629	138,363
Monroe	76,325	22,590	79,629	14,620
Nassau	80,578	19,781	48,278	22,288
Okaloosa	200,737	34,266	113,764	488,452
Okeechobee	40,572	6,503	25,711	7,674
Orange	1,321,194	212,921	722,551	287,402
Osceola	338,619	75,948	242,603	73,183
Palm Beach	1,446,277	119,419	451,160	87,656
Pasco	510,593	42,116	189,032	41,797
Pinellas	957,875	77,300	323,367	69,593
Polk	668,671	59,378	216,652	76,340
Putnam	72,766	11,158	31,663	20,900
Santa Rosa	170,442	25,221	72,684	328,009
Sarasota	412,144	33,364	172,668	30,869
Seminole	455,086	57,070	211,298	83,013
St. Johns	235,503	52,400	146,826	64,048
St. Lucie	305,591	32,485	123,906	33,399
Sumter	120,999	18,650	81,585	39,117
Suwannee	43,924	6,797	24,927	37,358
Taylor	22,098	2,485	13,282	28,803
Union	15,239	1,969	5,943	5,892
Volusia	527,634	59,332	207,636	71,310
Wakulla	31,877	2,727	13,516	74,185
Walton	65,858	22,328	80,607	340,526
Washington	24,566	3,504	12,590	74,250

1.2 Behavioral Metrics

The following behavioral metrics are obtained directly from the LBS Data include:

- **Evacuation Rates:** Evacuation rates refer to the percentage of people who will leave their homes to go someplace safer during a hurricane threat. This is a critical variable for planning because it drives the number of vehicles on the roadways during an evacuation. Responses will vary even for hurricanes of the same intensity, depending on how great the threat appears to be to one's specific location, as well as other factors. Evacuation rates on the periphery of warning areas tend to be lower than in areas closest to the projected path of a threatening storm.

- **Out of County Trips:** Many evacuees go farther than necessary to reach safety, and a certain percentage of evacuees who will go to destinations outside their own county. Going out-of-county can increase evacuation clearance times but has occurred in the past and will in the future until officials are more successful at dissuading evacuees from doing so. Very few out-of-county evacuees seek refuge in public shelters. The great majority go to the homes of friends and relatives or to hotels and motels.

- **Type of Refuge:** The rate at which evacuees go to public shelters, the homes of friends and relatives, hotels and motels, and other types of refuge (such as churches, workplaces, and second homes) is crucial to understand demand for shelters, especially among the poor and vulnerable. Historically, survey respondents tend to overstate their likelihood of using public shelters and understate their likelihood of going to the homes of friends and relatives.

The rest of the report is organized as follows. Section 2 details the methodology and Section 3 discusses the results of the analysis for Hurricanes Matthew, Irma, and Michael. Section 4 talks about updating the planning rates.

2.0 Methodology

This section details the methodology used to develop the behavioral rates from the LBS data. Table 2.1 shows the landfall date along with the dates formed and dissipated of the three big hurricanes, Matthew, Irma, and Michael.

Table 2.1 Hurricane Details

Hurricane	Landfall	Formed	Dissipated	Notes
Matthew		9/28/2016	10/10/2016	Tracked Parallel to Coast
Irma	9/10/2017	8/30/2017	9/14/2017	
Michael	10/10/2018	10/7/2018	10/16/2018	

Source: National Weather Service, NOAA.

2.1 Definitions

2.1.1 Bounding Box

It is a rectangular box defined by the minimum and maximum latitude and longitude of selected counties. Any device seen in the Bounding Box is considered as a potential evacuation device. A Bounding Box contains both residents of the impacted counties as well as residents of counties who are in the Bounding Box but not in the affected counties. Residents outside the Bounding Box are considered as visitors to the county. This comes about because the Bounding Box is rectangular in shape and geography is irregular. So the Bounding Box captures counties that do not necessarily inhabit the characteristics of a hurricane evacuee. Figure 2.1, Figure 2.2, and Figure 2.3 shows the Bounding Boxes for Hurricanes Matthew, Irma, and Michael respectively.

2.1.2 Hexagon or Hex-bin

In order to reduce computational complexity, each observation with a latitude/longitude is tagged to an hexagon (or hex-bin). Open sourced by Uber, the H3 system allows to index data quickly and efficiently for later querying. Geospatial indexing is essential for aggregating and querying data at scale. This type of data is generally abundant, difficult to index or search, and can be structurally complex. Polygons that discriminate particular areas can be very complex to handle. Think of a city's boundaries. How many points do you need to efficiently determine if a given vehicle has entered a town or even a gas station? The more points needed, the more calculations required, overburdening hardware which translates to slower response times and higher resource usage. An efficient geospatial indexing system helps to overcome these hurdles. In the case of H3, the solution takes the form of a hashing scheme.

The H3 algorithm partitions the Earth's surface into a network of hexagons. The analyst can select the amount of detail each hexagon contains by choosing among the available sixteen levels (think of these as "zoom" levels on a map) (Table 2.2). Each hexagon is unique and is identifiable as such. Individual hexagons are addressed through a unique 64-bit identifier, an ideal key for a database table, or an in-memory dictionary. These identifiers are consistent across "zoom" levels, so the hex-bins can be mixed and matched as desired. For this analysis Hex9 was chosen which has edge length of 0.1 miles or 26 acres in area because it was optimal – small enough to capture device location without noise due to GPS or other

Figure 2.1 Bounding Box for Hurricane Matthew (2016)

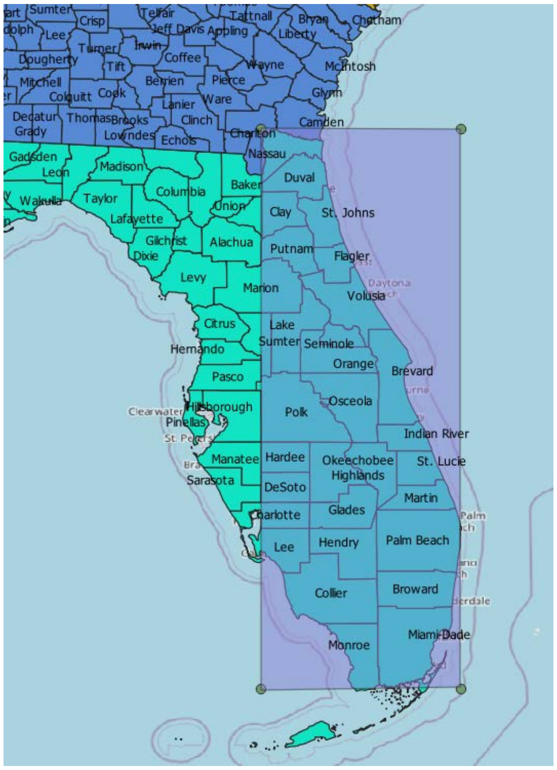


Figure 2.2 Bounding Box for Hurricane Irma (2017)

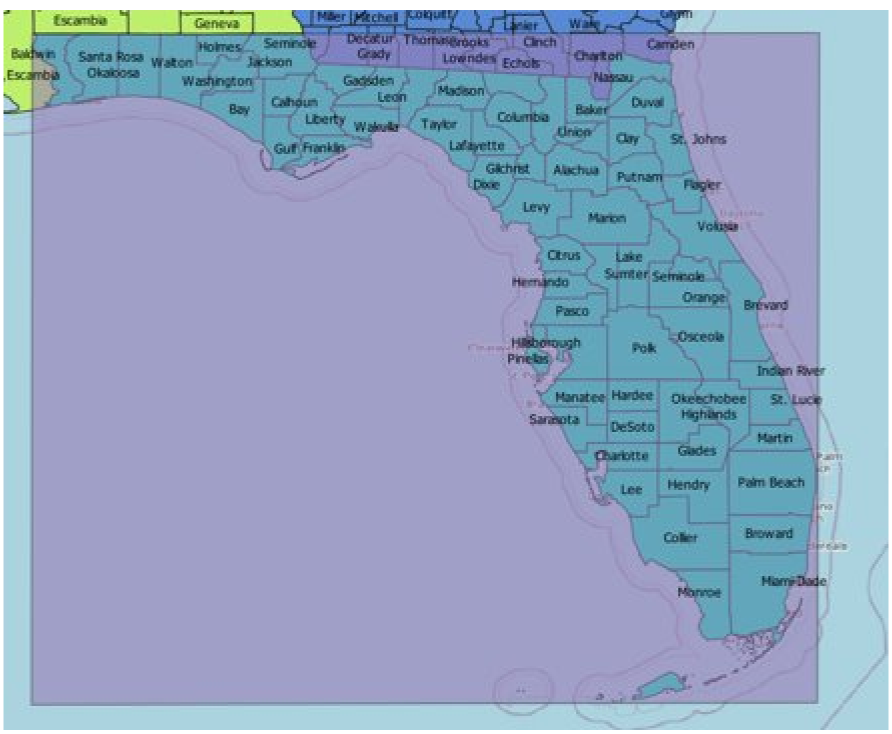


Figure 2.3 Bounding Box for Hurricane Michael (2018)

