

Evaluating Responses to Contraflow for Hurricane Evacuation

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ABSTRACT

The very high travel demands associated with hurricane evacuations require some strategies, such as contraflow sections, to be included in evacuation plans. However, the response or reaction of the evacuees to these strategies has not been given much attention in the past. This study concentrated on one particular strategy, contraflow segments, and investigated evacuees' willingness to use them through an animated survey.

The first part of the study dealt with six factors (service availability, police presence, exit location, entry congestion, availability of multiple entries, and limited choice) which were studied independently and compared against individual background characteristics. The distribution of the responses from the survey indicated that the presence of multiple entries or the availability of information about services increased the likelihood of evacuees switching to contraflow lanes, while the presence of police personnel for instance did not greatly alter the decision. Other factors like entry congestion or exits well before or well after initially desired ones decreased the willingness to use contraflow lanes. In the case where contraflow lanes were the only option on the main evacuation route (without the regular lane alternative), evacuees were willing to take detours to avoid the use of contraflow facilities.

The second part of the study dealt with congestion and information about congestion levels along the regular and contraflow lanes. Overall, evacuees demonstrated a willingness to benefit from any congestion improvement offered by contraflow lanes as opposed to assumptions in the literature claiming underutilization of these segments due to drivers' discomfort and unfamiliarity.

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GENERAL AUDIENCE ABSTRACT

The very high travel demands associated with hurricane evacuations require some strategies, such as contraflow sections, to be included in hurricane evacuation plans. However, the response or reaction of the evacuees to these strategies has not been given much attention in the past. This study concentrated on one particular strategy, contraflow segments, and investigated evacuees' willingness to use them through an animated survey. Usable data was collected from 821 respondents. The first part of the study dealt with six factors (service availability, police presence, exit location, entry congestion, availability of multiple entries, and limited choice) which were studied independently and compared against individual background characteristics. The distribution of the responses from the survey indicated that the presence of multiple entries or the availability of information about services increased the likelihood of evacuees switching to contraflow lanes, while the presence of police personnel for instance did not greatly alter the decision. Other factors like entry congestion or exits well before or well after initially desired ones decreased the willingness to use contraflow lanes. In the case where contraflow lanes were the only option on the main evacuation route (without the regular lane alternative), evacuees were willing to take detours to avoid the use of contraflow facilities. However, the effects of the above listed factors were associated with the background characteristics of the evacuees as the odds ratios in this study indicated. Previous contraflow or reverse lane experience for instance attenuated the effect of entry congestion on avoiding contraflow lanes. Contraflow experience on the other hand increased the likelihood of using the first entry when two entries were available and increased the willingness to switch to contraflow lanes when information about services was provided. Also, evacuation experience, presence of passengers affecting stops, and having dependents in the family improved the willingness to use contraflow lanes given information about services. Other characteristics like living in a hurricane prone area increased the inclination to use contraflow in the presence of police personnel and having passengers affecting destination choice increased the willingness to detour and avoid

contraflow when regular lanes were not part of the main evacuation route from the respondent's origin.

The second part of the study dealt with congestion and information about congestion levels along the regular and contraflow lanes. Different combinations of levels of congestion and information were presented to the respondents in the animated part of the survey. Respondents indicated their preference for contraflow or regular lanes in these scenarios. This data was used to develop a conditional logit model which predicted choice based on the presented options. Evacuees demonstrated an overall willingness to switch to contraflow lanes when these lanes were less congested than the regular lanes. However, with similar congestion levels on the regular and contraflow lanes, willingness to switch to contraflow lanes decreased as congestion levels increased. Information about upcoming congestion influenced evacuees' route choice decisions. Information motivated switching to contraflow lanes when conveying better downstream conditions along these lanes. Overall, evacuees demonstrated a willingness to benefit from any congestion improvement offered by contraflow lanes as opposed to assumptions in the literature claiming underutilization of these segments due to drivers' discomfort and unfamiliarity.

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Chapter 1: Introduction

Hurricanes pose a triple threat to coastal areas: wind, storm surge, and fresh water flooding. As with Hurricane Matthew, a common protective action is to evacuate coastal areas, involving the movement of hundreds of thousands or even millions of people over the transportation system. Demand typically surges during the morning one or two days before the hurricane makes landfall (Murray-Tuite and Wolshon, 2013). This demand surge often exceeds the capacity of the transportation system and thus results in extensive delays, which bring major safety concerns. During evacuations, if people have not evacuated during a specific time limit, their lives could be endangered due to the hurricane landfall (Wolshon, 2001).

Handling such high demand requires a safe and resilient transportation system, one that operates well under unusual conditions, particularly one that is adaptable or flexible (e.g., Murray-Tuite, 2006; Godschalk, 2003). Many evacuation management strategies exist to adapt the surface transportation system to the emergent demand. Some of these strategies focus on demand by implementing a staged evacuation, for instance. Other strategies focus on the supply side where special signal timings, ramp closure, or crossing elimination, for example, work on improving the flow of traffic, while other strategies like shoulder use or contraflow provide additional capacity to the transportation network (Murray-Tuite and Wolshon, 2013). Contraflow strategies in particular are very popular, especially after Hurricane Floyd in 1999, all coastal states vulnerable to hurricanes now have preserved evacuation plans that include contraflow strategies (Wolshon, 2008). Thus, this thesis focuses on the use of contraflow facilities.

1.1. Contraflow Strategy Solution

Contraflow operations involve the use of roadway lanes in the opposite direction of their normal flow. Since during evacuations outbound traffic is the one that is significantly increasing, inbound lanes are reversed to be used as outbound lanes. Thus, lane reversal offers an increase in outbound roadway capacity as compared to typical lane scenarios (FEMA, 2000).

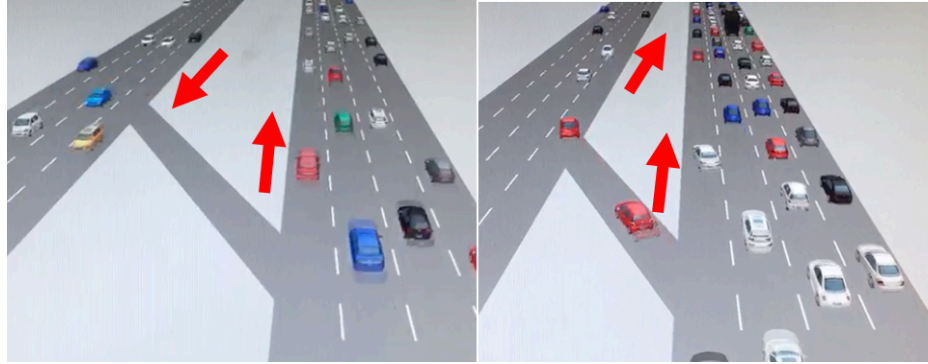


Figure 1: Regular conditions (left figure) vs. Contraflow conditions (right figure) - red arrows indicate direction of flow

Starting in the 1990s, contraflow strategies have been widely used and incorporated into different hurricane evacuation plans (Xie et al., 2010). Setting up contraflow operations is resource intensive. Personnel are needed for clearing contraflow sections, closing entry and exit points, diverting traffic, and conducting law and traffic enforcement in general. Also, logistic requirements include signs and marking for information conveyance and infrastructure installations (such as the different crossovers). Thus, given the various requirements, capacity gains from implementation of strategies must also be weighed against the associated execution cost (Wolshon, 2001).

1.2. Research Need

Several researchers (e.g., Collins, 2008; Fang and Edara, 2014; Lim and Wolshon, 2005; Stephen, 2007; Theodoulou and Wolshon, 2004) have investigated the performance and design of contraflow sections and strategies, primarily through simulation. However, most of the previous literature, depending on data availability and the extent allowed by simulation models, did not account for driver behavior when faced with different scenarios and conditions, and relied on assumptions about driver behavior and evacuees' willingness to use the contraflow lanes. ***Thus, a fundamental gap exists in the literature when it comes to understanding and predicting drivers' willingness to use contraflow lanes and the traffic conditions and other factors that influence their selection of contraflow lanes or facilities.*** Depending on evacuees' knowledge of the contraflow evacuation plan and road design, the influencing factors are not necessarily just related to traffic conditions. As Wolshon (2001) and Lim and Wolshon (2005) noted, speeds tend to be slower, signage is often facing the wrong way, safety features are typically designed for impact in the normal direction, and access to fuel and rest facilities is

limited. Access to destination points may also be heavily restricted by the contraflow plan, possibly requiring avoidance of contraflow lanes altogether. Researchers such as Fang and Edara (2014) have also begun exploring intermediate cross-over points for access to the contraflow lanes. Such access points provide other opportunities for evacuees to use the contraflow lanes. Also, when making route choice decisions, drivers not only rely on factors they can observe or on their personal experiences but also look for additional information that can support their choices (Ben-Elia and Shiftan, 2010). Robinson and Khattak (2010) emphasized the importance of information provision on alternative routes in assisting travelers, even those facing long congestion periods and who are more inclined to change routes, to make their final route change decisions.

Previous studies on evacuation (e.g., Wolshon, 2001; Sadri et al., 2013) have started to identify different route choice influencing factors, but failed to go into the details of evacuation scenarios and particular evacuation traffic management strategies or even traffic conditions. Rather, the focus was on the general behavior and needs. For instance, evacuees often travelling with children, pets, elderly, and people with special needs must ensure proper access to services and facilities ranging from food to fuel, medication, and restrooms. For that reason, evacuees prioritize routes providing these services (Wolshon, 2001). Similarly, different factors like information provision, recommendations, distance travelled, destination, and socioeconomic characteristics (Sadri et al., 2013) influenced evacuees' route choices. However, the relative importance of the different factors in the general context was not well captured.

Part of our study focuses on the evaluation of the evacuee's choices and preferences to determine the statistical importance of the different factors influencing their choices between contraflow and regular lanes. The effects of the different factors on evacuees' route choice decisions were evaluated using measures of association and a conditional logit model.

1.2.1. Experiments for route choice studies

For more day-to-day situations, drivers' route choices have been studied through a variety of experimental methods, including field (Zhang and Levinson, 2008) and laboratory controlled simulation experiments (Hartman, 2006). Many of these studies will be discussed in Chapter 2 of this thesis. In general, while field experiments and laboratory simulation experiments can be costly and often have limited test subjects, surveys can more quickly obtain a larger number of subjects. However, scenario visualization becomes more problematic.

With advances in survey design and administration and other visualization tools, surveys can combine traditional questions with visual experiments. For instance, Wilmot and Gudishala (2013) mailed participants a DVD which introduced video animation and sound to help participants contextualize different decisions in a hurricane evacuation case. However, their study focused on the evacuate/stay decision, timing, mode, and destination choice rather than route choice.

When it comes to hurricane evacuations and particularly specific strategies, route choice decisions can be complicated. The infrequency of such events and the level of urgency and stress associated with them make it difficult to study driver route choice behavior in the field. Thus, other means such as interactive surveys become the most practical method. Hence, a visually animated survey presented itself as the best way to expand the number of test subjects while mimicking field evacuation situations that cannot be tested every day on the ground. Our study developed an animated survey that included video attachments of simulated contraflow conditions, which exposed potential evacuees to different scenarios with the objective of collecting insight into their respective choices under contraflow circumstances.

The survey was administered entirely online and was divided into three parts. The first part collected demographic information that allowed normalizing the population differences. The second part tested the relative significance of path choice influencers. The third part presented the animated videos of different combinations of traffic and real time information at the contraflow entry points and asked survey respondents to make route choice decisions.

1.3. Goals and Objectives

The overall purpose of this thesis was to understand better hurricane evacuees' willingness to use contraflow lanes. The objectives focused on identifying the conditions and factors that influence this willingness. The factors investigated were based on what has been previously identified in the literature, including visual inspection and comparison of traffic conditions on regular and contraflow lanes, information through dynamic message signs, availability of police personnel on site, and the location of contraflow lanes' exit relative to individual desired destinations. Furthermore, congestion at the contraflow entry point and the availability of multiple entries; limited egress and access to facilities, and contraflow in general; familiarity with contraflow; evacuation experience; general route use; general driving behavior; and socio-demographic and economic characteristics were examined.

1.4. Contributions

This thesis addresses a gap in the existing literature and helped determine how willing evacuees are to use contraflow lanes and the factors influencing this willingness. Without this information, both research and practice are limited to assumptions about how drivers behave when presented with requirements or opportunities to use contraflow lanes. Researchers so far have been investigating the performance and design of contraflow sections and strategies primarily through the use of simulation and assumptions about evacuees' behavior in this setting. If these assumptions are not consistent with intended route selections, unexpected congestion may arise, deteriorating the evacuation experience and potentially exposing evacuees to hazards for longer periods of time.

Through the statistical analysis of data collected from the animated survey, a model predicting evacuee behavior under contraflow conditions based on traffic and real time information conditions was developed to provide a basis for researchers and policy makers for the assumptions of evacuees' route choice behavior. This model provides information for the development and design of contraflow strategies in future studies.

The benefits of this study will become more relevant as greater en-route communication among infrastructure and vehicles/drivers becomes available by updating the system in a way that optimizes the use of the capacity of the contraflow lanes. If properly communicated, future evacuation plans will enhance contraflow implementations in particular and evacuation operations in general and thus improve evacuees' overall experience during an evacuation.

1.5. Organization of the Thesis

The outline of the thesis is as follows. The current Chapter 1 identifies the research need and introduces the research goals and contributions. Chapter 2 presents a review of previous studies and literature around contraflow and route choices and concludes by the identification of the research hypotheses. Chapter 3 presents the data collected during the study. It first reviews the design of the survey used to collect the data and then provides an overview of the data. Chapter 4 discusses the methodology that was used to analyze the collected and cleaned data. Finally, Chapter 5 presents the results and Chapter 6 provides the conclusions of the research.

Chapter 2: Literature Review

Previous literature has addressed subjects related to contraflow and route choices, separately or jointly in regular or under special evacuation conditions. This chapter focuses on contraflow studies in part one, reviews route choice experimental studies in part two, and identifies factors previously identified to influence contraflow usage in part three, upon which the different hypotheses were proposed (part four).

2.1. Contraflow Studies

The study of contraflow integration into evacuation plans sometimes focused on the particular design of entry or termination points or special features of the contraflow section. Models in several studies followed a microscopic approach which allowed for specific detailed design allocations using VISSIM (e.g., Dixit et al., 2008; Yu et al., 2014), CORSIM (e.g.: Lim, 2003; Ren et al., 2012; Theodolou and Wolshon, 2004; Williams et al., 2007), Synchro, SimTraffic (Collins, 2008), Paramics (Stephen, 2007), and Transims (Zhang and Wolshon, 2016). However, other studies (e.g., Chiu et al., 2008; Montz et al., 2012; Songchitruksa et al., 2012; Yu et al., 2014; Zhang and Wolshon, 2016) looked at larger areas and overall networks and strategies to optimize the larger picture of the evacuation plan, including contraflow. In these “bigger picture” studies, contraflow improved evacuation performance in most cases (e.g., Chiu et al., 2008; Kim et al., 2008; Songchitruksa et al., 2012; Zhang and Wolshon, 2016). In many of these “big picture” studies (e.g.: Chiu et al., 2008; Hausknecht et al., 2011; Montz et al., 2012; Zhang and Wolshon, 2016), other strategies were integrated into the plan in addition to the contraflow strategies. For instance, the phased evacuation strategy (Chiu et al., 2008; Zhang and Wolshon, 2016) which moved evacuees at different times and the flexible or dynamic plans (Hausknecht et al., 2011; Montz et al., 2012) which allowed for strategy update based on real time information complemented contraflow plans. Also, more holistic plan considerations accommodated emergency traffic management and emergency response needs (Konstantinidou et al., 2015) and provided consideration for evacuation priority and setup times required to prepare the contraflow sections (Wang et al., 2013).

Even when traffic management strategies are set in place during evacuation events the problem resides in their proper use by evacuees. Thus, even when contraflow sections are introduced as a traffic management strategy during evacuations, the willingness of evacuees to switch routes and use them remains not well understood. Evacuees sometimes comply with

recommended routes, however, precisely predicting traffic distribution and direction changes at particular intersections and on routes is very difficult (Williams et al., 2007). Drivers do not always decide on their route choices before the trip (e.g.: Gao et al., 2008; Gao et al., 2010) and their behavior can be reactive in some cases. (Li et al., 2014).

2.2. Route Choice Experiments

When making a trip, drivers are faced with several choices, such as destinations, routes, and times. Route choice is an important aspect affecting drivers' trips and traffic conditions. Making route and destination choices is not limited to a specific phase of the trip; route choice decisions can be made before the start of trip or during the trip (Pel et al., 2009).

2.2.1. Evacuation Route Choice Models

Evacuation studies that accounted for route choice behavior relied on more traditional methods that were adjusted to suit the evacuation situations. For instance, shortest path algorithms were applied on networks with capacities and delays taken from highly congested periods (Shen et al., 2008) or dynamically adjusted for what was described as “panic situations” (Song et al., 2009). In other instances, traditional individual optimum routing and system optimum routing under the dynamics of evacuations were applied (Lämmel and Flötteröd, 2009). However, adjustments of route choice models to apply to evacuation situations are not straightforward. Researchers debate whether previous network experience in regular conditions applies to routing for evacuation conditions or evacuation should be considered as a “new” situation which could not benefit from previous experiences. For instance, Brown et al. (2009) applied an incremental traffic assignment by time for they considered trips unable to benefit from learning or previous experience. On the contrary, Wu et al. (2012) found that equilibrium can be achieved through repeated evacuations in a certain area where they considered past experience to play the major role in route selection. The models listed above, however, were not based on observed choices and thus did not depict evacuees' specific situational behavioral choices.

2.2.2. Experimental Route Choice Studies

Experimental studies are applied to observe individuals' reactions or responses to specific sets of conditions. Scenarios could be tested or created in the field as well as in tailored laboratory situations for hands-on responses or could be described in surveys in different ways. The following sections describe several field and laboratory experimental studies in addition to surveys that were applied in route choice studies.

2.2.2.1. *Field and Laboratory Experiments*

The purpose of experiments is to try to make subjects react as closely as possible to the way they would when faced with the same conditions in real life. For instance, allowing subjects to experience driving on a highway as opposed to arterial routes with different levels of development and scenery, allowed travelers to trace their preferences according to the type of trip they are making (Zhang and Levinson, 2008). In other instances, laboratory simulations imitated actual route driving to make drivers face different hypothetical scenarios. For example, drivers could be placed in actual car cabins and surrounded by cameras allowing them to have front and back views and even sounds (Katsikopoulos et al. (2000), Yan and Wu (2014)). In these situations, although not driving on a real network, drivers were able to physically experience wait time (Hartman (2006)) and receive travel information at particular times and locations along the network (Ben-Elia and Shifan (2010), Yan and Wu (2014)). These experiments saved the burden of having experimental subjects imagine themselves on hypothetical networks and allowed them to make decisions based on observed networks. Unfortunately, these field and laboratory experiments are expensive and typically have limited scenarios and test subjects.

2.2.2.2. *Surveys*

Another way to determine route choice behavior is through the use of Stated Preference (SP) surveys. These surveys might use existing or hypothetical scenarios to gain insight from different respondents (Harline and Burris, 2014). As an example, surveys could be distributed to drivers on a real route at specific locations (e.g., Khattak et al., 1993; Chen et al., 2013) and mailed back. In those situations, drivers are asked about the specific locations between which they are driving and asked to give information about the characteristics they considered, the choices they made, and information they had. These types of surveys draw attention to the way people are perceiving or assessing situations and information they get on the routes. In other cases, survey questionnaires could provide participants with different scenarios and ask them to make route choices depending on the described situation (e.g., Katsikopoulos et al., 2000, Avineri and Prashker, 2004).

Enough information should be provided to survey respondents for them to be able to imagine the real life scenario and its specific attributes and characteristic (Harline and Burris, 2014). However, a large amount of material presented to the subjects comes with a risk of

overwhelming them and thus negatively affecting their responses (e.g., Arentze et al., 2003; Wang and Timmermans, 2001; Mazzotta and Opaluch, 1995). One solution is to provide images that could simplify the communication task through visualization.

Interactive experiments combine the simplicity of surveys with the efficiency of visualization to ease the burden on the participants. The most advanced of these interactive experiments were mostly carried out under in-lab supervision. For instance, Razo (2010) conducted guided survey sessions with computer based surveys portraying an interactive map which allowed participants to make decisions along the way as to which routes to take with real time information provided along the route in some cases. Other interactive surveys did not have to be supervised (e.g., Mahmassani et al., 2003; Kraan et al., 2000; Wilmot and Gudishala, 2013). The study by Wilmot and Gudishala (2013) which visualized scenarios of flow directions in a hurricane evacuation case did not need supervision for instance. The mailed DVD included the scenario videos and enabled respondents to provide their evacuation decisions. Surveys by Mahmassani et al. (2003) and Kraan et al. (2000) did not deal with the particular case of evacuation but considered less repetitive, shopping trips. In Mahmassani et al. (2003) and Kraan et al. (2000), the interactive surveys allowed the provision of information to make destination choices before the start of the trip. Also, conditional questions were possible with this framework. In other words, the set of choices given at each step depended on the previous choices; whether destination or route choices. This survey allowed the participants to visualize the timing and the locations for which they were getting travel information, and interactively select their choice of destination or route.

The issue with this type of survey is the bias introduced by limiting the participants to the ones who have access to technology and have the capability of dealing with more complicated methods of question provision (Mahmassani et al., 2003). However, these surveys still present the advantages of fast recruitment, self administration, automatic data collection, greater population outreach and time flexibility allocated to respondents. Also, with special purpose surveys like the one dealing with specific evacuation scenarios, the internet remains an easy and relatively cheap way to administer surveys (Kraan et al. (2000)).

2.3. Factors Affecting Contraflow Usage

While contraflow strategies are a key component for addressing capacity problems during highly congested evacuation periods, emergency management agencies do not have absolute

control over their operation, and they can be underutilized in many cases (Theodolou and Wolshon, 2004). With the improvements that accompany contraflow implementation come different drawbacks that were identified in the literature (e.g., Urbina and Wolshon, 2003; Wolshon, 2001; Wolshon, 2002). Because contraflow sections were initially designed to be operated in the opposite direction, safety is a prime concern. Signs and markings or even crash attenuators are usually specifically designed for the particular route direction, and thus operating the segment in the opposite direction will make these elements less or even not useful, generate driver confusion, and often result in serious accidents. Also, the driver's unfamiliarity with the routes might disturb flow operations, reduce speeds, and cause vehicles to flow in wrong directions specifically if there is a lack of sufficient personnel to control traffic and enforce operations on these routes, which can lead to head-on accidents (Urbina and Wolshon, 2003; Wolshon, 2001; Wolshon, 2002). In a field study by Lambert and Wolshon (2010), speeds were almost the same on normal and contraflow lanes and drivers did not seem to execute extra caution when on contraflow routes (Lambert and Wolshon, 2010). However, these findings were based on field experiments during peak day periods or football events and cannot be perfectly generalized to extreme event cases involving life threatening conditions and requiring long evacuation times like hurricanes but can still raise the question of the extent to which conditions can be varying on contraflow sections. To the best of the author's knowledge, the literature has not provided solid evidence on the extent of driver's response to contraflow sections during extreme events.

To accommodate the lack of data under occasional event conditions like hurricanes, many assumptions were made throughout the literature. Speed, for instance, was assumed to drop on contraflow lanes due to unfamiliarity and extra caution (Dixit et al., 2008). Also, a preference of normal over contraflow lanes was assumed based on the assumption of driver discomfort on evacuation lanes (e.g., Dixit et al., 2008; Lim, 2003). Drivers prefer more familiar routes, even when congested, because of their concerns about the status of alternative routes (Dow and Cutter, 2002; Akabarzadeh, 2012; Bai et al., 2011). From a comfort point of view (e.g., Dixit et al., 2008; Lim, 2003) or familiarity point of view (Dow and Cutter, 2002; Akabarzadeh, 2012; Bai et al., 2011), drivers may prefer more familiar regular flowing lanes. An assumption in this thesis was that when conditions on regular lanes were obviously better than those on contraflow lanes, drivers continue on their regular routes and thus these situations were not presented to the survey

respondents. Nonetheless, preference for regular over contraflow lanes and the choice between them by evacuees is not absolute and depends on many factors, which were discussed in the literature.

2.3.1. Number of Reversed Lanes

In his study, Stephen (2007) highlighted the importance of allowing an inbound lane to be used for emergency and service vehicle access. Songchitruksa et al. (2012) differentiated between contraflow and “evaculanes” which are shoulders used in evacuations to add capacity; their study indicated that the best configuration combines the use of a contraflow and an “evaculane.”

Nonetheless, most studies indicated that full lane reversal provides the best capacity increase when normal operations without contraflow lanes do not provide sufficient capacity (e.g., Chiu et al., 2008; Dixit et al., 2008; Urbina, 2002). Full lane reversal provides 70% increased capacity and offers evacuees safer and more comfortable conditions in the absence of inbound traffic that could cause head-on accidents (FEMA, 2000). Thus, the scenarios in this study only consider lanes to be fully reversed.

2.3.2. Information Provision

Information is a major determinant in socio-economic schemes like transportation (Hino and Nagatani, 2014). Advanced Traveler Information Systems (ATIS) can provide real-time information to users through Variable Message Signs, radio, or onboard computers (Wahle et al., 2000). With multiple information outlets, drivers can search for information that can support their route choice decisions (Ben-Elia and Shifan, 2010). Some drivers are even willing to pay for the information during trips, which are occasional and often unfamiliar or in times of high congestion (Zhang and Levinson, 2008; Hartman, 2006), thus information, particularly reliable information, is important during critical events and high congestion periods like during hurricane evacuations. The importance of information on route choice was further highlighted in several other studies (e.g.: Zhang and Levinson, 2008; Lu et al., 2011; Khattak et al., 1993; Chen et al., 2013; Yan and Wu, 2014; Ben-Elia and Shifan 2010).

Similar to the way route choices are made during different phases of the trip, information can be provided at the beginning of the trip and dynamically during the trip (Mahmassani and Chen, 1991; Pel et al., 2009). The better the quality and the accuracy of the information, its relevance to the situation, its timeliness and format, the more likely it is for the information to be

taken into account by drivers and to affect their route choices (Zhang and Levinson (2008)). However, information conveyed to drivers is not limited to travel time estimates and ranges (Ben-Elia and Shiftan, 2010). It can cover incident occurrence, forgone payoff (“travel times on nonchosen routes”) (Lu et al., 2011), delay (Khattak et al., 1993), and alternative routes (Chen et al., 2013).

This importance of communication of information (in route or pre-evacuation) is further highlighted in most of the route choice considerations implemented in evacuation simulations. Pel et al. (2009) for instance, developed a hybrid model that combined in-route information provision with pre-trip information or official path recommendations. Their model allowed different evacuee compliance levels with recommended evacuation routes and adaptation with realistic conditions when provided with in-route updated information. However, their model was generic and did not address any particular response to specific scenarios (Pel et al., 2010). Robinson and Khattak (2010) also called for information when travelers face alternative routes because even drivers facing long congestion periods make their final path decision based on real-time information provided to them.

Predicting travelers’ reaction to the information and drivers’ decision-making processes is complicated. Static drivers may ignore provided information for different reasons like lack of confidence and their personal experience (Wahle et al., 2010), but information impacts traffic operations in a transportation system. ATIS is implemented to improve drivers’ confidence and reliability in the system rather than establishing optimum equilibrium conditions (Hall, 1996). Drivers can rely on ATIS to support their choices (Gao et al., 2010). As such, given the importance of information, scenarios considered included provision of real time information.