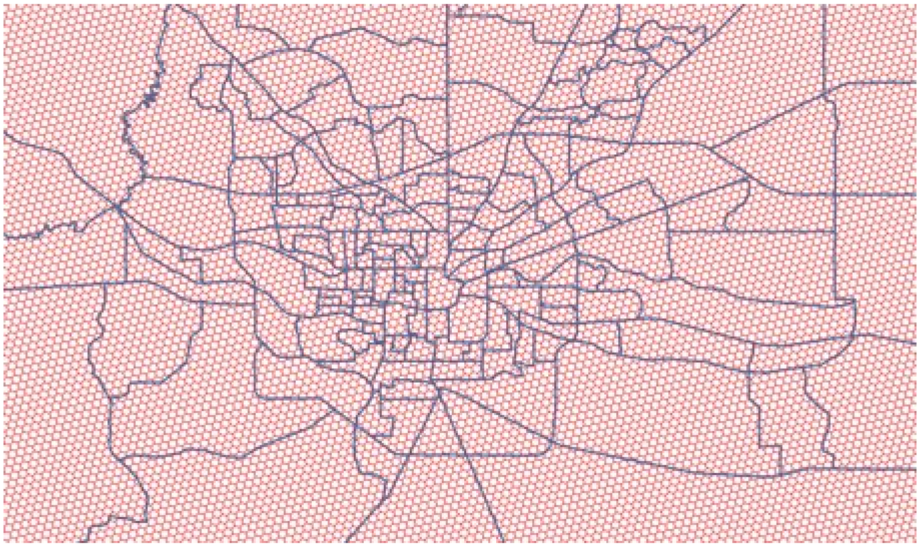
Table 2.2 Cell Areas for H3 Resolutions

H3 Resolution	Average Hexagon Area (km^2)	Average Hexagon Edge Length (km)	Number of unique indexes
0	4,250,546.8477000	1,107.712591000	122
1	607,220.9782429	418.676005500	842
2	86,745.8540347	158.244655800	5,882
3	12,392.2648621	59.810857940	41,162
4	1,770.3235517	22.606379400	288,122
5	252.9033645	8.544408276	2,016,842
6	36.1290521	3.229482772	14,117,882
7	5.1612932	1.220629759	98,825,162
8	0.7373276	0.461354684	691,776,122
9	0.1053325	0.174375668	4,842,432,842
10	0.0150475	0.065907807	33,897,029,882
11	0.0021496	0.024910561	237,279,209,162
12	0.0003071	0.009415526	1,660,954,464,122
13	0.0000439	0.003559893	11,626,681,248,842
14	0.0000063	0.001348575	81,386,768,741,882
15	0.0000009	0.000509713	569,707,381,193,162

Source: https://h3geo.org/docs/core-library/restable.

errors and not too small to overwhelm computing resources. Figure 2.4 shows a sample of Hex9 for Tallahassee overlaid with Census Block groups in blue.

Figure 2.4 Hex-bin (Resolution 9 with edge length of 0.1 mile) for Tallahassee vs Census Blockgroups



2.2 Methodology

The LBS data for a hurricane event are analyzed over a two-month timeframe, which are divided into three analysis periods - Before, During, and After. The “Before” period spans one month before the start of “During” period. The data from this period is used to infer the home locations of the devices that are sighted in the study region. The “During” period starts one or two days before the evacuation orders are issued (to account for pre-evacuations and shadow evacuations), and elapses when the evacuation orders are lifted (four-five days). Data from this period are used to characterize the evacuation behavior of devices. The “After” period spans the remaining days left in the two-month period. Data from this period are used to characterize the post-evacuation behavior of devices – return to old home location, relocate to new location, etc.

Figure 2.5 Overall Process

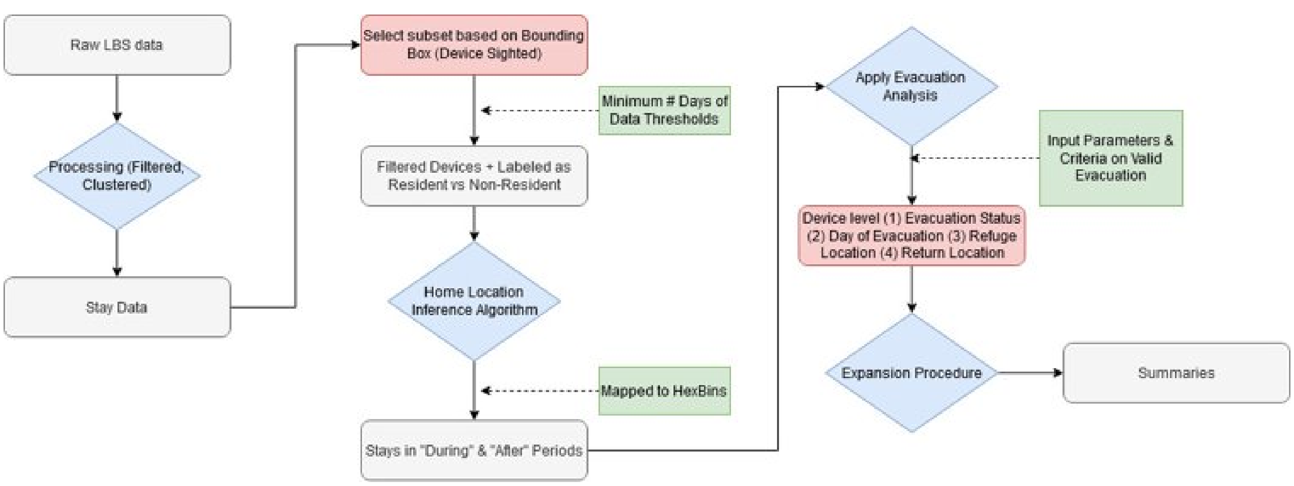


Figure 2.5 shows the overall process of data analysis and development. All raw data points showing up in the bounding box for the study are selected and processed (filtered and clustered) into device stays. Only devices that have data in all three periods (Before, During, and After) are filtered for further analysis. This allows us to study the behavior of devices across different phases of a hurricane event.

Next, the "Before" data are parsed through a series of algorithms that analyzes spatial-temporal visitation patterns and infers the home locations for these devices. This home location (expressed as a latitude/longitude pair) is tagged with a geographic tag (used hex-bins) to reduce the computational complexity of the next steps. An appropriate hex-bin size is chosen (Hex9) for proper mapping of home locations with the evacuation zones.

In order to identify visitors, we process the stays (persistent presence of a device) data for all devices (including stays outside of the Bounding Box – to infer resident vs non-resident home locations). We looked at four weeks of stays in the "Before" period, tagged it with the County, and identified the frequent county as Home County. For visitor devices, we relaxed the conditions for selection in the analysis – the devices do not need to be present in the "During" and "After" periods and the algorithms were run separately for these devices.

Once the home location is identified, the stays in the "During" and "After" period are geo-tagged with hex-bins and analyzed on a per day basis to identify evacuation day and time period, evacuation location, and post-evacuation patterns. First we Identify the highest duration hex-bin for each day in the during/after periods. We applied duration thresholds (minimum of six or eight or 10 hours were tested and settled on six hours) for a hex-bin to qualify as a viable candidate. Next, the algorithm identifies the first instance where the high duration hex-bin is different from home – this gives the evacuation day. Following this step, we identify when the last departure time from the home hex-bin on that day – this gives the time of evacuation (start time of evacuation trip). Once the evacuation day is inferred, the algorithm looks at the highest duration hex-bins for the next couple of days – this gives the refuge location.

Having identified the home location, the evacuation day and time along with evacuation location, the algorithm then identifies the day when the device's high duration hex-bin first returns to home and home hex-bin is the maximum duration location for a minimum of N days (we tested 6, 7, and 14 days). If the return location is not home, a persistent high duration new location (satisfying the minimum number of days threshold) will give the relocated home.

To test the validity of our process we applied the algorithms to a period of time where there were no hurricanes or evacuations ordered. Applying our algorithms indicated that around 10 percent or less trip making occurred during this non evacuation period that exhibited patterns similar to our algorithms. Having evacuation-like trips being under ten percent or less provides a level of comfort to proceed with our analysis.

2.2.1 Algorithm Refinements

Once our base algorithms were designed and tested, we made a series of refinements to these algorithms to ensure that the evacuation locations, rates, and durations were consistent with observed data. These observed data are from a survey done by the Florida Department of Transportation of residents of coastal counties and evaluate their evacuation and travel behavior for hurricanes Matthew, Irma, and Michael. The sample size for this survey was 6,038 and it was expanded by age, race, and income to the population.

The following refinements were made to the algorithm to meet the survey targets as well as match total numbers developed by the Florida Division of Emergency Management (FDEM).