2.3.3. Traffic Conditions

Drivers tend to try to minimize their travel times. The multinomial logit model developed by Bai et al. (2011) confirms that travel time is the major factor affecting drivers’ route choices. Specifically, when the time is critical, like during evacuation situations, route switching to avoid congestion becomes more likely. The situation can be compared to a work trip where a worker is restricted by his work schedule. Dalumpine et al. (2017) noted that during work trips, as compared to shopping trips, drivers look for roads that minimize their overall travel time. Switching routes is thus a matter of perceived overall traffic conditions. There exists a natural resistance to switching routes (Kraan et al., 2000), but when the perception of traffic on current

routes shows greater congestion, drivers switch to alternative routes given a minimum threshold of improvement (Mahmassani and Liu, 1999). However, with high congestion levels, with the absence of this required threshold of improvement, evacuees might be discouraged to switch to contraflow lanes. From here the first hypothesis to be tested in this study: *H1--Under similar congestion conditions, evacuees are more likely to stay on regular lanes.*

2.3.4. Contraflow Entries

The design of transition points from and into the contraflow sections is critical (Lim and Wolshon, 2005) because of the congestion that accompanies the merge requirements. Several studies discussed later in this section focused on the comparison of the contraflow performance under different scenarios for these critical points (e.g., Lim, 2003; Lim and Wolshon, 2005; Urbina, 2002; Urbina and Wolshon, 2003). Mostly, the transition between normal and contraflow lanes occurs through a crossover in the median ramps for traffic rerouting (e.g., Urbina, 2002; Urbina and Wolshon, 2003).

Entry points were studied in detail and were responsible for dictating the flow entries in the crossover section where the capacity usage of the crossover section relies on these entries (Wolshon and Lambert, 2004). For instance, Williams et al. (2007) compared the contraflow flow plan for I-40 in North Carolina to a modified plan with a different entry point location with an increased number of lanes on the crossover and showed how increasing the capacity of the crossover improved performance. This improved performance can be explained by the reduced congestion at the entry points and improved utilization of the contraflow section.

2.3.4.1. *Entry Congestion*

Contraflow sections may be underutilized like in the I-10 case in New Orleans (Theodolou and Wolshon, 2004). If there is not enough capacity for entry into contraflow sections, congestion is generated before the entry points, and then free flow governs the underutilized segments. One option for addressing congestion at entry points is to increase the capacity of the transition section (Williams et al., 2007). Nevertheless, entry congestion is not always completely mitigated and could affect the number of evacuees willing to switch to contraflow lanes. Drivers usually tend to avoid bottlenecks and congestion (Hino and Nagatani, 2014), and a congested entry consequently might decrease the likelihood to switch to contraflow lanes. However, people who have contraflow lane experience might be familiar with the

underutilization of these lanes in the case of congested entry points and thus might not be affected, leading to *H2- People with contraflow/ reverse lane experience are less likely to be affected by congestion on the contraflow entry.*

2.3.4.2. Entry Spread

Having more than one crossover is also possible, as in the study by Fang and Edara (2014) who studied the impact of having intermediate crossovers on mobility. They developed a heuristic based on iterative eliminations to determine the number of adequate intermediate crossovers and applied it to a case study on I-64 in Hampton Roads. These intermediate crossovers, which allowed movement between normal and contraflow lanes and access to roadside facilities (e.g., gas, food), demonstrated improved network performance by reducing the average travel time on the network. These increased intermediate points increase the number of entries into the contraflow section, thus increasing the number of vehicles able to access the contraflow section and benefit from its extra capacity (Theodolou and Wolshon, 2004). Thus, these multiple entries will encourage the overall use of the contraflow lanes. An assumption here is that people with contraflow previous experience will be the most aware of the benefits of having multiple entries. People with such experience may expect other people to join the contraflow lanes at the upcoming entries and will so be encouraged to switch to the contraflow lanes at the first entry, trying to gain the most benefit from the contraflow lanes. The third hypothesis focuses on the willingness to switch to contraflow lanes when multiple entries exist: *H3- People with contraflow/ reverse lane experience are more likely to switch to contraflow lanes at the first entry when more than one entry is available.*

2.3.5. Destination Access

Termination points at the end of contraflow sections can be grouped into two main categories: split and merge designs. Split configurations direct the contraflow and normal lanes onto two distinct paths, whereas merge configurations combine the flows from the normal and contraflow lanes to proceed on a common roadway (Lim, 2003; Lim and Wolshon, 2005; Urbina and Wolshon, 2003).

When comparing different termination point configurations, exits upstream of the merging section allowed for a reduction in congestion at merging termination points (Lim, 2003; Lim and Wolshon, 2005; Urbina, 2002; Urbina and Wolshon, 2003). In Lim (2003), when 25%

of the traffic exited upstream of the crossover, the capacity upstream of the merge increased by 35% and doubled if 50% of traffic were to exit before the crossover location. Similarly, Lim and Wolshon (2005), when comparing merge configurations with median crossovers varying by the location of median crossovers with respect to the termination point and the availability and location of exits along each side of the route, demonstrated that exits prior to the crossover reduced traffic at the merge points and thus relieved congestion (Lim and Wolshon, 2005). However, split configurations which separate lanes and forbid merging at exits, result in minimal interference between routes and thus provide the most improvements to traffic performance with the absence of merge congestion (Lim, 2003; Lim and Wolshon, 2005). In either termination point design, for evacuees to use contraflow lanes, they should be willing to exit at a location other than their most direct (desired) exit. This leads to the fourth hypothesis: *H4- Evacuees are more likely to use contraflow lanes if they can exit prior to their desired exit rather than after their desired exit.*

Also, when choosing evacuation routes, in addition to being able to move quickly and safely, evacuees' primary concern could be the ability to use a route that would enable them to reach their selected destination. As such, if evacuees are about to use other than their initially desired exit, they want to make sure that they would still be able to access their desired destinations. Moreover, evacuees might be more concerned about destination access if accompanied by people during the evacuation who might affect their destination choice, leading to the sub hypothesis: *H4- a- People with passengers who might affect their destination choice are less likely to use other than their initially desired exit.*

2.3.6. Services Along Contraflow

Evacuees' behavior during evacuation operations focuses on their general needs. Wolshon (2001) mentioned evacuees' attention to safety along contraflow routes and the provision of services (fuel, restrooms) along with their evacuation route. Also, as the situation worsens (approaching storm or increased levels of congestion), availability of services along evacuation routes becomes more important with the uncertain wait time on the route, which brings the fifth hypothesis: *H5- Information about services along contraflow routes increases the likelihood of evacuees switching to these lanes.*

It is expected that people who have evacuated before are familiar with the long wait times during evacuations. Also, people who have used contraflow lanes before recognize the need to

have access to services along the contraflow lanes by experience. Particularly, evacuees accompanied by people who affect the frequency of their stops care about ensuring access to stops along any route their take. From here the sub hypotheses: *H5- a- People with previous evacuation experience are more likely to switch to contraflow lanes when information about services is available along these lanes. H5- b- People who have previously experienced reversible lanes are more likely to switch to contraflow lanes when information about services is available along these lanes. H5- c- People who are accompanied by people who affect the frequency of their stops are more likely to switch to contraflow lanes when information about services is available along these lanes*

2.3.7. Police Presence

In general, and particularly during evacuation situations, police officers represent an authority to the public and result in greater positive response from evacuees (Aved et al., 2006; Fridolf et al., 2013). In Robinson and Khattak (2010), when police were present for route guidance, the greatest diversion was observed. Due to the confidence of the public in police officers for route guidance, hypothesis six can be stated as follows: *H6- The presence of police officers increases the likelihood of evacuees switching to contraflow routes.*

2.3.8. Limited Choice

Some evacuation plans, like that for Hampton Roads, do not provide evacuees with the choice to use contraflow lanes or not. In the Hampton Roads evacuation plan, vehicles entering east of the Hampton Roads Bridge Tunnel are forced into the contraflow lanes and not given the choice of accessing the I-64 regular flow lanes. However, vehicles would still be able to access side routes if they wanted to avoid the contraflow route (VDOT, 2015). Nevertheless, under regular conditions, willingness to switch to side detour routes only occurs where extended periods of delay are experienced and when drivers are familiar with the alternative routes and provided with real time information on these routes (Robinson and Khattak, 2010). Thus, the authors expect that under evacuation scenarios, where conditions on side routes are even more uncertain, evacuees will be less willing to take detours but might, if they are very familiar with the area, switch to avoid extensive congestion.

Chapter 3: Data Collection

Path choices during unusual events, especially environmental events are difficult to test on site and difficult to replicate. From that perspective, field experiments, which would have put drivers in the most realistic conditions, are not practical. Also, field experiments as well as in-lab simulation studies, limit the number of subjects that could potentially be tested and incur high costs.

Surveys, on the other hand, can be used to collect a high number of responses at a relatively low cost. The problem with surveys is that they make replicating reality or transmitting the desired idea to the respondent much harder. A survey that includes animations simulating traffic conditions could be more attractive to survey respondents and thus could obtain a high number of responses while mimicking reality and allowing several scenarios to be presented. Each survey participant was presented with choices to gain insight into evacuees' route choice when faced with contraflow facilities. The authors used a design of experiments approach to design the scenarios presented to each respondent.

3.1. Design of Experiments

As opposed to observational studies, where researchers have no control over the factors presented to the participants and where simple observation establishes inferences, designed experiments regulate potential controlling factors to establish connections based on a specific design of experiments. Rekab and Shaikh (2005, page 1) give the following definition for the design of experiments:

“Experimental design deals with establishing and actually conducting a test or a series of tests in which changes are systematically made to the input variables of a process in order to observe the corresponding changes in the output response.”

3.1.1. Attribute factors:

The first step to designing an experiment is to define the research question. As identified in Chapter 1, the question in this study is: how do different factors influence drivers' willingness to switch to contraflow lanes under evacuation situations? The next step is to specify the factors, which in this study are the traffic conditions and other factors that influence evacuees' selection of contraflow lanes or facilities as identified in Chapter 2.

The authors used simulation to mimic and visualize traffic situations faced by evacuees during hurricane evacuations. With this approach, the studied attribute factors were mostly

related to visible parameters at the entry to the contraflow lanes. Each attribute factor could have multiple levels. For example, traffic along regular lanes (one of the factors) could be “moving”, “moving slowly”, or “hardly moving”; these three states represent the three levels for the traffic factor. The greater the number of factors and the greater the number of levels, the more complicated the design, and the larger the required sample is to achieve statistically significant results.

As identified in Chapter 2, the selected attribute factors can be listed as follows:

1. Entry congestion
2. Availability of services
3. Number of entries
4. Destination or exit access
5. Police personnel availability
6. Choice limitation
7. Traffic conditions along regular lanes
8. Traffic conditions along contraflow lanes
9. Real time congestion information on regular lanes
10. Real time congestion information on contraflow lanes

These factors are expected to influence the path choice decisions along the evacuation route when faced with contraflow traffic management strategies. However, these factors' levels varied independently and/or interactively, and factorial design was needed. Before studying the levels of the treatment factors, the number of identified treatment factors was 10. With a minimum of two levels per factor, the minimum number of combinations for a full factorial design where all combinations were considered would be $2^{10}=1024$. A fractional factorial design could have reduced the number of combinations to 10% for instance but still required 100 combinations as a minimum. This still greatly exceeded the scenarios that could be practically simulated and implemented in this study.

Due to the practical limitations, the study was divided into two parts. The first section, dedicated to the first six identified factors, considered each factor independently and was presented in the survey as an independent, general, out-of-a-specific-context question, which obtained general insight on the level of influence of these factors.

The second section considered the last four identified factors (traffic conditions and real time congestion information along contraflow and regular lanes) and applied an experimental design considering interactions between these factors that resulted in different scenarios that were simulated and presented to the survey respondents. The intent of the simulated scenarios was to visually represent the hypothetical scenario. Thus, a microscopic simulation software that could visualize vehicle flows was required; the microscopic traffic flow simulation software PTV VISSIM was selected.

3.1.2. Factorial design of the considered factors

The study focused on two types of factors, traffic conditions and information, on both regular and contraflow lanes. The factors and their respective levels were portrayed to survey respondents through videos. Selected levels were tailored to make visualization practical and meaningful.

When dealing with traffic congestion, Level of Service (LOS) was used as the attribute level determinants since LOS is mostly a qualitative measure (from A to F where A is the best and F is the worst) congestion (representing a range of quantitative flow measures). However, since high demands are observed during evacuations, LOS A and B were not considered (they represent very light traffic). Also, since the representation of traffic was visual, LOS D which represents congested traffic (in-between level of congestion of LOS C and E) was not considered, to make scenarios more distinct and reduce possible confusion of respondents. As such, the three selected LOS were:

- LOS C: represented by moving traffic,
- LOS E: represented by highly congested traffic moving very slowly, and
- LOS F: represented as extremely slow traffic with the possibility of some stopped vehicles.

With the three LOS considered, the combinations of traffic congestion on regular and contraflow lanes were presented in Table 1. However, it was assumed that traffic situations with worse traffic on contraflow lanes would not be needed because people would not move from a lane doing better to a lane operating in a reversed direction and doing worse. Thus, greyed rows in Table 1 were eliminated. In the remainder of this thesis, the traffic condition combinations are indicated using the representation $[{\textit{regular LOS}} \ {\textit{contraflow LOS}}]$. For example, $[F \ C]$ indicates LOS F on the regular lanes and LOS C on the contraflow lanes.

Table 1: Traffic Congestion Combinations

	Regular			Contraflow		
	LOS C	LOS E	LOS F	LOS C	LOS E	LOS F
1	X	0	0	X	0	0
2	X	0	0	0	X	0
3	X	0	0	0	0	X
4	0	X	0	X	0	0
5	0	X	0	0	X	0
6	0	X	0	0	0	X
7	X	0	0	X	0	0
8	X	0	0	0	X	0
9	X	0	0	0	0	X

X: selected 0: not selected

The second two factors considered in the design were related to real time information. To simplify the study, possible levels were narrowed down to the following for LOS C:

- No Information
- Congestion Ahead 5 Miles
- Congestion Ahead 10 Miles

The “congestion ahead” wording was selected instead of travel times to particular destinations to keep the phrasing general enough to pertain to all survey respondents. However, with LOS E and LOS F, since traffic is already congested and will not be doing any better, the following levels were considered:

- No Information
- Congestion Ahead (meaning that it will continue being congested)

This information was portrayed in the videos on a Variable Message Sign. With the information levels, the combinations in Table 2 resulted. However, the researchers assumed that once information is available on the regular lanes, it is also available on the contraflow lanes. Thus, all combinations of information available only on one side were eliminated (greyed out). Also, having a [C C] level of service with both “Congestion Ahead 5 Miles” as information or both as “Congestion Ahead 10 Miles” information conveys the same meaning, thus [C C] with “Congestion Ahead 10 Miles” on both sides was also eliminated (blue row). After elimination, 16 combinations of traffic congestion and information remained. However, 16 scenarios are a lot to be taken by one survey respondent, where confusion and lack of concentration may result due to similar scenarios and fatigue.

Table 2: Traffic Congestion and Information Combinations

C C		Regular: C			Contraflow: C		
	No Information	Congestion Ahead 5 Miles	Congestion Ahead 10 Miles	No Information	Congestion Ahead 5 Miles	Congestion Ahead 10 Miles	
1	X	0	0	X	0	0	
	X	0	0	0	X	0	
	X	0	0	0	0	X	
	0	X	0	X	0	0	
2	0	X	0	0	X	0	
3	0	X	0	0	0	X	
	0	0	X	X	0	0	
4	0	0	X	0	X	0	
	0	0	X	0	0	X	
E C		Regular: E			Contraflow: C		
	No Information	Congestion Ahead		No Information	Congestion Ahead 5 Miles	Congestion Ahead 10 Miles	
5	X	0		X	0	0	
	X	0		0	X	0	
	X	0		0	0	X	
	0	X		X	0	0	
6	0	X		0	X	0	
7	0	X		0	0	X	
E E		Regular: E			Contraflow: E		
	No Information	Congestion Ahead		No Information	Congestion Ahead		
8	X	0		X	0		
	X	0		0	X		
	0	X		X	0		
9	0	X		0	X		
F C		Regular: F			Contraflow: C		
	No Information	Congestion Ahead		No Information	Congestion Ahead 5 Miles	Congestion Ahead 10 Miles	
10	X	0		X	0	0	
	X	0		0	X	0	
	X	0		0	0	X	
	0	X		X	0	0	
11	0	X		0	X	0	
12	0	X		0	0	X	
F E		Regular: F			Contraflow: E		
	No Information	Congestion Ahead		No Information	Congestion Ahead		
13	X	0		X	0		
	X	0		0	X		
	0	X		X	0		
14	0	X		0	X		

F F	Regular: F			Contraflow: F		
	No Information	Congestion Ahead		No Information	Congestion Ahead	
15	X	0		X	0	
	X	0		0	X	
	X	X		X	0	
16	0	X		0	X	

X: selected 0: not selected

3.1.2.1. Scenario randomization

The number of portrayed scenarios per person was limited to five, to reduce the respondent's burden. To be able to give different people different scenarios, the population had to be assumed homogeneous and normally distributed. A demographic and background questionnaire section was added to the survey to enable the identification of response differences by population sub-groups. Demographic and background questions focused on the factors presented in Table 3. Qualtrics was used to generate the online survey and to randomly select scenarios for each respondent. Each respondent received two [C C] scenarios with different information conditions to capture the influence of information. Each respondent also received one [E E] or [F F] scenario because they represented realistic, high congestion levels on both sides of the road where a choice of regular or contraflow lanes under similar severe conditions could be tested. The different blocks from which scenarios were randomly selected by Qualtrics are represented in Table 4. This selection of different blocks for randomization placed some control on the scenarios received by each respondent.

Table 3: Socio-demographic, Economic, and Background Factors

Factor number	Factor name
1	Vehicle Ownership
2	Driving experience
3	Reversible and contraflow experience
4	Residence area
5	Evacuation Experience
6	Age
7	Household composition
8	Gender
9	Education Level
10	Race

Table 4: Scenario Randomization Blocks of the 16 modeled scenarios

C C		Regular: C		Contraflow: C			
	No Information	Congestion Ahead 5 Miles	Congestion Ahead 10 Miles	No Information	Congestion Ahead 5 Miles	Congestion Ahead 10 Miles	
1	X	0	0	X	0	0	2 of 4
2	0	X	0	0	X	0	
3	0	X	0	0	0	X	
4	0	0	X	0	X	0	
E C		Regular: E		Contraflow: C			2 of 8
	No Information	Congestion Ahead		No Information	Congestion Ahead 5 Miles	Congestion Ahead 10 Miles	
5	X	0		X	0	0	
6	0	X		0	X	0	
7	0	X		0	0	X	
F C		Regular: F		Contraflow:			
	No Information	Congestion Ahead		No Information	Congestion Ahead 5 Miles	Congestion Ahead 10 Miles	
10	X	0		X	0	0	
11	0	X		0	X	0	
12	0	X		0	0	X	
F E		Regular: F		Contraflow: E			
	No Information	Congestion Ahead		No Information	Congestion Ahead		
13	X	0		X	0		
14	0	X		0	X		
E E		Regular: E		Contraflow: E			1 of 4
	No Information	Congestion Ahead		No Information	Congestion Ahead		
8	X	0		X	0		
9	0	X		0	X		
F F		Regular: F		Contraflow: F			
	No Information	Congestion Ahead		No Information	Congestion Ahead		
15	X	0		X	0		
16	0	X		0	X		

X: selected 0: not selected

	Block 1
	Block 2
	Block 3

3.2. Recruitment

The subject pool consisted of residents of the United States of America who were drivers 18 years or older. Adults were chosen since they were more likely to be the ones driving in evacuation situations as well as for ease of human subjects research approval. The population was limited to residents of the USA because the driving scenarios and traffic management strategies were designed for the USA (i.e., normally driving on the right-hand side). A variety of recruitment methods were used. This included emails, social media, VT News, and Amazon Mechanical Turk. To advertise the survey, a website (<http://www.nvc.vt.edu/murraytu/hurricane-path-choice>) was first created to form a credible reference to the study and the survey. An email including the website link and inviting people to participate in the study was sent to VT National Capital Region mailing list. Twitter was another recruitment method where hashtags related to evacuation and transportation topics were identified and then utilized to reach out to the audience engaging in the research topic. Identified influencers were tweeted directly and some of them supported the effort by retweeting the survey link. (No financial incentives were provided to respondents recruited through the above means.) Finally, Amazon Mechanical Turk was used to recruit respondents. A request specifying the anticipated time requirements and the \$2.00 USD compensation for taking the survey was advertised on Amazon Mechanical Turk, which allowed workers from Amazon Mechanical Turk to access and fill out the survey. Responses from Amazon Mechanical Turk were accepted or rejected based on the percentage of answered questions so that respondents who skipped the questions to get to the compensation were eliminated.

Survey bias was unavoidable. This was an online survey available in the English language only, which required respondents to be able to read and understand English, which is not a characteristic of everyone in the USA. Also, the fact that it was only available online introduced another bias related to access to a computer, tablet, or phone and an internet connection. The video inclusion dictated the necessity for an online survey, which cannot be achieved on paper. With a higher budget, this bias could have been reduced, for example, by on site interviews spread in different areas of the USA where people could be shown videos and asked questions orally in different languages. However, this idea, which also has its own bias, was impractical and exceeded the budget and time allocated for the study.

3.3. Overview of the survey

Survey takers provided responses to different questions that were then coded into the different variables used in the analysis. In general, questions were grouped into three parts:

1. Background and demographic questions which defined the respondents' experiences and demographic characteristics (factors identified in Table 3).
2. Attribute factor non-scenario questions, which presented independent questions related to the different factors affecting contraflow use except for the four that were used in the scenarios (traffic conditions and real time information along regular and contraflow lanes).
3. Scenario questions where respondents had to choose between switching to contraflow lanes or staying on regular lanes after watching each of the five videos as described in 3.1.2.1.

Variables from questions in parts one and two were then coded based on the questions and choices provided to the survey respondents and then recoded as binary variables for modeling purposes and for practical use in the analysis. The full set of variables and coding can be found in Appendix A of this thesis.

3.4. Data Cleaning

As discussed in 3.2 the survey was advertised on social media, emails and Amazon Mechanical Turk, which made it available to the general public. Thus, screening questions were needed to filter the target population. Also, the design of the survey in Qualtrics enabled responders to skip questions. Accordingly, some respondents who skipped most of the questions needed to be eliminated.

3.4.1. Screening Questions

The survey was limited to people living in the United States who were 18 years or older and held a drivers' license. Three screening questions were placed at the beginning of the survey to test for these three criteria and terminated the survey immediately if they were not satisfied. In addition, a consent screening question was mandatory for the completion of the survey. Failure to approve the consent form also resulted in immediate termination of the survey. Respondents who did not pass the screening questions were not included in the analysis.

3.4.2. Eliminated Responses

Responses did not always meet criteria used to guarantee quality responses. Survey completion time was one criterion. The survey introduced the concept of contraflow and explained that they should envision themselves in evacuation circumstances. Time to process this information as well as to watch the videos (150 seconds by themselves), suggested a minimum threshold of three minutes. Accordingly, respondents whose completion time was too short (three min and below) were assumed to not have thoroughly read the text and viewed the videos and were consequently eliminated.

In addition, five respondents did not complete any of the video scenario questions but fully completed the first two parts of the survey. These were considered in the analysis of the first parts but not the last (not in the choice model discussed later in Chapter 4). Six respondents answered four out of the five scenario questions, one respondent answered three out five and one other answered one out of five. Unanswered scenarios were not included in the analysis due to the fact that the issue was mainly technical (video did not run) as explained by many respondents. In total, 821 respondents were considered in the analysis of the six independent factors and 816 respondents recording 4067 responses were considered for the choice model (the five excluded respondents in the choice model did not answer any of the scenario questions).

3.5. Final Data Sample

As mentioned in 3.4.2, the final data sample was based on 821 total respondents. Out of these respondents, 718 were recruited through Amazon Mechanical Turk, 21 through emails, 62 through social media, 15 through word of mouth and five did not indicate the source where they heard about the survey. Due to the domination of respondents recruited via Amazon Mechanical Turk, differences due to different recruitment methods could not be detected.

3.5.1. Data Overview: Distribution of the different responses

Responses to the different survey questions resulted in categorical variables mostly. As such, the distribution function in JMP software was used to determine the spread of the categories among the respondents. This distribution function allowed the computation of the repartition percentages of the different responses.

Starting with the background questions, almost all survey respondents (98%) owned or leased a vehicle and 82% of them had one or two vehicles per household, others had more (Table 5). These respondents mostly drove on freeways except for the 2% who never did and 37% of

them drove on freeways more than five days a week (Table 5). When it comes to previous usage of reversible lanes, 64% of respondents had never used reversible lanes during peak hours in a regular week, but 43% experienced reversible lanes during special events (Table 5).

Table 5: Vehicle ownership, freeway and reversible lane usage

Variables	Percentage of respondents
VEH_OWN: vehicle ownership	
Owns or leases a vehicle	97.69%
NVEH: number of vehicles in household	
1	41.13%
2	41.13%
3	12.63%
4	3.25%
5	1.25%
6	0.25%
7	0.13%
8	0.13%
12	0.13%
FRFREQ: frequency of driving on a freeway	
Never	1.83%
Less than once a week	15.96%
1-2 days a week	24.12%
3-4 days a week	21.32%
5 or more days a week	36.78%
REVFREQ: frequency of usage of reversible lanes	
Never	64.31%
Less than once a week	21.07%
1-2 days a week	8.40%
3-4 days a week	4.51%
5 or more days a week	1.71%
REV_EXP 2: previous usage of reversible lanes during special events	
Previously used reversible lanes during special events	42.84%

The survey also asked about the respondents' home states to examine the rough geographical spread of the respondents and also to see if they lived in coastal or hurricane prone areas, which could imply familiarity with the hurricane hazard. Respondents were from different states, mostly California, Florida, Illinois, Pennsylvania, Texas, and Virginia, (Figure 2).

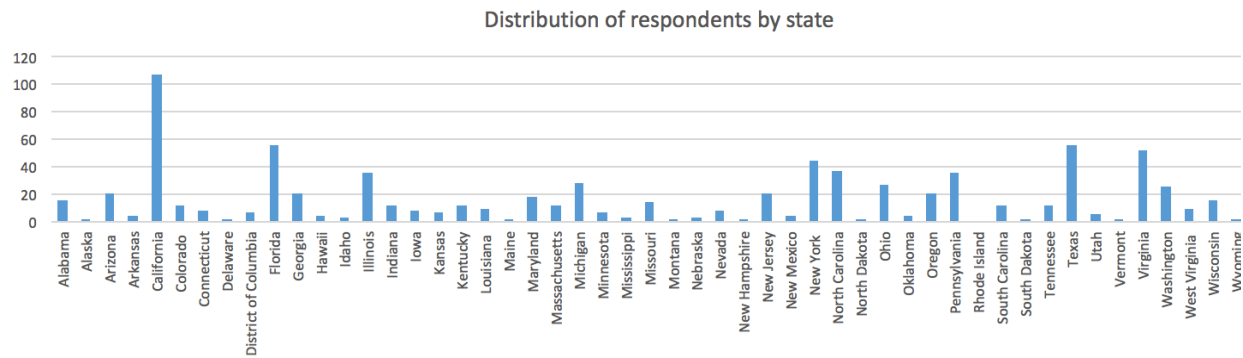


Figure 2: Distribution of respondents by state

However, only 28% and 26% of the respondents live (or at least consider themselves to live) in coastal and hurricane prone areas, respectively. Similarly, only 21% of respondents have previously experienced evacuations. Thus, some bias may be introduced to the results due to the fact that most of the respondents' residencies were not in areas directly concerned about hurricane evacuations (Table 6).

Table 6: Residence and evacuation experience

Variables	Percentage of respondents
COAST 2: whether respondent lives in a coastal area	
Respondent knows he/she lives in a coastal area	27.49%
HURR: Whether respondent lives in an area prone to hurricanes	
Respondent knows he/she lives in a hurricane prone area	25.55%
EVAC_EXP: Previous evacuation	
Previously evacuated	21.20%

Out of the 21.20% (173 people) who previously evacuated, 94% described the traffic as congested or very congested which makes them familiar with the high levels of demand accompanying evacuations. In addition, 37% of previous evacuators encountered contraflow in their previous evacuations and 87% of these used them and were willing to use them again in the future. Also, all of previous evacuators who did not use contraflow previously would use them in the future (Table 7). These responses demonstrate previous evacuees' readiness and willingness to use contraflow lanes in a future evacuation.