- For evacuation hex identification, added total duration as a tie breaker. If two or more hexes are the top locations on the same number of days in the evacuation period, then choose the hex-bin with the maximum duration is chosen as the evacuation hex-bin. This tie breaker rule was applied to the return hex-bin identification too.
- For the return hex-bin location, we applied the neighbor condition whereby the algorithm checks if the return hex-bin is a neighbor and if this condition is met assigns it to the home hex-bin.
- For evacuation day identification we added an additional condition that home hex-bin should not be the last activity on that day (e.g., a device on the supposed "evacuation day" spends maximum time at a non-home location, but then comes back home late in the night and this should not count as an evacuation).
- A valid evacuation does not involve return to home before the day of landfall.
- Hex-bins tagged for shelter and hotel/motels are extended to include the immediate ring of neighbors.
- In the evacuation location selection, consider the top two hex-bins based on the number of days and total duration.
  - Compare both hex-bin locations and choose the location with higher duration at night.
  - Also impose the additional criteria that the evacuation should not be to a hex-bin that is neighbor to the home hex-bin.
- Allow for second wave of evacuations on day of landfall by considering devices that did not evacuate in round 1 by applying less stringent criteria.
- The evacuation location is subjected to the following constraints.
  - Minimum time spent is three hours.
  - Minimum distance from home hex-bin location can be zero (to account for nearby shelters etc.), five, or ten miles from the home hex-bin.
  - This evacuation location is not an immediate neighbor to the home hex-bin.
  - The device should not return to the home location after evacuating for at least 16 hours. We initially kept it for 16 hours for all three hurricanes but the track taken by Irma where first it went east and then it went west made us remove the 16 hour away from home constraint.

2.2.2 Expansion

Even considering the data that ends up being filtered, sample sizes remain quite large. Nonetheless, LBS data provide samples of the population. As a result, we used the Census to expand our LBS data to the true population. This step is vital to generating accurate estimates of evacuation rates for each hurricane. Failure to expand the data could lead to biased evacuation rate estimates with certain geographic areas being over-represented in the sample due to higher sample penetration rates in those areas. For resident devices (within the bounding box) we expanded to the population in the home census tract using the

American Community Survey estimates. For non-resident devices we applied the average weight obtained for resident devices.

3.0 Results

This section provides the results of the analysis done for the three hurricanes. First we present the overall results. This is followed by evacuation results by shelter type and evacuation zone. Finally, we present the evacuation results at the county level and compare it to the evacuation rates obtained from the survey.

Table 3.1 Evacuation by Residents within Bounding Box

Evacuation Status	Matthew	Irma*	Michael
0 = Did Not Evacuate (Home Hex-bin & Evacuated to Neighbor Hex-bin)	95,953	234,559	19,923
1 = Did Not Evacuate	11,527,434	14,398,989	2,056,674
2 = Evacuated	1,367,240	4,005,827	418,544
3 = Evacuated & evacuation time < 2 days	355,879	813,932	88,347
4 = Evacuated on landfall day	441,258	1,245,614	140,029
Total Devices	**13,787,763**	**20,698,921**	**2,723,517**
Total Evacuated	**2,164,377**	**6,065,372**	**646,920**
Percent Evacuated	**15.7%**	**29.3%**	**23.8%**

* No constraint on landfall day evacuee returns

As Table 3.1 the evacuation rates range from 16 to 29 percent (expanded to the total population) and is consistent with the speed, intensity, and duration of the hurricane. Matthew, though a major storm, mainly stayed off the Florida coast and did not make landfall in Florida. Irma and Michael show higher evacuations due to the build up and the quick severity of each respectively. Note that for Irma we do not constraint people who evacuated on landfall day that they cannot return for 16 hours since the trajectory taken by Irma (first going east then going west) might have caused some evacuees to return home within half a day or less of evacuation. For Matthew and Michael we constraint the return to at least 16 hours after evacuation. For all three hurricanes, we do not impose any distance constraints on landfall day evacuees on where they evacuated to provide the evacuation location is not an immediate neighbor to the home hex-bin and they evacuate for at least three hours. The Irma evacuation numbers are consistent with numbers provided by the FDEM.

Next we look at the type of location the evacuees evacuated to within Florida. Table 3.2 shows the number (residents and non-residents from outside the bounding box) and percent of evacuees by evacuation location. As this table shows, the majority of evacuees prefer to evacuate with friends and family. Shelter usage is much lesser and could be due to the population who use shelters might not be using smartphones and/or an older cohort. In comparison with the Florida DOT survey, the use of Hotels and Motels is lower than that reported by respondents to the survey.

Table 3.2 Evacuation Location Type within Florida

Evacuation Status	Matthew	Irma*	Michael
Shelters only	36,035	145,263	4,231
Hotels/Motels Only	461,799	818,736	58,104

Evacuation Status	Matthew	Irma*	Michael
Shelters and Hotels	2,922	12,820	1,145
No Shelter and Hotel	1,994,541	4,480,805	311,561
Total Evacuated	2,495,297	5,457,624	375,041
% Evacuations			
Shelters only	1.4%	2.7%	1.1%
Hotels/Motels Only	18.5%	15.0%	15.5%
Shelters and Hotels	0.1%	0.2%	0.3%
No Shelter and Hotel	79.9%	82.1%	83.1%

* No constraint on landfall day evacuee returns

Next we look at the evacuation by zone type for each hurricane. This includes the evacuation for residents of the affected counties in the Florida DOT hurricane evacuation survey and is shown in Table 3.3. The counties for each hurricane from the Florida DOT survey are:

- **Matthew:** Brevard, Broward, Clay, Duval, Flagler, Indian River, Martin, Miami-Dade, Nassau, Okeechobee, Orange, Osceola, Palm Beach, Putnam, Seminole, St. Johns, St. Lucie, Volusia
- **Irma:** Brevard, Charlotte, Collier, Flagler, Franklin, Gulf, Hernando, Hillsborough, Lee, Levy, Manatee, Miami-Dade, Monroe, Nassau, Pasco, Pinellas, St. Johns, St. Lucie, Sarasota, Taylor, Wakulla
- **Michael:** Bay, Franklin, Gulf, Taylor, Wakulla, Walton

Table 3.3 Evacuation from Florida DOT Survey Counties by Evacuation Zone

Evacuation Zone	Matthew	Irma	Michael
A	38%	54%	55%
B	25%	44%	51%
C	19%	36%	49%
D	15%	30%	36%
E	17%	28%	27%
Not in an Evacuation Zone	14%	25%	34%

Table 3.4, Table 3.5, and Table 3.6 shows the day of evacuation for resident and non-resident devices for the three hurricanes. This table is only for those devices that evacuated under conditions 2 (evacuated) and 3 (evacuated and evacuation time < 2 days) of Table 3.1. As these tables show residents and non-residents start evacuating pretty early and take edge affects.

Table 3.4 Day of Evacuation for Resident and Non-Resident Devices (Matthew)

Date	Non-Resident	Resident
10/3/2016	20%	13%
10/4/2016	12%	9%
10/5/2016	11%	11%
10/6/2016	14%	24%
10/7/2016	43%	42%

Table 3.5 Day of Evacuation for Resident and Non-Resident Devices (Irma)

Date	Non-Resident	Resident
9/6/2017	15%	11%
9/7/2017	8%	9%
9/8/2017	9%	13%
9/9/2017	11%	24%
9/10/2017	56%	43%

Table 3.6 Day of Evacuation for Resident and Non-Resident Devices (Michael)

Date	Non-Resident	Resident
10/6/2018	23%	13%
10/7/2018	12%	7%
10/8/2018	12%	9%
10/9/2018	14%	18%
10/10/2018	39%	53%

Table 3.7 shows the comparison of survey evacuation rates to LBS derived evacuation rates for the three hurricanes by county and shows that LBS data evacuation rates are comparable to the survey results. Large differences are noted for some counties due to the lack of sufficient number of samples and the tendency of small numbers to magnify differences.

Figure 3.1, Figure 3.2, and Figure 3.3 show the comparison between the Florida DOT survey and LBS evacuation rates by county for Matthew, Irma, and Michael, respectively. The number within parenthesis shows the number of samples in the Florida DOT survey. As shown in the figures, when comparing the survey evacuation rates to the LBS rates, the evacuation rates are for the most part within 10 to 15 percent. Any outliers that are noticed are due to the very small number of observations in the survey data that tend to magnify the differences between the survey and the LBS data.

Table 3.7 Evacuation Comparisons by County

Hurricane Event	County	Percent Evacuated (Survey)	Percent Evacuated (LBS Data)	Difference
Irma	Bay	10%	24%	14%
Irma	Brevard	25%	29%	4%
Irma	Broward	21%	27%	6%
Irma	Charlotte	45%	46%	2%
Irma	Citrus	21%	28%	7%
Irma	Collier	41%	50%	9%
Irma	Duval	19%	24%	5%
Irma	Escambia	5%	23%	17%
Irma	Flagler	27%	23%	-4%
Irma	Franklin	30%	38%	8%
Irma	Gulf	74%	33%	-41%
Irma	Hernando	27%	25%	-2%
Irma	Hillsborough	30%	34%	3%
Irma	Indian River	19%	32%	13%
Irma	Lee	49%	45%	-4%
Irma	Levy	75%	36%	-39%
Irma	Manatee	29%	39%	10%
Irma	Martin	22%	29%	7%
Irma	Miami-Dade	28%	28%	-1%
Irma	Monroe	50%	75%	25%
Irma	Nassau	34%	28%	-6%
Irma	Okaloosa	3%	22%	19%
Irma	Palm Beach	19%	29%	11%
Irma	Pasco	31%	32%	2%
Irma	Pinellas	37%	39%	3%
Irma	St. Johns	34%	28%	-5%
Irma	St. Lucie	26%	25%	-1%
Irma	Santa Rosa	4%	21%	17%
Irma	Sarasota	33%	39%	5%
Irma	Taylor	27%	39%	12%
Irma	Volusia	18%	26%	8%
Irma	Wakulla	43%	33%	-10%
Irma	Walton	16%	25%	9%
Michael	Bay	56%	48%	-8%

Hurricane Event	County	Percent Evacuated (Survey)	Percent Evacuated (LBS Data)	Difference
Michael	Escambia	8%	15%	7%
Michael	Franklin	69%	57%	-12%
Michael	Gulf	48%	52%	3%
Michael	Levy	12%	26%	13%
Michael	Okaloosa	14%	20%	6%
Michael	Santa Rosa	8%	14%	6%
Michael	Taylor	27%	23%	-4%
Michael	Wakulla	32%	35%	3%
Michael	Walton	48%	34%	-14%
Matthew	Brevard	34%	27%	-7%
Matthew	Broward	18%	13%	-5%
Matthew	Duval	22%	26%	5%
Matthew	Flagler	29%	27%	-2%
Matthew	Indian River	27%	20%	-7%
Matthew	Martin	20%	18%	-2%
Matthew	Nassau	45%	39%	-7%
Matthew	Palm Beach	19%	14%	-5%
Matthew	St. Johns	42%	39%	-3%
Matthew	St. Lucie	26%	15%	-11%
Matthew	Volusia	22%	24%	2%

Figure 3.1 Comparison between Survey and LBS Evacuation Rates (Matthew)

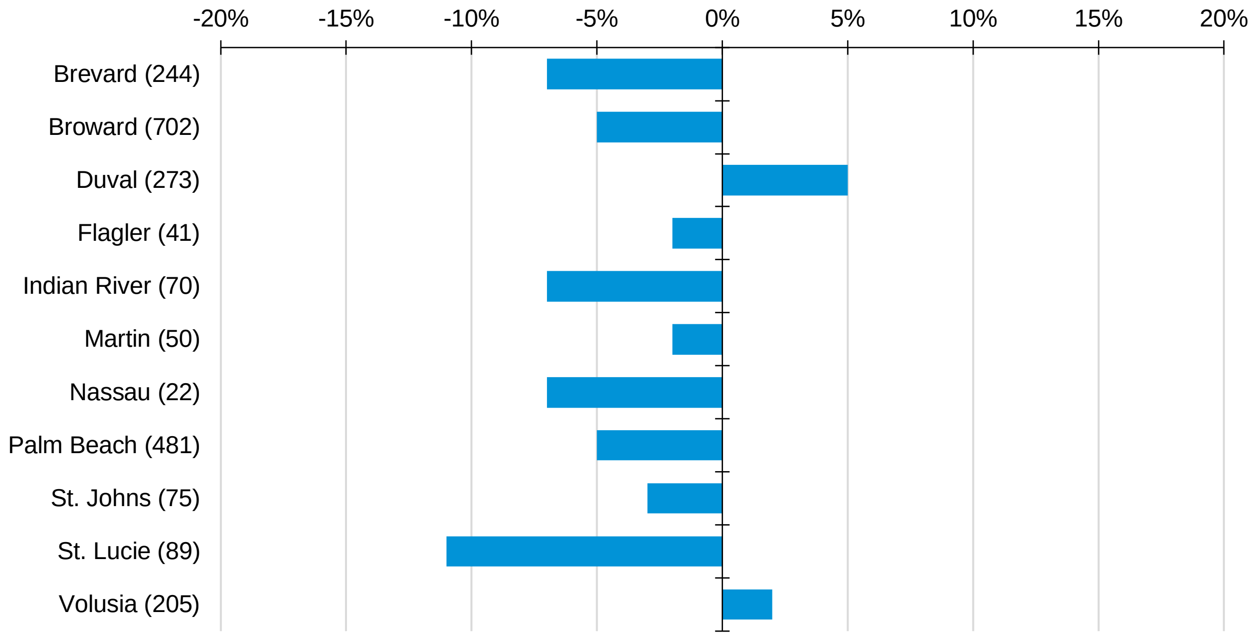


Figure 3.2 Comparison between Survey and LBS Evacuation Rates (Irma)

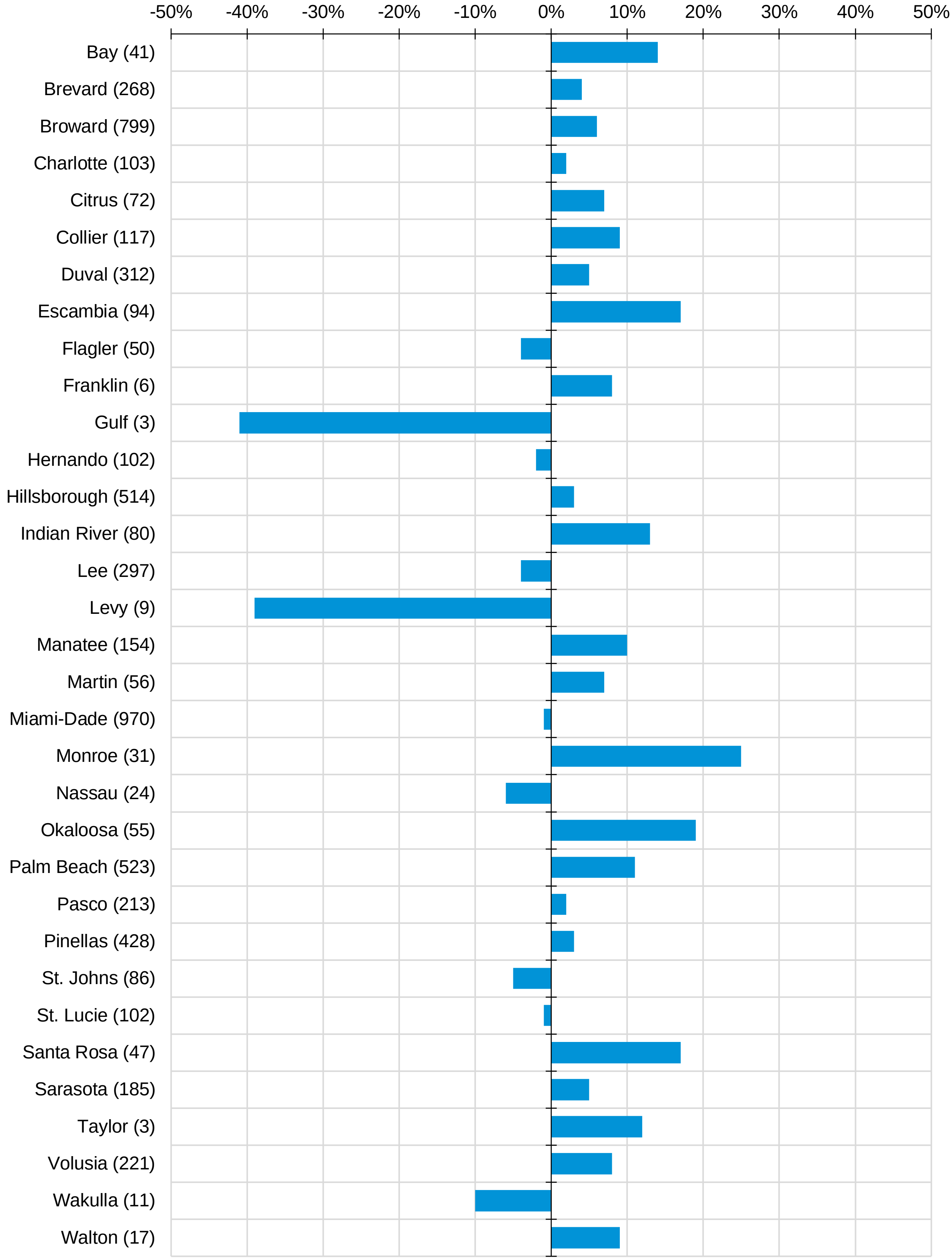


Figure 3.3 Comparison between Survey and LBS Evacuation Rates (Michael)