Table 7: Previous evacuation experience

Variables	Percentage of previously evacuated respondents
EVAC_CONG 2: Congestion in previous evacuation	
Congested or very congested	93.64%
Not congested	6.36%
EVAC_CONTRA 2: Contraflow availability in previous evacuation	
Available	37.32%
CONTRA_EXP 2: Previous usage of contraflow lanes in an evacuation	(Percentage of respondents who encountered contraflow during evacuation)
Previously used contraflow lanes in an evacuation	86.79%
CONTRA_AGAIN 2: Willingness to use contraflow lanes after using them in a previous evacuation	(Percentage of respondents who used contraflow during evacuation)
Will use contraflow again in another evacuation	100%
CONTRA_FUTURE 2: Willingness to use contraflow lanes after not using them in a previous evacuation	(Percentage of respondents who did not use contraflow when available in previous evacuation)
Will use contraflow in another evacuation	100%

People who did not experience evacuations before were also asked about some possibilities in case of a future evacuations. It was found that 83% of the survey respondents were likely to be the drivers during future evacuations, which made them the primary route decision makers. However, the decision on the route might not be a one-person choice since they may not be driving alone. Respondents expected to be accompanied mostly by 1 to 3 people during their evacuation and around 50% of them might have people who could affect their frequency of stops or their destination in a future evacuation (Table 8).

Demographic questions asked household composition questions which determined different age groups in the household as shown in Table 9, and determined age, race, gender, educational level and marital status of the respondents. Respondents were mostly 18 to 44 years old (80% of participants [grouping based on the categories used in the 2010 Age and Sex composition census brief (Howden and Meyer, 2010)]) and had high educational levels (61% more than a bachelor's degree), which might be due to the fact that respondents needed to use computers or smart devices, needed access to the internet, and most of them were Amazon Mechanical Turk workers. Both males and females were recruited with a 56%/ 44% split between males and females. Out of the total respondents, 39% were married and therefore may evacuate with others in the same vehicle. When it comes to race, 74% of the respondents were

white which makes the sample representative of the American community having 77% whites (United States Census Bureau, 2016).

After answering the demographic and background questions, respondents first answered the independent questions related to the identified factors affecting willingness to switch to contraflow lanes (service availability, police presence, exit location, entry congestion, availability of multiple entries, limited choice), and then provided their route choice decisions for the five scenarios presented to them. Responses to these questions will be discussed in the analysis part in Chapter 5.1.

Table 8: Driving and company in case of an evacuation

Variables	Percentage of respondents
DR 2: Driving in a future evacuation	
Respondent will drive in a future evacuation	83.45%
COMP: Number of accompanying people in an evacuation	
0	8.95%
1	24.51%
2	23.77%
3	20.96%
4	13.11%
5	5.64%
6	1.72%
7	0.12%
10	0.37%
20	0.12%
30	0.12%
50+	0.61%
STOP 2: influence on stop frequency	
Accompanying people might influence stop frequency	51.00%
DEST 2: influence on destination choice	
Accompanying people might influence destination choice	50.13%

Table 9: Demographic characteristics

Variables	Percentage of respondents
AGE_NG: Age group	
Between 18 and 44 years old	80.39%
Between 45 and 64 years old	17.05%
Greater than 65 years old	2.56%
N5: Number of household members less than 5 years old	(Percentage of the 16.69% of total respondents having
1	73.72%
2	24.09%
3	1.46%
4	0.73%
N17: Number of household members between 5 and 17	(Percentage of the 22.53% of total respondents having
1	56.22%
2	32.43%
3	9.73%
4	1.62%
N24: Number of household members between 18 and 24	(Percentage of the 17.66% of total respondents having
1	68.97%
2	24.83%
3	4.14%
4	2.07%
N44: Number of household members between 25 and 44	(Percentage of the 69.55% of total respondents having
1	52.01%
2	44.13%
3	3.50%
4	0.35%
N64: Number of household members between 45 and 64	(Percentage of the 35.2% of total respondents having
1	53.63%
2	46.02%
3	0.35%
N80: Number of household members between 65 and 80	(Percentage of the 9.74% of total respondents having
1	68.75%
2	28.75%
3	2.50%
N81: Number of household members greater than 81	(Percentage of the 1.58% of total respondents having
1	92.31%
2	7.69%
GENDER 2: Gender	
Male	56.07%
Female	43.93%
MAR 2: Marital Status	
Married	38.95%
Single, widowed, or divorced	61.05%
ED 2: Grouped educational levels	
No school / Some school, no degree/ High school	1.34%
Some college, no degree / Associate's degree,	37.44%
Bachelor's degree / Master's degree / Professional	61.22%
RACE 2: Race	
Caucasian/white	74.27%
Non Caucasian/white	25.73%

Chapter 4: Methodology

The data that was collected through the survey was used as the basis for the estimation of a conditional logit model that allows the prediction of drivers' choices of contraflow lanes over regular lanes. Additionally, factors were independently studied through distributions and odds ratios, which helped determine evacuees' route choice inclination when facing contraflow segments.

4.1. Distribution and Association

Most of the variables identified in this study were categorical. At first, the distributions of the different factors (identified in 2.3) were analyzed. Afterwards, coding the decision variables as binary response variables allowed the computation of the odds ratio as part of the analysis. Odds Ratio (OR) is a measure of association. OR quantifies the association between the occurrence of a certain outcome given the presence or the absence of a certain exposure (Schlesselman, 1982). For instance, in this study, OR can give a measure of the likelihood to switch to contraflow lanes when services are available given the absence or presence of people who might require extra stops (STOP 2). Particularly, OR was used to investigate different background characteristics. To determine the significance of the association between the route choice decisions and the background characteristics, JMP software was used to compute OR and P-values. "A P value is the probability of observing data as or more extreme as the actual outcome when the null hypothesis is true" (Dallal, 1999, P Values). In other terms, P-value is used to determine the significance of the results or the association, a small P Value (<0.05) indicates significant results. In the following Chapter 5.1, the OR will be shown for the factors and characteristics with significant associations as indicated by the P values.

4.2. Conditional Logit Model

The conditional logit model is based on a random utility model. An individual i facing m choices tends to maximize his utility. The overall utility of an individual i selecting choice j among presented alternatives is given by:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad \text{Equation (1)}$$

where:

- U_{ij} is the overall utility of choice j for individual i
- V_{ij} is the systematic utility component of choice j for individual i

- ε_{ij} is the random the random utility component (errors, unobserved individual taste, unobserved attributes) (Louviere, 2001).

Since individuals tend to maximize their utility, individual i will select choice j when presented with choice j against choice k ($j \neq k$), if:

$$U_{ij} > U_{ik} \quad \text{Equation (2)}$$

Therefore, in order to estimate probabilities of making a certain choice, assumptions must be made with regard to the distribution of the random component of the overall utility. The random component follows a standard Type I extreme value distribution where the conditional Logit Model assumes Independence of Irrelevant Alternatives (IIA). For the IIA, the relative probability between choices is independent of other alternatives. If j is chosen between j and k , inclusion of X (which is not currently considered) should not mean a selection of k over j when X is included (McFadden, 1973). This assumption leads to the general equations of the model taking the forms shown in Equations (3) and (4).

$$P_{ji} = \frac{\exp(V_{ij})}{\sum_{l=1}^m \exp(V_{il})} \quad \text{Equation (3)}$$

$$P_{ji} = \frac{\exp(\beta(X[i] \otimes Z[j]))}{\sum_{l=1}^m \exp(\beta(X[i] \otimes Z[l]))} \quad \text{Equation (4)}$$

where:

- P is the probability for the i th subject to the j th choice of m choices
- $X[i]$ is a subject attribute design row, with intercept
- $Z[j]$ is a choice attribute design row, without intercept
- β are the parameter estimates of the coefficients of utility associate with each effect level
- \otimes is the Kronecker rowwise product (product between two matrices) (JMP, 2014)

The model uses a maximum likelihood method, which estimates parameters β to maximize the LogLikelihood function:

$$\text{Log } L = \sum_j \sum_i \gamma_{ji} P_{ji} \quad \text{Equation (5)}$$

Where $\gamma_{ji}=1$ if respondent i choses alternative j and 0 otherwise (Hoffman and Duncan, 1988; Train, 2009; McFadden, 1973).

In this study, the Conditional Logit Model was used to estimate contraflow choices based on the experimental scenarios presented in the video part of the survey. Each video presented

two alternatives from which respondents had to make a binary choice. As such, binary choice modeling was suitable to estimate selected choices out of the presented alternatives (JMP, 2014). Also, in this study, the LOS and information on both regular and contraflow lanes were used to define the different alternatives, and thus, these factors were the choice attributes upon which selection can be estimated. Since each individual’s choice depended on the attributes of the alternatives provided to him/her in each case, a Conditional Logit Model was appropriate. The model enabled the estimation of contraflow choices based on the alternatives’ factors (choice attributes) in each case primarily, in addition to the demographics and background characteristics (subject attributes) of the individuals (Hoffman and Duncan, 1988).

4.2.1. Coding in JMP

In JMP, the choice modeling platform is the one using conditional logistic regression to estimate probabilities. To run the model in the choice platform, first, the choice options possibly available were coded and the factors’ levels were specified as shown in Figure 3. Afterwards, each participant was coded with a separate ID and choices presented to each subject and his/her selected choice were indicated as shown in Figure 4. Finally, each subject’s characteristics were entered based on its corresponding ID as shown in Figure 5.

LOS_R	Information_R	LOS_C	Information_C	ID
C				RC
C	Congestion Ahead 5 miles			RC5
C	Congestion Ahead 10 miles			RC10
		C		CC
		C	Congestion Ahead 5 miles	CC5
		C	Congestion Ahead 10 miles	CC10
E				RE
E	Congestion Ahead			REA
		E		CE
		E	Congestion Ahead	CEA
F				RF
F	Congestion Ahead			RFA
		F		CF
		F	Congestion Ahead	CFA

Figure 3: Possible choice options

Note that, as opposed to the rest of this paper, notations entered in JMP used “R” (for regular) and “C” (for contraflow) as a first letter to specify the type of lane.

ID	Choice 1	Choice 2	Choice
1	CC5	RC10	RC10
1	CC10	RC5	CC10
1	CC	RE	CC
1	CC10	REA	CC10
1	CFA	RFA	CFA
2	CC	RC	RC
2	CE	RF	CE
2	CEA	RFA	CEA
2	CEA	REA	REA
3	CC5	RC10	RC10
3	CC10	RC5	CC10
3	CC5	REA	CC5
3	CC5	RFA	CC5
3	CFA	RFA	RFA
4	CC5	RC5	RC5
4	CC10	RC5	RC5
4	CC5	REA	CC5
4	CFA	RFA	CFA

Figure 4: Participants options and choices

ID	AGE	DEPENDENTS	ED 2 2	exp 2	FRFR
1	21	0	2	1	
2	20	•	1	0	
3	29	0	3	0	
4	25	0	2	1	
5	27	•	3	1	
6	22	0	3	1	
7	22	•	2	1	

Figure 5: Subjects' characteristics

Chapter 5: Results and Analysis

In this chapter, the data are analyzed using distributions and associations in Section 5.1 and then used for the conditional logit modeling in Section 5.2. The study of the distribution of the different factors in 5.1 confirms how factors like presence of multiple entries or availability of services increase the likelihood of evacuees switching to contraflow lanes, while the presence of police personnel for instance does not greatly alter the decision. The distribution also shows how other factors like exit availability, entry congestion, or regular lane alternative on the main evacuation route decrease the willingness to use contraflow lanes in some cases. The effect of the different factors was also affected by the background characteristics of the evacuees. Characteristics like evacuation and contraflow lanes experience for instance demonstrated high influence on the direction of choice under different conditions. Section 5.2 on the other hand, thoroughly examines the effect of the congestion level and information provision along regular and contraflow lanes. The following analysis shows how evacuees demonstrated an overall willingness to switch to contraflow lanes when these lanes carried less congestion than the regular lanes, and how increased congestion on the contraflow lanes decreased evacuees' willingness to switch. Also, in section 5.2, the power of congestion real time information on directing the direction of evacuees' choices is demonstrated.

5.1. Distribution and Association

This section focuses on the different factors previous literature suggested would affect drivers' willingness to switch to contraflow lanes. The distributions of the variables that represented the independently studied factors (entry congestion, entry spread, exit location, availability of services, police presence, limited choice) were used to analyze the effect of those factors on the willingness to use contraflow lanes. Also, odds ratios were used to determine the influence of evacuees' background characteristics (like previous evacuation or contraflow experience) on the likelihood to switch to contraflow in the context of the listed factors. In addition, the distribution of the responses to the LOS and information combination scenarios is studied in section 5.1.7. before running the model in Section 5.2.

5.1.1. Entry Congestion

The survey question regarding entry congestion is shown in table 10; responses were distributed as shown in table 11. Congestion at the contraflow entry generally made respondents less likely to switch to contraflow lanes where 25 % and 44 % of the respondents were extremely

unlikely and somewhat unlikely to switch to contraflow lanes respectively (table 11). With only 19% of total respondents likely (extremely or somewhat likely) to switch to contraflow lanes (table 11), congested entry points to the contraflow lanes decrease the likelihood of switching to contraflow lanes.

Table 10: Survey question about entry congestion

Question	If the entrance to the contraflow lanes is congested, how likely are you to switch to contraflow lanes?
Choice Options	<input type="radio"/> Extremely likely <input type="radio"/> Somewhat likely <input type="radio"/> Neither likely nor unlikely <input type="radio"/> Somewhat unlikely <input type="radio"/> Extremely unlikely

Table 11: Distribution of responses when provided with information about entry congestion

Variable	Percentage of respondents	Binary variable	Percentage of respondents
ENTRY: Likelihood to switch to contraflow with congested entry		ENTRY 2	
Extremely likely	6.10%	Likely	18.78%
Somewhat likely	12.68%		
Neither likely nor unlikely	12.07%	Otherwise	81.22%
Somewhat unlikely	44.15%		
Extremely unlikely	25.00%		

The odds ratios were computed in JMP for the different background characteristics. With a statistically significant odds ratio for ENTRY 2 vs. exp 2 (P-value <0.0001: table 12), the results confirm that the choice to use contraflow lanes when the entry is congested is affected by reverse or contraflow previous experience. As shown by the odds ratio, people who have previously experienced some sort of reversed lanes were 2.07 times more likely to use contraflow when the entry was congested. Those people who have previously used reversed lanes, by experience, might be more aware that congested entries do not necessarily reflect the congestion level along the contraflow lanes. As such, hypothesis *H2- People with contraflow/ reverse lane experience are less likely to be affected by congestion on the contraflow entry* is supported.