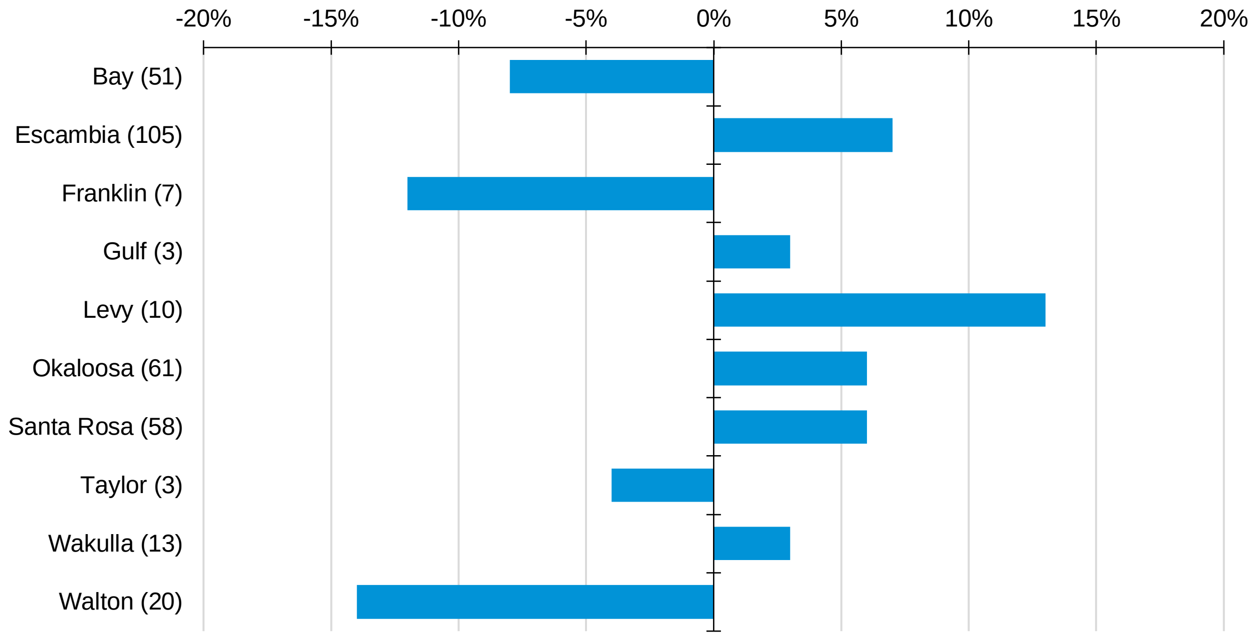


Figure 3.4, Figure 3.5, and Figure 3.6 shows the out of county rates for the three hurricanes. These estimates are consistent with the tracking path of the hurricanes and where they made landfall.

Figure 3.4 Out of County Rates (Matthew)

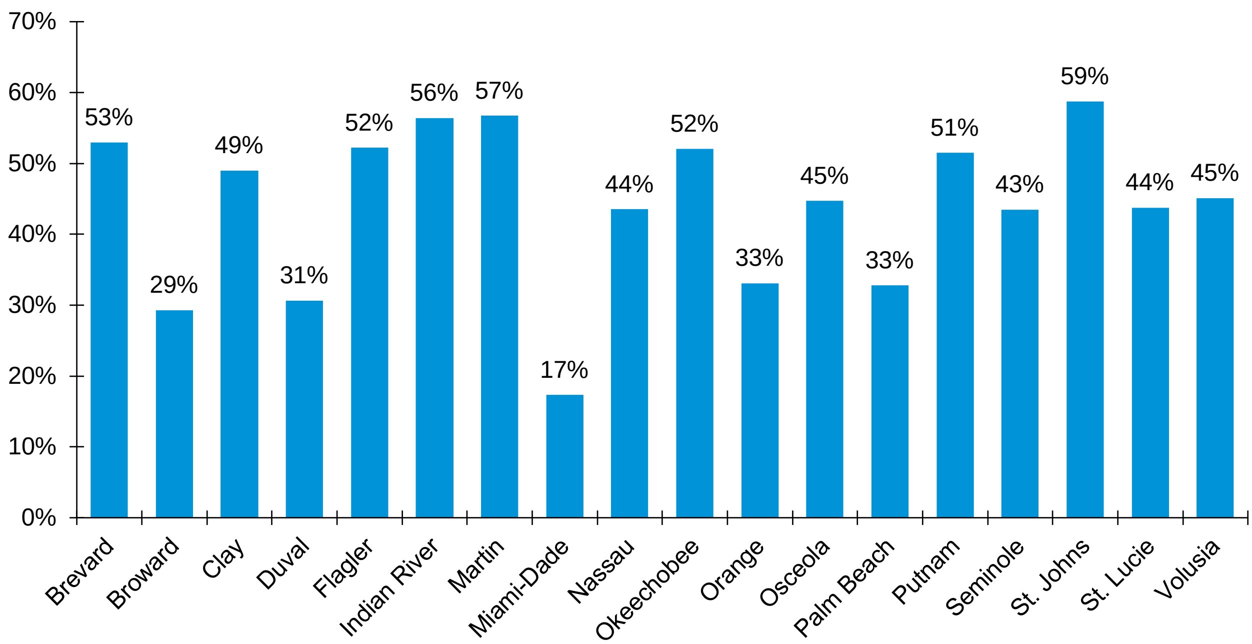


Figure 3.5 Out of County Rates (Irma)

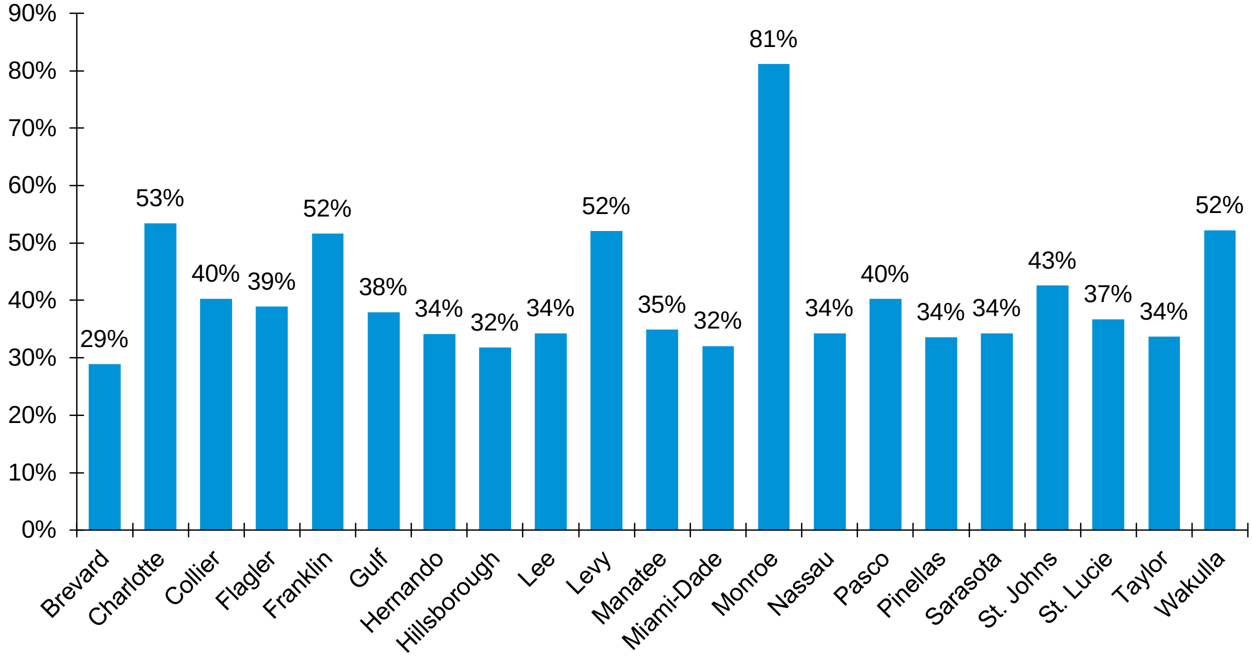
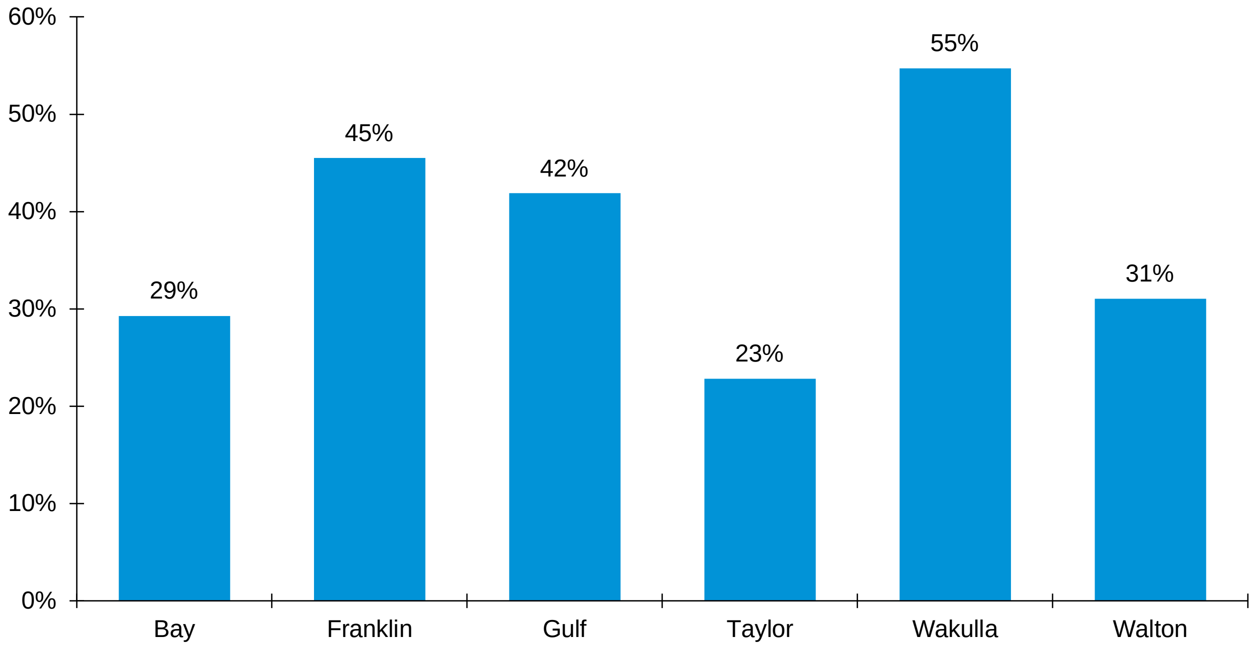


Figure 3.6 Out of County Rates (Michael)



4.0 Updated Planning Rates

In this section, the procedures used to develop behavioral rates for updated study are presented along with results of those methods.

4.1 Framework for Updated Planning Rates

As a precursor to updating the planning rates, it was clear that while the new LBS data was very robust in terms of sampling the population within a hurricane, only five hurricanes were analyzed, which is a very small sample of hurricanes. Furthermore, Hurricane Nate only had a peripheral impact on the state of Florida since its path passed west of the state and Hurricane Hermine was a relatively weak storm that impacted a remote area of Florida, which resulted in particularly small samples for that storm. As a result, only three hurricanes were considered in the process of updating the planning rates for this study (Hurricanes Matthew, Irma, and Michael).

Due to the small sample size of hurricanes, it was determined that the framework for updating the behavioral rates for this planning study should build off of the 2008 rates, rather than replace them entirely. This was accomplished by blending the 2008 rates with rates estimated from mobile location data analyzed for this study. However, given the small sample size of hurricane events, confidently estimating behavioral patterns specific to individual counties from the mobile location data was not possible.

Instead, composite rates were developed from the mobile location data for each category of hurricane (1 through 5). This was done using the following steps:

- First, composite behavioral rates were computed for each of the three major hurricanes studied. This was done for each behavioral rate category (including evacuation rates, friends/family refuge rate, hotel/motel refuge rate, shelter refuge rate, and out of county rate). This process is described in more detail in the following sections.

- The highest evacuation rates were found for Hurricane Michael, which not coincidentally, was the highest rated hurricane among the three when it made landfall at a category 4 rating. Hurricane Irma had slightly lower evacuation rates, and this hurricane was rated a category 3 when it made landfall in mainland Florida. Hurricane Matthew had the lowest evacuation rates. While it was also rated a category 3/4 as it approached the Florida coast, Matthew never actually made landfall. To account for this fact, Matthew was considered a category 2 hurricane for the purposes of analyzing how people responded to storms.

- Hurricane Michael was treated as representative of category 4 storms, Hurricane Irma was treated as representative of category 3 storms, and Hurricane Matthew was treated as representative of category 2 storms.

- Next, for each behavioral rate category, rates appropriate for category 1 and category 5 storms were inferred from the rates observed for Matthew, Irma, and Michael. This process is described in more detail in the following sections.

- Last, the composite rates developed from the mobile location data were averaged with each county's 2008 behavioral rates to obtain new planning rates for this study. The result is a set of new behavioral rates that still vary by county in important ways, but also reflect the new information gained from the mobile location data.

The following sections describe in more detail how the composite behavioral rates, which were used for the blending approach with 2008 rates, were developed for each hurricane category.

4.2 Evacuation Rates

Before determining a blending approach, the mobile location rates for each storm by county and by evacuation zone were analyzed to get a better sense of how individuals in the affected counties responded to each hurricane. The first step of this process was to identify the counties that were most impacted by the hurricane. This was done by examination of the evacuation rates estimated for each hurricane. The first step was to take a relatively broad view of counties in the path of the hurricane. Next, the set of affected counties was filtered down to the ones with the highest and similar evacuation rates.

4.2.1 Identifying Affected Counties

Table 4.1 shows site-built evacuation rates of those affected counties for Hurricane Irma. As shown in the table, the evacuation rates by county for like evacuation zones are relatively similar. Counties in the path of the hurricane that had lower evacuation rates were filtered. The population-weighted evacuation rates across the set of 19 counties is shown in the second to last row. The final row shows a smoothed version of that weighted average, which attempts to maintain consistency in evacuation rates lowering as hurricane risk lowers while also generally adhering to the derived rates from the mobile location data. We believe this smoothing is necessary because the data is noisy.

Table 4.1 Hurricane Irma Site Built Evacuation Rates by Affected County

			Evacuation Zone Type						
County	**Type**	**Population**	**A**	**B**	**C**	**D**	**E**	**Inland**	**No Zone**
Monroe	Coastal	75,798	75.1	n/a	n/a	n/a	n/a	91.5	n/a
Collier	Coastal	371,453	61.7	50.4	39.0	30.6	54.7	49.9	n/a
Lee	Coastal	737,468	58.6	46.7	39.7	32.2	28.7	25.2	n/a
Charlotte	Coastal	181,067	57.0	46.8	31.9	36.4	n/a	49.4	n/a
Sarasota	Coastal	419,496	57.7	44.3	36.2	31.7	34.7	35.6	n/a
Manatee	Coastal	384,213	57.6	43.6	43.2	36.2	29.7	30.5	n/a
Pinellas	Coastal	964,666	58.1	46.7	35.1	31.1	30.3	27.0	n/a
Hillsborough	Coastal	1,422,278	54.8	44.1	38.9	33.8	30.4	27.8	n/a
Pasco	Coastal	524,602	51.2	43.8	35.6	28.8	27.1	25.3	n/a
Hernando	Coastal	186,313	52.7	57.9	32.4	26.6	22.2	21.6	n/a
Citrus	Coastal	145,169	55.3	30.0	30.7	29.5	13.8	19.9	n/a
Levy	Coastal	40,403	47.5	40.3	39.8	27.7	25.9	31.5	n/a
Dixie	Coastal	16,589	60.2	40.8	n/a	19.1	20.6	29.2	n/a
Taylor	Coastal	21,870	60.7	66.7	18.1	60.6	33.8	33.1	n/a
Hendry	Inland	40,732	59.8	100.0	53.1	n/a	72.3	52.3	n/a
Desoto	Inland	36,903	58.2	47.2	18.8	26.4	100.0	37.9	n/a
Glades	Inland	13,516	51.2	56.2	46.1	53.9	33.9	34.7	n/a
Hardee	Inland	27,131	n/a	n/a	n/a	n/a	n/a	n/a	36.8
Polk	Inland	686,218	n/a	n/a	n/a	n/a	n/a	n/a	24.6
Weighted average		6,295,885	56.7	46.0	37.4	32.1	31.8	30.8	25.1
Smoothed			60.0	50.0	40.0	35.0	30.0	30.0	25.0

Table 4.2 shows the results for Hurricane Matthew. Since Hurricane Matthew never made landfall, we limited analysis of this storm to coastal counties only. Seven counties were identified as the affected counties based upon the evacuation rates derived from the mobile location data. Again, the weighted average and smoothed weighted average rates across the set of counties are shown in the last two rows of the table.

Table 4.2 Hurricane Matthew Site Built Evacuation Rates by Affected County

			Evacuation Zone Type						
County	**Type**	**Population**	**A**	**B**	**C**	**D**	**E**	**Inland**	**No Zone**
Brevard	Coastal	585,507	43.7	17.6	24.0	34.0	24.4	19.7	n/a
Volusia	Coastal	536,487	43.6	41.5	26.7	26.0	25.5	18.7	n/a
Indian River	Coastal	153,989	40.6	22.2	33.3	17.1	n/a	16.7	n/a
Flagler	Coastal	109,801	46.7	49.9	25.0	30.2	20.1	20.4	n/a
St. Johns	Coastal	244,674	58.5	51.3	35.4	57.2	n/a	21.6	n/a
Duval	Coastal	936,186	39.9	51.7	28.5	20.4	24.9	21.0	n/a
Nassau	Coastal	83,098	64.2	n/a	36.2	26.9	18.9	18.7	n/a
Weighted average		2,649,742	44.5	39.9	28.2	28.3	24.5	20.0	n/a
Smoothed			45.0	40.0	35.0	30.0	25.0	20.0	n/a

Table 4.3 shows the results for Hurricane Michael. Only five counties were identified as being affected counties in this case.

Table 4.3 Hurricane Michael Site Built Evacuation Rates by Affected County

			Evacuation Zone Type						
County	**Type**	**Population**	**A**	**B**	**C**	**D**	**E**	**Inland**	**No Zone**
Gulf	Coastal	15,576	69.2	63.7	44.6	61.5	n/a	31.1	n/a
Bay	Coastal	182,161	58.1	61.0	55.5	39.2	n/a	41.0	n/a
Calhoun	Inland	14,362	n/a	n/a	n/a	n/a	n/a	n/a	38.1
Franklin	Coastal	11,811	59.9	55.8	n/a	n/a	n/a	n/a	n/a
Liberty	Inland	8,345	n/a	100.0	n/a	n/a	n/a	n/a	39.2
Weighted average		232,255	59.0	60.9	54.7	40.9	n/a	40.2	38.5
Smoothed			65.0	60.0	55.0	50.0	45.0	40.0	40.0

As noted earlier, the highest evacuation rates for affected counties were found for Hurricane Michael, followed by Irma, and then Matthew. These were treated as representative category 4, 3, and 2 storms, respectively. The smoothed evacuation rates developed for the three storms follow the pattern of increasing evacuation rates for increasing intensity storm.