Table 12: Factors affecting willingness to switch to contraflow with congested entry

Dependent variable	Independent variable	ODDS RATIO	P-Value
ENTRY 2: willingness to switch with congested entry	exp2: experience with any type of reverse or contraflow lanes	2.07	<0.0001

5.1.2. Entry Spread

Table 13 shows the question presented to survey respondents about the availability of multiple entries. Data in Table 14 indicated that 10% of the respondents were definitely willing to use the first entry, 30% were more likely to use the first entry, 21% intended to use the second entry, and 32% were not affected by that information and wanted to evaluate each entry at a time. Respondents also indicated that other factors might affect their choice in such a case. Mostly they mentioned considering the congestion on both lanes, congestion at the entry, how much fuel they have, their rush to make the next stop, safe transition and destination. Setting apart the availability of a second entry, evacuees may look at congestion conditions to select the route that would save them more time. Also, evacuees might feel uncomfortable with switching at a particular entry if they are worried about the safety of the transition, or if they find it congested; they might consider waiting for the other entry if it could provide safer or less congested conditions. Moreover, if evacuees are short on fuel or are rushing to a stop for services, they might reconsider switching to a contraflow route with the absence of information on stops or if they know that the stop on the contraflow lanes is farther away. Finally, evacuees might worry contraflow lanes will not provide them with the same destination access. These factors mentioned by survey respondents (e.g., congestion, services, destination) line up with the selected factors for the analysis in this study.

With information about the availability of more than one entry, 39% of respondents indicated a willingness to switch to contraflow lanes at the first entry. However, 61% of respondents were either determined not to switch to contraflow lanes, were waiting for the second entry, or were still looking into other factors to decide on whether to use either entry or not (table 14).

Table 13: Survey question about entry spread

Question	Suppose that you have reached the first entrance to the contraflow lanes where you learn that there is another entrance 15 miles ahead. How would you react?
Choice Options	<input type="radio"/> I will definitely use the first entry <input type="radio"/> I will be more likely to use the first entry <input type="radio"/> I prefer to wait for the second entry <input type="radio"/> I will not use either entry <input type="radio"/> It will not affect my decision; I will evaluate each entry when I get there <input type="radio"/> It depends on other factors, specify

Table 14: Distribution of responses when provided with information about availability of multiple entries

Variable	Percentage of respondents	Binary variable	Percentage of respondents
MULT: Choice when a second entry is available		MULT 2	
Definitely first	9.51%	Use first entry	39.51%
More likely first	30.00%		
Second	21.10%	Otherwise	60.49%
Not use either	2.56%		
Evaluate each at a time	32.20%		
Other	4.63%		

To test the effect of demographic and background characteristics on the decision to switch at the first entry, odds ratios are computed. The odds ratio confirms the association of having previously used contraflow or reverse lanes with the likelihood of using the first entry when information about multiple entries is provided. people with previous contraflow lanes are 1.68 times more likely to decide to enter contraflow lanes by using first entry when given information about the availability of two entries (table 15), supporting hypothesis *H3*.

Table 15: Factors affecting willingness to switch to contraflow lanes with the availability of multiple entries

Dependent variable	Independent variable	ODDS RATIO	P-Value
MULT 2: Likely to use first entry when multiple entries are available	exp2: experience with any type of reverse or contraflow lanes	1.68	0.0003

5.1.3. Destination Access

The question regarding exit access is shown in table 16. Responses showed that people were willing to use contraflow lanes mostly when the exit was at (71%), a little past (57%), or a little before (80%) their desired exit (Figure 6). When considering combinations of choices, while 25% of the subjects chose combinations of exits before their desired exit, the highest percentage went to combinations of exits before or after their desired exit but within 5 miles of their initially desired exit, 50%, as shown in table 17. As such the fourth hypothesis is supported but is incomplete, *H4- Evacuees are more likely to use contraflow lanes if they can exit prior to their desired exit rather than after their desired exit*, but the exit should be within a reasonable distance of the initially desired one.

An unexpected result is having a lower percentage for the exit exactly at the desired exit where a lower percentage (71%) was observed (figure 6). This lower percentage could be explained by either lack of attention since it was placed as the last choice in the choice set, not knowing that multiple answers could be picked, unwillingness to switch either way, or congestion concerns at the initially desired exit.

As mentioned in Section 2.3.5., evacuees are more concerned about using exits other than their initially desired exits and destination access when accompanied by people during the evacuation who might affect their destination choice. However, odds ratios did not show any significant correlation between any of the background characteristics and the exit location. Particularly, having people that might affect destination choice did not affect the willingness to switch depending on exit access and hypothesis H4- a is not supported in this case *H4- a- People with company who might affect their destination choice are less likely to use other than their initially desired exit*.

Table 16: Survey question about exit location

Question	If you are given information about exit access from the contraflow lanes, under which conditions would you consider using contraflow lanes? Check all that apply.
Choice Options	<input type="checkbox"/> You could exit contraflow lanes a little past your desired location (within 5 miles) <input type="checkbox"/> You could only exit contraflow lanes well beyond your desired location <input type="checkbox"/> You could exit contraflow lanes a little before your desired location (within 5 miles) <input type="checkbox"/> You could only exit contraflow lanes well before your desired location <input type="checkbox"/> You could exit contraflow lanes exactly at your desired location

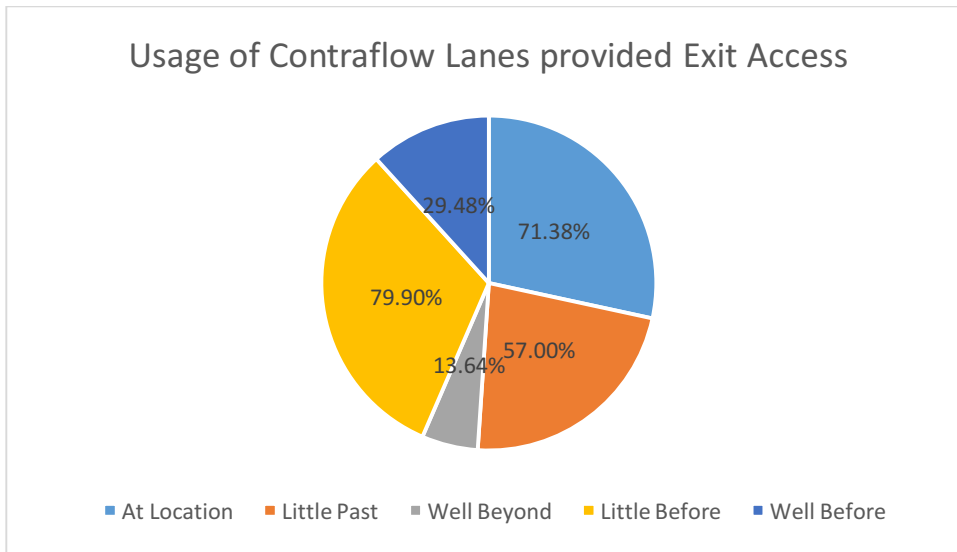


Figure 6: Usage of contraflow lanes provided exit access

Table 17: Exit combination choice distribution

Exit possibility	Percentage of respondents
EXIT_ALL: Exit anywhere (at, before or after desired exit)	4.14%
EXIT_2,3: Exit a little or well past desired exit	7.92%
EXIT_4,5: Exit a little or well before desired exit	24.73%
Exit_2,4: Exit within 5 miles of desired exit (before or after)	50.18%
Exit_1,2,4: Exit at or within 5 miles of desired exit (at, 5 miles before, or 5 miles after)	45.55%

5.1.4. Services Along Contraflow Lanes

The questionnaire also included a question concerning the availability of services as shown in table 18. When provided with information about services along contraflow lanes, 40% of the respondents were extremely likely to switch and 41% were somewhat likely to switch as compared to 5% and 1% somewhat unlikely and extremely unlikely to switch, respectively (Table 19). Consequently, with 81% of the respondents more willing to switch to contraflow lanes when provided with information about services, Hypothesis 5 was supported: *H5- Information about services along contraflow routes increases the likelihood of evacuees switching to these lanes.*

Table 18: Survey question about availability of services

Question	Suppose you were told that services (gas, food, public restrooms, etc.) are available along the contraflow lanes at the same frequency as the regular lanes. How likely is it that this information will affect your willingness to use the contraflow lanes instead of the regular lanes?
Choice Options	<input type="radio"/> Extremely likely <input type="radio"/> Somewhat likely <input type="radio"/> Neither likely nor unlikely <input type="radio"/> Somewhat unlikely <input type="radio"/> Extremely unlikely

Table 19: Distribution of responses when provided with information about the availability of services

Variable	Percentage of respondents	Binary variable	Percentage of respondents
SERV: Likelihood to switch to contraflow with available services along contraflow		SERV 2	
Extremely likely	39.95%	Likely	80.63%
Somewhat likely	40.68%		
Neither likely nor unlikely	13.40%	Otherwise	19.37%
Somewhat unlikely	4.63%		
Extremely unlikely	1.30%		

For a better understanding of the willingness to switch (likely or extremely likely) to contraflow when information about services is provided, different factors were jointly examined with this variable. Hypotheses 5- a to c suggest that (a) *People with previous evacuation experience, (b) who have previously experienced reversible lanes and (c) who are accompanied by people who affect the frequency of their stops are more likely to switch to contraflow lanes when information about services is available along these lanes.* People with previous contraflow experience might be more likely to consider factors such as services along the contraflow lanes if they had a bad experience in the past or if they usually count on these stops. Also, people who have previously evacuated and have experienced long delays and recognized the need for services will be concerned about the availability of stops. The presence of dependents or people affecting the frequency of stops was also considered since having stops and services along contraflow lanes was expected to be a major determinant of selecting contraflow lanes.

The odds ratio (statistically significant at the 0.01 level) shows that respondents who have previous contraflow experience are 1.7 times more likely to use contraflow when information about services is provided (table 20) supporting hypothesis H5- b. Also, when considering other travelers in the vehicle, table 20 shows that respondents who are accompanied with people requiring extra stops are 1.9 times more likely to use contraflow when information about available services is provided (supports H5- c). In addition to the above listed factors (reverse experience and people requiring extra stops), an association seems to be significant between people who have experienced evacuation and who are motivated by information on the availability of services. Consequently, hypothesis H5-a is also supported since people with evacuation experience are 2.1 times more likely to switch to contraflow lanes when information about services is provided (table 20).

In addition to the factors identified in the hypotheses, the presence of dependents in the household seems to play a significant role. Whether defined as people requiring extra stops or not, old and young people usually require more services for food and restrooms. Thus, respondents with dependents in their households require information about services along the contraflow routes to be able to make their decisions. Respondents with dependent household members are 1.9 times more likely to switch to contraflow when information about services is provided.

Table 20: Factors affecting willingness to switch to contraflow with the availability of services

Dependent variable	Independent variable	ODDS RATIO	P-Value
SERV 2: Willingness to switch given service availability	exp2: experience with any type of reverse or contraflow lanes	1.704	0.0026
	EVAC_EXP 2: previously evacuated	2.09	0.0022
	STOP 2: Accompanying people might influence stop frequency	1.92	0.0006
	DEPENDENTS: household with children younger than 17 and people older than 65	1.88	0.0015

5.1.5. Police Presence

As shown in table 22, the availability of police at the entry to the contraflow section made 26% of the respondents extremely likely to switch to contraflow lanes and 23 % somewhat likely to switch according to their response to the survey question shown in table 21. However, the highest percentage of respondents were indifferent to the presence of police (neither likely nor unlikely) which constituted 39% of the total respondents. The percentage of people extremely unlikely and somewhat unlikely to use contraflow given the availability of the police is low (3 and 9 % respectively). Consequently, the availability of police increased the willingness to switch to contraflow 49% of the times in our test sample but was insignificant 39% of the times. As such, police presence cannot be considered one of the strong factors affecting likelihood to use contraflow lanes. The sixth hypothesis (*H6- The presence of police officers increases the likelihood of evacuees switching to contraflow routes*) is weakly qualitatively supported since almost half of the respondents were more likely to switch when police are available. However, the hypothesis was not statistically supported as the probability of switching to contraflow motivated by the presence of the police is not higher than the probabilities of being indifferent or not switching.

Table 21: Survey question about police presence

Question	Suppose that there are police standing at the switching point between the two routes. What effect does their presence (as opposed to signs only) have on your willingness to use the contraflow lanes as opposed to the regular lanes?
Choice Options	<input type="radio"/> It makes me much more likely to use contraflow lanes <input type="radio"/> It makes me somewhat more likely to use contraflow lanes <input type="radio"/> It makes me neither likely nor unlikely to use contraflow lanes <input type="radio"/> It makes me somewhat less likely to use contraflow lanes <input type="radio"/> It makes me much less likely to use contraflow lanes

Table 22: Distribution of responses when provided with information about the availability of police

Variable	Percentage of respondents	Binary variable	Percentage of respondents
POL: Likelihood to switch to contraflow with available police at entrance		POL 2	
Extremely likely	25.58%	Likely	48.84%
Somewhat likely	23.26%		
Neither likely nor unlikely	38.86%	Otherwise	51.16%
Somewhat unlikely	8.89%		
Extremely unlikely	3.41%		

Generally, the distribution of the POL variable reflecting the likelihood to switch to contraflow when police are available was not statistically associated with the background characteristics of individuals. However, when compared with residency in hurricane prone areas, the factor seems to be significant ($P\text{-Value: } 0.0045 < 0.01$) as people who live in hurricane prone areas are 1.6 times more likely to switch to contraflow lanes when police are present at their entry (table 23).