4.2.2 Composite Evacuation Rates for Site Built Residents

In order to develop composite rates for each category of storm, it was necessary to develop composite rates for category 1 and category 5 storms, of which none existed in the LBS dataset. This was done by comparing the smoothed composite rates developed from the observed hurricanes against the existing 2008 planning rates. In the first step of the approach, the 2008 rates were examined across counties for specific category storms and using those rates, a range of rates that the model uses were developed. These are shown in Table 4.4.

Table 4.4 Evacuation Rates for Site Built—2008 Planning Assumptions

		Evacuation Zone Type					
Current range		**A**	**B**	**C**	**D**	**E**	**Inland**
Category 5	min	90	85	75	70	60	20
	max	95	95	90	85	80	40
Category 4	min	80	75	65	60	40	10
	max	90	85	80	75	55	30
Category 3	min	65	60	50	30	15	10
	max	80	75	70	50	35	25
Category 2	min	50	40	15	10	5	5
	max	70	65	35	25	25	15
Category 1	min	40	25	10	10	5	5
	max	60	45	25	20	15	10

In some cases, there were one or two counties that fell outside of these ranges, and those were considered outliers. From these set of evacuation rate ranges, a 2008 average evacuation rate was computed as the midpoint of the range as shown in Table 4.5.

Table 4.5 Evacuation Rates for Site Built—Average of Ranges

	Evacuation Zone Type					
Current Average	**A**	**B**	**C**	**D**	**E**	**Inland**
Category 5	92.5	90.0	82.5	77.5	70.0	30.0
Category 4	85.0	80.0	72.5	67.5	47.5	20.0
Category 3	72.5	67.5	60.0	40.0	25.0	17.5
Category 2	60.0	52.5	25.0	17.5	15.0	10.0
Category 1	50.0	35.0	17.5	15.0	10.0	7.5

Next, the midpoint evacuation rates from the 2008 ranges were compared against the observed rates from the mobile location data, taking the difference of the observed mobile location rate and the 2008 midpoint. This was done for category 2 to 4 storms, since that is all the data that was available from the mobile location data. These differences are shown in Table 4.6.

Table 4.6 Evacuation Rate Differences for Site Built—Mobile Location Data vs. 2008 Planning Averages

	Evacuation Zone Type					
Difference	**A**	**B**	**C**	**D**	**E**	**Inland**
Category 4	-20.0	-20.0	-17.5	-17.5	-2.5	20.0
Category 3	-12.5	-17.5	-20.0	-5.0	5.0	12.5
Category 2	-15.0	-12.5	10.0	12.5	10.0	10.0

As shown in the table, the 2008 rates tend to be much larger in the most at-risk evacuation zones, but much smaller in the areas outside of the evacuation zones. Examination of this table also allows for estimating what the differences might be for category 1 and 5 storms. Evacuation rates for these storm categories were inferred by comparison with the rate differences in the observed storms. For instance, a -20 difference was computed for observed A zone evacuation rate for that category, which was maintained for category 5. For zone E in category 5, there was a trend across the observed storms where the bigger the storm, the lower the differences for less risky evacuation zones. For instance, category 4 observed differences are relatively large and negative for zones A to D, but become small for zone E. For category 3, a similar trend is observed except that the large and negative differences only appear for zones A to C and become smaller for zones D and E. For category 2, the inflection point is between zone B and C. Observing this trend, it was inferred that a relatively large and negative difference for zone E in category 5 storms was appropriate. Similar observations were used to set the category 1 rates. Inferred values for these differences are shown in Table 4.7.

Table 4.7 Inferred Evacuation Rate Differences for Category 1 and 5 Storms

	Evacuation Zone Type					
Difference	**A**	**B**	**C**	**D**	**E**	**Inland**
Category 5	-20.0	-20.0	-20.0	-20.0	-15.0	20.0
Category 4	-20.0	-20.0	-17.5	-17.5	-2.5	20.0
Category 3	-12.5	-17.5	-20.0	-5.0	5.0	12.5
Category 2	-15.0	-12.5	10.0	12.5	10.0	10.0
Category 1	-14.0	-10.0	10.0	10.0	10.0	10.0

Based upon these differences by storm category, it is then possible to develop new evacuation rates for each storm category. For category 2 to 4 storms, the smoothed data are taken directly from the storms shown in Tables 1 to 3. For category 1 and 5 storms, the differences from Table 4.7 are applied to the average rates shown in Table 4.5, which yields results in Table 4.8. These rates were then considered to be representative site-built evacuation rates by storm category derived from the mobile location data.

Table 4.8 2021 Study Evacuation Rates by Hurricane Category for Site Built

	Evacuation Zone Type					
Difference	A	B	C	D	E	Inland
Category 5	72.5	70.0	62.5	57.5	55.0	50.0
Category 4	65.0	60.0	55.0	50.0	45.0	40.0
Category 3	60.0	50.0	40.0	35.0	30.0	30.0
Category 2	45.0	40.0	35.0	30.0	25.0	20.0
Category 1	36.0	25.0	27.5	25.0	20.0	17.5

4.2.3 Composite Evacuation Rates for Mobile and Manufactured Home Residents

A similar analysis was done with mobile and manufactured homes evacuation rates. Table 4.9 presents those rates for Hurricane Irma, Table 4.10 presents results for Hurricane Matthew, and Table 4.11 shows results for Hurricane Michael.

Table 4.9 Hurricane Irma Mobile and Manufactured Evacuation Rates by Affected County

			Evacuation Zone Type						
County	Type	Population	A	B	C	D	E	Inland	No Zone
Monroe	Coastal	75,798	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Collier	Coastal	371,453	68.0	n/a	88.4	62.8	57.7	n/a	n/a
Lee	Coastal	737,468	64.4	8.8	65.8	58.7	25.8	n/a	n/a
Charlotte	Coastal	181,067	78.1	65.8	66.0	62.3	n/a	31.3	n/a
Sarasota	Coastal	419,496	64.3	52.0	64.9	65.6	37.6	60.0	n/a
Manatee	Coastal	384,213	63.5	60.8	62.4	64.9	44.8	51.5	n/a
Pinellas	Coastal	964,666	49.6	50.4	41.6	32.1	40.5	38.9	n/a
Hillsborough	Coastal	1,422,278	55.0	66.1	47.2	57.6	51.2	42.4	n/a
Pasco	Coastal	524,602	68.0	42.4	36.2	38.5	37.2	45.6	n/a
Hernando	Coastal	186,313	60.7	37.8	52.8	45.4	32.4	41.9	n/a
Citrus	Coastal	145,169	48.0	46.8	47.6	40.4	61.7	38.4	n/a
Levy	Coastal	40,403	47.3	49.0	64.9	67.6	44.6	40.4	n/a
Dixie	Coastal	16,589	61.2	31.1	n/a	42.5	24.6	29.1	n/a
Taylor	Coastal	21,870	36.9	n/a	85.0	35.9	40.8	35.6	n/a
Hendry	Inland	40,732	n/a	n/a	n/a	n/a	n/a	65.3	n/a
Desoto	Inland	36,903	55.2	76.3	39.6	32.3	n/a	56.5	n/a
Glades	Inland	13,516	47.7	61.8	59.7	60.3	62.9	57.2	n/a
Hardee	Inland	27,131	n/a	n/a	n/a	n/a	n/a	n/a	48.3
Polk	Inland	686,218	n/a	n/a	n/a	n/a	n/a	n/a	46.4
Weighted Average		6,295,885	59.4	45.6	54.0	52.0	42.6	43.4	46.5
Difference from Site Built			2.3	-0.6	15.7	15.2	12.3	14.0	21.4

Table 4.10 Hurricane Matthew Mobile and Manufactured Evacuation Rates by Affected County

			Evacuation Zone Type						
County	**Type**	**Population**	**A**	**B**	**C**	**D**	**E**	**Inland**	**No Zone**
Brevard	Coastal	585,507	49.7	n/a	n/a	41.9	38.1	36.2	n/a
Volusia	Coastal	536,487	100.0	44.8	39.2	76.4	60.4	19.4	n/a
Indian River	Coastal	153,989	n/a	5.8	n/a	n/a	n/a	23.7	n/a
Flagler	Coastal	109,801	72.7	6.1	n/a	n/a	n/a	16.0	n/a
St. Johns	Coastal	244,674	77.6	21.8	n/a	n/a	n/a	21.6	n/a
Duval	Coastal	936,186	56.4	32.7	32.5	21.5	28.9	16.1	n/a
Nassau	Coastal	83,098	63.5	n/a	30.6	27.8	49.8	24.3	n/a
Weighted Average		2,649,742	67.2	31.1	34.8	41.1	40.1	22.4	n/a
Difference from Site Built			23.4	-9.4	5.9	13.2	14.8	2.6	n/a