Table 23: Factors affecting willingness to switch to contraflow lanes with the availability of police

Dependent variable	Independent variable	ODDS RATIO	P-Value
POL 2: Willingness to switch given police availability	HURR 2: living in an area prone to hurricanes	1.601	0.0045

5.1.6. Limited Choice

When having no other option but contraflow on the main evacuation route, some people might decide to detour through another town to avoid the use of contraflow lanes. The situation was presented to the survey respondents as shown in table 24 and resulted in heterogeneous responses. Some people were indifferent (25%), some were slightly inclined to take detours (27%) while 5% were likely to avoid detours (table 25). In general, 32% of the respondents were likely (extremely or somewhat) to take detours to avoid contraflow which is not a small percentage (table 25).

The self-reported subjective likelihood of detouring was compared against different characteristics. The only significant association (P-value 0.0051) was with the characteristic concerned with being accompanied by people who might affect destination choice, which made people 1.55 times more likely detour (table 26). Contraflow plans including forced contraflow (or detour) use might limit accessible destinations, or at least people could be afraid it would. This concern could encourage people to look for detours that offer greater choice and flexibility over route selection.

Table 24: Survey question about limited choice

<p>Question</p>	<p>Suppose that you are NOT given the choice of using regular lanes. All drivers from a particular town/city who wish to use a particular road will have to use the contraflow segment because regular lanes will be used by other traffic. However, the area has smaller secondary routes (which are not official evacuation routes) that will allow you to access the regular lanes if you first go through a nearby town/city. How likely do you think you will be to go through the other town/city to access the regular lanes to avoid the contraflow section?</p>
<p>Choice Options</p>	<ul style="list-style-type: none"> <input type="radio"/> Extremely likely <input type="radio"/> Somewhat likely <input type="radio"/> Neither likely nor unlikely <input type="radio"/> Somewhat unlikely <input type="radio"/> Extremely unlikely

Table 25: Distribution of responses when detour is the only option to avoid contraflow

Variable	Percentage of respondents	Binary variable	Percentage of respondents
DET 2: Likelihood of detour to avoid contraflow lanes		DET 2	
Extremely likely	5.00%	Likely	32.32%
Somewhat likely	27.32%		
Neither likely nor unlikely	25.49%	Otherwise	67.68%
Somewhat unlikely	32.56%		
Extremely unlikely	9.63%		

Table 26: Factors affecting willingness to detour when contraflow is the only other option available

Dependent variable	Independent variable	ODDS RATIO	P-Value
DET 2: Likelihood of detour to avoid contraflow lanes	DEST 2: Accompanying people might influence destination choice	1.55	0.0051

5.1.1.7. Information Provision and Entry Congestion

The last part of the survey dealt with responses to the scenarios; responses differed depending on the presented scenarios. About 10% of the respondents were presented with the first four C C scenarios and about 5% answered each of the remaining 12 scenarios. From the responses shown in Table 27, when facing similar conditions along regular and contraflow lanes, respondents almost equally spread at low congestion levels (C C and C5 C5) but had a preference for regular lanes at high congestion levels (E E, EA EA, F F, FA FA). C10 C5 presented a case where regular lanes were expecting farther upcoming congestion (based on the provided information), 73% stayed on the regular lanes whereas 27% still decided to switch to contraflow lanes. Likewise, with C5 C10 where contraflow lanes were expecting farther upcoming congestion (based on the provided information), 77% switched to contraflow whereas 23% decided to stay on the regular lanes. When contraflow showed better conditions most of respondents decided to switch to contraflow which can be shown in the F C, E C and F E cases, and even in the C C case where information communicated closer congestion on the regular lanes (C5 C10). Thus, evacuees are more likely to switch to contraflow lanes when real time information is portraying better traffic flow conditions on the contraflow lanes as compared to the regular lanes, which is consistent with intuition.

Table 27: Scenario response distribution

Scenario [<i>{regular LOS}{regular info}</i>] <i>{contraflow LOS}{contraflow info}</i>]	% presented	Regular	Contraflow
C C	9.59%	49.23%	50.77%
C5 C5	10.15%	50.12%	49.88%
C10 C5	10.20%	73.25%	26.75%
C5 C10	9.96%	23.46%	76.54%
E C	5.01%	5.39%	94.61%
EA C5	4.70%	9.42%	90.58%
EA C10	4.70%	9.42%	90.58%
F C	5.04%	2.93%	97.07%
FA C5	5.24%	6.57%	93.43%
FA C10	4.82%	7.14%	92.86%
F E	5.60%	7.46%	92.54%
FA EA	4.94%	14.43%	85.57%
E E	5.29%	61.40%	38.60%
EA EA	5.53%	58.22%	41.78%
F F	4.87%	75.76%	24.24%
FA FA	4.38%	67.42%	32.58%

When the LOS on the contraflow lanes was clearly better than that on the regular lanes (F C and E C cases) more than 90% of the respondents decided to switch to contraflow lanes (as shown in the different cases in table 27). Although, with lower percentages, respondents had a clear preference to switch to contraflow lanes when the contraflow showed slightly better operations than the regular lanes (76% for the C5 C10 case). This data indicated that evacuees are more likely to switch to contraflow lanes when traffic flow on these lanes is better than the flow on the regular lanes.

For cases with close levels of service on both sides of the route, decisions to switch did not have a dominant direction, but with the gridlock case on both sides (LOS F) a general preference to stay on the regular lanes was observed (76% and 67% staying on the regular lanes for F F and Fa FA). However, looking at the percentages we can see how adding information increased the percentage of those switching to contraflow in both cases E E and F F (E E to EA EA 39% to 42% and F F to FA FA 24% to 32% respectively).

The first two scenarios presented to each respondent were picked out of four C C scenarios with different information levels in order to separately analyze the impact of information on each respondent. The possible combinations of options given to each respondent with their respective response patterns are shown in table 28. The results demonstrate that when respondents were provided with a C C case followed by a C10 C5 case, 53% of the respondents chose either contraflow for both scenarios or regular for both scenarios and as such were not affected by the information conveyed to them. However, 35% of the respondents chose contraflow when given C C then chose regular when given C10 C5 where information conveys better conditions on the regular lanes. Similarly, when respondents were presented with C C followed by C5 C10, 59% chose the same type of lanes in both cases whereas 32% shifted to the better performing contraflow lanes (based on information) when given C5 C10. As such, more than 30% of the respondents were changing their route choice decisions as directed by the information on upcoming congestion.

Switching to the worse performing lanes when provided with information (12 % switch to contraflow in the C10 C5 case) may be due to misunderstanding of the information, or to visually assessing the congestion level to be lower on contraflow lanes and thus not relying on real time information. Since the videos presented the beginning of the contraflow lanes, some initial lack of congestion might have created the feeling of having the contraflow lanes less congested.

Even in cases where both of the first two scenarios provided information, respondents stuck to their decisions in many cases. This might be due to misunderstanding of information, insensitivity to upcoming changes in congestion levels or information in general. However, the C10 C5, C5 C10 combination showed the greatest change in congestion level as communicated by the information and resulted in 67% shifting to the better performing lanes. However, a general pattern of avoiding congestion based on the information provided was observed. These congestion levels and information levels were further studied in the choice model.

Table 28: Response pattern to first two C C scenarios

Combination of the first two scenarios	Similar Answers	First choice regular-Second choice contraflow	First choice contraflow-Second choice regular
CC C5C5	0.57%	0.28%	0.14%
CC C10C5	53.00%	12.00%	35.00%
CC C5C10	59.00%	32.00%	10.00%
C5C5 C10C5	54.00%	11.00%	35.00%
C5C5 C5C10	50.00%	44.00%	6.00%
C10C5 C5C10	23.00%	67.00%	10.00%

5.2. Choice Model

The choice model is used to replicate the behavior of hurricane evacuees when given the choice to enter contraflow lanes. The decision is expected to depend on the traffic level (or LOS) and the congestion information on the regular lanes where the evacuees are initially located and the contraflow lanes to which drivers can switch.

The choice model is based on the survey data where respondents were asked to choose whether or not to move to the contraflow lanes when presented with scenarios of different information and congestion levels along the regular and contraflow lanes. Scenarios included cases with and without information.

Data from the survey is used to create a Conditional Logit model. At first, the model is run without consideration for individual characteristics, this model gives a general idea of evacuees' behavior and will be analyzed in section 5.2.1. Afterwards, in section 5.2.2 individual characteristics are included to provide an improvement over the initial (no individual characteristics) model and to show how different sections of the population might vary in behavior.

5.2.1. No Characteristics Model

Data from the survey enabled the analysis of the conditional logit model based on the LOS and information levels on the regular and contraflow lanes. Likelihood ratio tests enable the determination of the significance of the effect that each parameter has on the model: The higher the L-R ChiSquare values, the smaller the p-values, and the higher the effect of the parameter on the choice model. As shown in table 29, LOS_R and LOS_C have the highest L-R ChiSquare values; as such, LOS seems to play the most significant role in this model both on the regular and the contraflow lanes, suggesting that participants primarily base their decisions on the observed LOS. On the other hand, information both on regular and contraflow lanes, although not as significant as LOS, also played a significant role in the model (p-values smaller than 0.001). LOS and information on the regular lanes seemed to have a little more significance on the choice than LOS and information on the contraflow lanes (L-R ChiSquare of 626 and 72 for Regular vs. L-R ChiSquare of 622 and 56 for Contraflow: table 29).

Table 29: L-R Chi Square Values and Significance of no characteristics model

	No Characteristics
Source	L-R ChiSquare
<i>LOS_R</i>	626.138***
<i>Information_R</i>	72.443***
<i>LOS_C</i>	622.436***
<i>Information_C</i>	56.447***

*** indicates $p < 0.001$

** indicates $p \leq 0.01$

* indicates $p \leq 0.05$

Parameter estimates obtained after running the model in JMP software (table 30) reflect the influence of each parameter level on the utility of a choice including that parameter. Individuals aim at maximizing their utility when making choices. As such, the larger the parameter estimates, the more inclination individuals have to choosing options comprising those parameters. For instance, as shown in table 30, having a LOS of C on the contraflow lanes will have the most positive effect on selecting choice options including that parameter ($LOS_C[C]=2.687$ being the largest positive estimate). The negative estimate of a LOS F on the contraflow lanes ($LOS_C[F]=-2.648$) on the other hand reflects a high repulsion to choices with LOS F on contraflow lanes.

The estimates obtained from the model are accompanied with some variation as shown by the confidence intervals in table 30. At a 95% confidence level, the true value of the parameter estimates falls within the lower and the upper 95% values shown in the table. In general, the lower and upper bounds of the interval keep the same direction of effect as the estimates in the first column of table 30. For instance, $LOS_C[C]$ falls within 2.355 and 3.058 which both reveal a high positive effect on selecting choice options including that parameter. Only in the cases of $LOS_C[E]$ (estimate -0.038: interval [-0.255|0.166]) and $Information_C$ [Congestion Ahead 10 miles] (estimate 0.232: interval [-0.007|0.463]), the effect direction moves from negative at the lower bound to positive at the upper bound of the interval, since their estimate values are the closer to zero and have the least influence on the utilities of choices containing those parameter levels.

Nevertheless, comparing the impact of the different parameter levels on the utilities of choices containing those parameters, a choice with a LOS C gives the utility a higher value than a choice with a LOS E which in turn results in a higher utility value than a choice with a LOS F,

both on the regular and contraflow lanes, (Table 30: 2.313, -0.223, -2.090 and. 2.687, -0.038, -2.648). In fact, choices with lower congestion levels will always have better chances at being selected and thus have higher utility values. Also, information conveying congestion ahead in 5 miles, both for the regular and contraflow lane cases, seems to lower the utility of choices containing this type of information since congestion is relatively close (estimate -0.781 for regular and -0.671 for contraflow). On the other hand, congestion ahead in 10 miles, confirms a farther congestion ahead (the congestion level will stay at C in the cases presented in this experiment for 10 miles before any congestion starts to build), and thus strengthens choice options with this type of information (estimate 0.338 for regular and 0.232 for contraflow). Similarly, congestion ahead, confirming the continuance of the observed LOS, makes people more confident about their choice as they know that the congestion level they observe is ongoing, and thus increases the utilities of choice options (estimate 0.443 for regular and 0.439 for contraflow).

Table 30: Parameter estimates of the no characteristics model

Parameter Estimates			
Term	Estimate	Lower 95%	Upper 95%
LOS_R[C]	2.313	2.003	2.667
LOS_R[E]	-0.223	-0.426	-0.035
LOS_R[F] ¹	-2.090	-1.577	-2.632
Information_R[Congestion Ahead]	0.443	0.079	0.839
Information_R[Congestion Ahead 10 miles]	0.338	0.086	0.583
Information_R[Congestion Ahead 5 miles] ¹	-0.781	-0.164	-1.422
LOS_C[C]	2.687	2.355	3.058
LOS_C[E]	-0.038	-0.255	0.166
LOS_C[F] ¹	-2.648	-2.100	-3.224
Information_C[Congestion Ahead]	0.439	0.085	0.826
Information_C[Congestion Ahead 10 miles]	0.232	-0.007	0.463
Information_C[Congestion Ahead 5 miles] ¹	-0.671	-0.078	-1.289

¹ For each factor, the estimate of the last level is equal to the negative sum of the estimates of the previous levels. Example: Estimate LOS_R[F]=-(Estimate LOS_R[C]+ Estimate LOS_R[E]) =-(2.313-0.223) =-2.090

The effects that parameter estimates (table 30) play on choice options translate in the selection probabilities in the different scenarios shown in table 31. The probabilities computed based on the estimates reflect evacuees' preferences depending on the scenarios. Scenarios

comprised some including congestion information and others without any information provision. In the following, the effect of this information provision at different congestion levels is examined.

To start with, the first four choice combinations presented in table 31 (CC choices) offered options with LOS C on both lanes. The probabilities reflect the power of information provision in decisions for the same level of congestion along routes. In fact, without information, and with similar medium congestion levels on both lanes (CC), people divide themselves between the two lanes with a little higher tendency to move to contraflow lanes (59%). The addition of information reflecting similar congestion levels on both lanes (C5 C5) slightly increased that tendency (62%). However, when information portrays different levels of congestion ahead, only 35% of evacuees will still be moving to contraflow lanes when congestion arises earlier on the contraflow lanes (C10 C5), whereas 80% will switch to contraflow to skip the earlier congestion on the regular lanes (C5 C10). Accordingly, at medium congestion levels (LOS C), when comparing the same conditions (scenarios C C and C5 C5) to different congestion information scenarios (C10 C5 and C5 C10), additional information on upcoming traffic resulted in more than 20% changes in the probabilities of switching to contraflow lanes (C C: 59% - C10 C5: 35% and C5 C10 80% - C C 59%).