Table 4.11 Hurricane Michael Mobile and Manufactured Evacuation Rates by Affected County

			Evacuation Zone Type						
County	**Type**	**Population**	**A**	**B**	**C**	**D**	**E**	**Inland**	**No Zone**
Gulf	Coastal	15,576	68.0	56.4	58.2	56.0	n/a	36.2	n/a
Bay	Coastal	182,161	46.6	56.8	58.0	41.5	n/a	42.7	n/a
Calhoun	Inland	14,362	n/a	n/a	n/a	n/a	n/a	n/a	43.4
Franklin	Coastal	11,811	54.7	55.7	n/a	n/a	n/a	0.0	n/a
Liberty	Inland	8,345	n/a	n/a	n/a	n/a	n/a	n/a	50.2
Weighted Average		232,255	48.6	56.7	58.0	42.7	n/a	42.2	45.9
Difference from Site Built			-10.4	-4.2	3.3	1.7	n/a	2.0	7.3

For mobile and manufactured homes, a composite rate was again computed as shown in the second to last row of each table. The composite was compared against the site-built rates for the same hurricane, as shown in the last row of each table. Due to the smaller sample sizes of mobile and manufactured records in the LBS dataset, the data are less reliable. As a result, a composite of the differences was developed as shown in Table 4.12, which compares the individual composite differences for each hurricane, it shows the final smoothed differences aggregated across the different storms. These results showed that, on average, mobile and manufactured home residents evacuate at a rate that is about 10 percentage points higher than rates for site-built residents. This difference of 10 percentage points was used to populate the smoothed composite evacuation rates for mobile and manufactured homes shown in the last five rows of Table 4.12.

Table 4.12 Mobile and Manufactured Home Composite Evacuation Rates

		Evacuation Zone Type						
Metric	**Hurricane**	**A**	**B**	**C**	**D**	**E**	**Inland**	**No Zone**
Difference from Site Built	Irma	2.3	-0.6	15.7	15.2	12.3	14.0	21.4
	Matthew	23.4	-9.4	5.9	13.2	14.8	2.6	n/a
	Michael	-10.4	-4.2	3.3	1.7	n/a	2.0	7.3
Smoothed Composite Difference		10.0	10.0	10.0	10.0	10.0	10.0	10.0
Final Evacuation Rates by Hurricane Category	Category 1	46.0	35.0	35.0	35.0	30.0	28.0	25.0
	Category 2	55.0	50.0	45.0	40.0	35.0	30.0	25.0
	Category 3	70.0	60.0	50.0	45.0	40.0	40.0	35.0
	Category 4	75.0	70.0	65.0	60.0	55.0	50.0	50.0
	Category 5	83.0	80.0	73.0	68.0	65.0	60.0	50.0

4.3 Refuge Rates

In order to determine refuge rates, the same set of affected counties were used for each observed hurricane. The composite refuge rates for each hurricane by home type and refuge rate type are shown in Table 4.13.

Table 4.13 Observed Composite Refuge Rates for Affected Counties

			Evacuation Zone Type						
Home Type	**Refuge Rate Type**	**Hurricane**	**A**	**B**	**C**	**D**	**E**	**Inland**	**No Zone**
Site Built	Friends & Family	Matthew	79.6	82.2	85.9	80.5	78.5	81.1	n/a
		Irma	82.1	83.7	81.6	82.2	81.6	81.9	81.4
		Michael	76.0	75.8	73.8	80.7	n/a	79.1	91.4
	Hotel & Motel	Matthew	18.9	16.7	12.7	19.3	17.0	17.6	n/a
		Irma	15.6	13.4	14.9	13.5	14.4	12.0	15.1
		Michael	23.4	23.3	24.9	17.5	n/a	18.5	8.0
	Shelter	Matthew	1.5	1.0	1.4	0.2	4.5	1.2	n/a
		Irma	2.3	2.9	3.5	4.3	4.0	6.1	3.4
		Michael	0.6	1.0	1.3	1.8	n/a	2.4	0.6
Mobile & Manufactured Homes	Friends & Family	Matthew	97.0	92.6	85.8	88.0	82.4	81.7	n/a
		Irma	85.1	83.4	87.3	77.7	83.8	88.4	85.9
		Michael	71.6	75.9	70.0	71.3	n/a	87.2	90.0
	Hotel & Motel	Matthew	3.0	5.8	13.5	12.0	15.3	13.9	n/a
		Irma	12.3	7.7	11.8	16.0	13.7	7.7	10.2
		Michael	28.0	23.9	28.7	26.7	n/a	11.0	9.0
	Shelter	Matthew	0.0	1.6	0.6	0.0	2.3	4.5	n/a
		Irma	2.6	2.1	0.9	6.3	2.5	3.7	3.9
		Michael	0.4	0.2	1.3	2.1	n/a	1.7	1.0

The refuge rates are shown to be noisy in general, but several trends are observable:

- First, shelter rates tend to be higher for evacuation zones that are less at risk and lower for evacuation zones that are more at risk. This is particularly evident for Hurricane Irma and Michael site-built residents.
- Second, the changes in shelter rates tend to be offset by changes in hotel/motel rates where the hotel/motel rates tend to be higher for evacuation zones that are more at risk and lower for evacuation zones that are less at risk. Friends and family rates tend to be more stable across evacuation zones.
- Third, hotel/motel rates tend to be lower for mobile and manufactured homes than for site-built home residents. These trends tend to be offset by differences in friends and family refuge rates.
- Last, there were higher shelter use rates for Irma than Matthew and Michael. Because Michael's sample sizes were smaller than the other two hurricanes and particularly small for the group that used shelters, Michael's shelter use rate numbers were considered to be less reliable. Based on the data from Irma and Matthew, shelter rates were taken to be higher for higher category storms, which can be explained by more people needing refuge for larger storms, meaning less availability of hotels and motels, in general.

Based upon these observations, smoothed composite refuge rates were developed. No discernable difference could be identified across hurricanes, so each hurricane category was assumed to see identical refuge rates. Table 4.14 shows the final set of smoothed refuge rates developed in the study.

Table 4.14 Final Smoothed Composite Refuge Rates

			Evacuation Zone Type						
Home Type	**Refuge Rate Type**	**Hurricane**	**A**	**B**	**C**	**D**	**E**	**Inland**	**No Zone**
Site Built	Friends & Family	Category 1	80	80	80	80	80	80	80
		Category 2	80	80	80	80	80	80	80
		Category 3	80	80	80	80	80	80	80
		Category 4	80	80	80	80	80	80	80
		Category 5	80	80	80	80	80	80	80
	Hotel & Motel	Category 1	18	18	17	17	16	16	16
		Category 2	18	17	17	16	16	15	15
		Category 3	17	17	16	16	15	15	15
		Category 4	17	16	16	15	15	14	14
		Category 5	16	16	15	15	14	14	14
	Shelter	Category 1	2	2	3	3	4	4	4
		Category 2	2	3	3	4	4	5	5
		Category 3	3	3	4	4	5	5	5
		Category 4	3	4	4	5	5	6	6
		Category 5	4	4	5	5	6	6	6
Mobile & Manufactured Homes	Friends & Family	Category 1	85	85	85	85	85	85	85
		Category 2	85	85	85	85	85	85	85
		Category 3	85	85	85	85	85	85	85
		Category 4	85	85	85	85	85	85	85
		Category 5	85	85	85	85	85	85	85

Home Type	Refuge Rate Type	Hurricane	Evacuation Zone Type A	B	C	D	E	Inland	No Zone
	Hotel & Motel	Category 1	13	13	12	12	11	11	11
		Category 2	13	12	12	11	11	10	10
		Category 3	12	12	11	11	10	10	10
		Category 4	12	11	11	10	10	9	9
		Category 5	11	11	10	10	9	9	9
	Shelter	Category 1	2	2	3	3	4	4	4
		Category 2	2	3	3	4	4	5	5
		Category 3	3	3	4	4	5	5	5
		Category 4	3	4	4	5	5	6	6
		Category 5	4	4	5	5	6	6	6

4.4 Out of County Rates

Out of county rates were developed differently than the rates described above because trends in these rates across hurricanes, evacuation zones, and housing types could not be detected. However, it was found that out of county rates were correlated with the population of the county. Larger counties saw lower out of county rates and smaller counties observed higher out of county rates. This is likely a result that smaller counties have fewer opportunities for shelter inside the county than larger counties.

To account for this trend, a regression model was developed using the observed out of county rates for Hurricanes Matthew, Irma, and Michael. The dependent variable of the regression model was taken as the out of county rate for each county as a whole. The independent variable was the population of the county. A logarithmic model was then fit to the data. Figure 4.1 shows the observed data points along with the fitted line corresponding to the fitted regression model. The results indicate that very low population counties have higher out of county rates. For instance, Hamilton County with a population of about 15,000 is estimated to have an out of county trip of 72 percent, while Miami-Dade County with a population of about 2.7 million is estimated to have an out of county rate of only 46 percent.

Figure 4.1 Out of County Rates vs. Population