The other choice combinations all had very high congestion levels on the regular lanes (LOS E or F). These high congestion levels on the regular lanes paired with medium congestion levels on the contraflow lanes (LOS C) resulted in very high probabilities of moving to contraflow lanes without any information provided (95 % with EC and 99% with FC). Nevertheless, additional congestion information again proves to affect people's choices. As shown in the probabilities in table 31, adding information about an upcoming congestion in 5 miles on the contraflow lanes lowers the probability of switching to the contraflow lanes during an E C scenario by 9% (95 % E C – 86% EA C5). On the other hand, sharing information about congestion ahead in 10 miles on the less congested contraflow lanes did not affect peoples' decision (EA C10 94% and E C 95%) where 10 miles seemed to be a large enough distance prior to reaching congestion to not affect the choice of switching to contraflow. This result could also confirm the benefit of switching to contraflow at that point. However, when the situation gets worse on the regular lanes with almost gridlock conditions (LOS F), nearly everyone will switch to the LOS C contraflow lanes even when they know that congestion is as close as 5 miles ahead

on the contraflow lanes (97% FA C5). Information about congestion ahead does not prevent people from trying to escape the gridlock conditions.

Moving on to the choice combinations with high congestion levels on contraflow lanes, information about continuing congestion ahead does not play a role in changing choice decisions. Probabilities are the same for the F E, E E, F F scenarios as compared to the FA EA, EA EA, FA FA scenarios respectively. In fact, information does not bring variation to the situation reflected by the observed congestion.

Concerning choice decisions based on the congestion levels, a high percentage of drivers will still switch to contraflow lanes when provided only slightly better conditions on contraflow lanes (F E 89%). Comparing this F E scenario to the F C scenario where contraflow lanes were recognizably less congested, it shows a 10% decrease in the probability of switching to contraflow lanes when congestion on these lanes increased from a LOS C to a LOS E (F C 99% - F E 89%). When conditions are similar on both lanes and highly congested, the tendency to switch to contraflow lanes decreases as congestion increases. While 59% switch to contraflow with the medium congestion C C scenario, 55 % switch with EE conditions, and the percentage further drops to as low as 36% with the F F scenario. Thus, the first hypothesis (*H1- Under similar congestion conditions, evacuees are more likely to stay on regular lanes*) is only supported at high congestion levels and preference for the regular over contraflow lanes increases as congestion level on the similarly congested lanes increases.

On the other hand, comparing the different computed probabilities enables one to distinguish choice combinations that led to similar probabilities of switching to contraflow lanes. For instance, C10 C5 combinations result in close probabilities to those obtained with F F and FA FA scenarios (35%, 36%, 36% respectively). In a way, with medium congestion levels, having a 5 miles earlier congestion on the contraflow lanes (C10 on regular vs C5 on contraflow) had similar impact on the probability of drivers deciding to switch to contraflow as having a gridlock condition on both lanes. Likewise, EA C5(86%) can be compared to C5 C10(80%) and F E and FA EA (89%). It seems that in situations where contraflow lane conditions are moderately better than those on the regular lanes (congestion 5 miles further away in the EA C5 cases and C5 C10 cases, and F vs. E congestion levels in the F E and FA EA cases) probabilities are close. However, when conditions on contraflow lanes are significantly better than those on the regular lanes (E C and F C cases) probabilities increase to higher than 95% (E C 95%, F C

99%, FA C5 97%). Finally, moderate similar congestion levels on both sides (E E and C C) implied comparable probability distributions (59 and 54% respectively).

To sum up, the analysis of the probabilities demonstrates evacuees' general tendency to use contraflow lanes as opposed to the previous beliefs on underutilization of these reversed lanes (provided demand is such that congestion is caused on the regular lanes). Particularly when these contraflow lanes are less congested than the regular lanes, drivers tend to switch to the less congested lanes and do not hesitate to use contraflow lanes. Concerning information, the probabilities indicate that congestion information alters decisions when it brings additional informative facts on congestion states ahead. However, when information just confirms ongoing congestion levels, it did not induce decision changes.

Table 31: Contraflow selection probability based on the no characteristics model

Choice combination	Contraflow selection Probability
C C	0.59
C5 C5	0.62
C10 C5	0.35
C5 C10	0.80
E C	0.95
EA C5	0.86
EA C10	0.94
F C	0.99
FA C5	0.97
FA C10	0.99
F E	0.89
FA EA	0.89
E E	0.55
EA EA	0.54
F F	0.36
FA FA	0.36

5.2.2. Model considering individual characteristics

In an attempt to improve the initial model with no individual characteristics and to display the difference in decisions for different segments of the population, individual

characteristics were included in subsequent models. The different demographic and background characteristics collected in the survey were added one by one to the original model.

The conditional logit model is computed based on the maximization of the loglikelihood function (see section 4.1, equation 5). Thus, a model with a larger loglikelihood value, or in other terms a smaller $-2\loglikelihood$ value (this one will be used) provides an improvement over the one with a smaller loglikelihood or larger $-2\loglikelihood$. However, for the model to provide a significant improvement over the first (no characteristics) model, the difference between the $-2\loglikelihood$ values of the two models should be higher than the corresponding critical value of the chi-square distribution considered at the 5% level of significance (Manly et al., 2017, page 33). Likelihood ratio test results and the degrees of freedom (DF) of the different models including the different characteristics are shown in appendix B (tables 33, 34, 35). When subjects' characteristics were considered, all models when compared to the no-characteristics model resulted in lower $-2*\text{LogLikelihood}$ values, indicating improvement. However, vehicle ownership (VEH_OWN), educational level (ED 2), and grouped ages (AGE_NG) resulted in a loss of significance of the main factors based on obtained P-values (larger than 0.05: Appendix B, tables 33,35). On the other hand, factors like living in a hurricane prone area (HURR 2) and being a driver (DR 2) kept the significance of the four main factors and showed newly introduced interaction factors to be significant (Appendix B, tables 33, 34). However these models did not offer significant improvement over the no-characteristics model with their $-2*\loglikelihood$ difference being smaller than the critical chi-square (13.57 and 13.26 vs. 15.51 critical value for DF=8). The two characteristics that offered significantly improved models over the no characteristics model are COAST 2 (living in a coastal area: $-2*\text{LogLikelihood}$ difference of 17.1 vs. critical chi-square of 15.51 for DF=8) and exp 2 (having reversible or contraflow experience: $-2*\text{LogLikelihood}$ difference of 19.3 vs. critical chi-square of 15.51 for DF=8). When COAST 2 and exp 2 were put together in the same model, the best fit model resulted. The model (with COAST 2 and exp 2) resulted in a better fit when compared to the initial no characteristics model ($-2*\text{LogLikelihood}$ difference of 35.1 vs. critical chi-square of 26.31 for DF=16), the model with exp 2 only ($-2*\text{LogLikelihood}$ difference of 17.95 vs. critical chi-square of 15.51 for DF=8), and the model with COAST 2 only ($-2*\text{LogLikelihood}$ difference of 15.71 vs. critical chi-square of 15.51 for DF=8).

Subsequently, the probabilities from the model including both COAST 2 and exp 2 were computed (based on estimates obtained from JMP) for different combinations of experience and living in coastal area. Results are presented in table 32 where exp2 [1] indicates having some sort of contraflow or reversible lane experience and [0] indicates not having the experience. Also, COAST 2 [1] /[0] indicate living or not living in a coastal area, respectively.

As mentioned earlier, interaction terms between the considered characteristics (exp 2 and COAST 2) and the LOS and information on the regular and contraflow lanes are not significant based on the computed P-values (less than 0.05 for all interaction terms, Appendix B, table 35). Consequently, looking at the probabilities from the different models, in general, probabilities are mostly similar for the different cases. The similarities between probabilities indicate an overall comparable direction of response for the population. However, some inferences can be made by examining the results.

Comparing people with and without previous reversible lane experience, at similar medium congestion levels and provided information (C5 C5), evacuees with no previous reversible lane experience are less likely to switch to contraflow lanes as compared to people with experience (49% vs 61% and 58% vs 69%), holding their location constant. Thus, with upcoming similar congestion levels, people who have not used reversible lanes before tend to be a little more reluctant to use the contraflow lanes. However, in cases like E C where contraflow lanes have clearly better congestion levels, people with no reversible experience tend to be a little more optimistic about the use of contraflow than the ones with experience (95% vs. 91% and 97% vs. 94%).

On the other hand, comparing the responses of people who live and those who do not live in coastal areas, those who live in coastal areas generally have a little lower tendency to switch to contraflow lanes in the different cases. Consequently, for people who live in a coastal area, in a case like C5 C5, where information lowers the tendency of switching to contraflow for people with no reversible lane experience, the probability of choosing contraflow lanes could decrease to as low as 49%. Thus, when designing evacuation plans for the hurricanes in coastal areas, the slightly lower percentages could be used when estimating the potential use of contraflow lanes. In general, differences in probabilities based on background characteristics could help using customized probability distributions, depending on the characteristics of the population for which the evacuation plans are being designed, for the assumptions related to evacuees' behavior when

faced with contraflow lanes. Thus, for example, designs for areas where people are used to the concept of reversible lanes, due to previous reversible lanes applications (special events, peak times, previous evacuations, etc.), could be based on the probabilities specific to (exp 2 = 1) cases depending on how much people used these reversible lanes in the previous applications. However, although inclusion of characteristics resulted in a better fit model, the general trend of the probability distribution was relatively close in the different cases, which allows contraflow use assumptions to be fairly similar across different population segments.

Table 32: Contraflow selection probability for the model including contraflow experience and living in a coastal area

Case	exp 2 [1], COAST 2[1]	exp 2 [1], COAST 2[0]	exp 2 [0], COAST 2[1]	exp 2 [0], COAST 2[0]
Choice combination	Contraflow selection Probability	Contraflow selection Probability	Contraflow selection Probability	Contraflow selection Probability
C C	0.56	0.60	0.57	0.61
C5 C5	0.61	0.69	0.49	0.58
C10 C5	0.38	0.35	0.36	0.33
C5 C10	0.76	0.82	0.75	0.82
E C	0.91	0.94	0.95	0.97
EA C5	0.76	0.89	0.77	0.89
EA C10	0.86	0.94	0.91	0.96
F C	0.97	0.99	0.99	1.00
FA C5	0.93	0.98	0.93	0.99
FA C10	0.96	0.99	0.98	1.00
F E	0.85	0.90	0.85	0.90
FA EA	0.83	0.90	0.85	0.91
E E	0.59	0.54	0.57	0.52
EA EA	0.56	0.52	0.58	0.54
F F	0.35	0.36	0.36	0.38
FA FA	0.32	0.35	0.37	0.40

Chapter 6: Conclusions

The very high demands associated with hurricane evacuations require some strategies, such as contraflow segments, to be included in hurricane evacuation plans. Contraflow segments involve the reversal of inbound lanes to the outbound direction, increasing outbound capacity. However, the response or reaction of the evacuees to the strategies has not received much attention in the past. This study investigated evacuees' willingness to use contraflow facilities instead of regular outbound facilities.

Data for the analysis was obtained through an animated survey. Factors that could affect willingness to use contraflow lanes were identified from the literature and studied in two distinct parts. The first part dealt with six factors (service availability, police presence, exit location, entry congestion, availability of multiple entries, limited choice); the influence of these factors was determined from separate text questions in the survey, studied independently and were tested for association with individual characteristics. The second part dealt with congestion and information about congestion levels along the regular and contraflow lanes; these factors were portrayed in videos in the animated part of the survey and then modeled in a conditional logit model which predicted choice preferences based on presented options.

The analysis indicated the effect of the different considered factors on the willingness to use contraflow lanes under evacuation scenarios. The inspection of the distribution of the responses and their association with individual background characteristics mostly aligned with intuition and the hypotheses addressed in this thesis. The outcomes of the hypotheses were as follows:

H1- Under similar congestion conditions, evacuees are more likely to stay on regular lanes. This hypothesis was only supported at high congestion levels. Results from the distribution and conditional logit model indicated a relatively even split at medium congestion levels, with the preference for regular lanes increasing as congestion (on the similarly congested lanes) increases.

H2- People with contraflow/ reverse lane experience are less likely to be affected by congestion on the contraflow entry. This hypothesis was supported. Congested entries to contraflow sections discouraged use of contraflow lanes; however, the odds ratio supported the hypothesis.

H3- People with contraflow/ reverse lane experience are more likely to switch to

contraflow lanes at the first entry when more than one entry is available. This hypothesis was supported by the odds ratio associating reverse lane experience with the likelihood to switch to contraflow lanes at the first entry when provided with information about the availability of two entries.

H4- Evacuees are more likely to use contraflow lanes if they can exit prior to their desired exit rather than after their desired exit. This hypothesis was supported but is incomplete because this exit should be within a reasonable distance of the initially desired one. Exits located further away from the initially desired exit discouraged the use of contraflow lanes. However, exits within 5 miles, especially if located before the initially desired exit, established high likelihood of evacuees to switch to contraflow lanes, irrespective of their background or demographic characteristics.

H4- a- People with passengers who might affect their destination choice are less likely to use other than their initially desired exit. This hypothesis was rejected as the odds ratio did not indicate an association between people with passengers affecting destination choice and the likelihood to switch when the exit is other than the initially desired one.

H5- Information about services along contraflow routes increases the likelihood of evacuees switching to these lanes. This hypothesis was supported since the provision of information at the contraflow entry about the availability of services along these lanes resulted in a high percentage (81%) of people being more willing to switch to contraflow lanes.

H5- a- People with previous evacuation experience are more likely to switch to contraflow lanes when information about services is available along these lanes.

H5- b- People who have previously experienced reversible lanes are more likely to switch to contraflow lanes when information about services is available along these lanes.

H5- c- People who are accompanied by people who affect the frequency of their stops are more likely to switch to contraflow lanes when information about services is available along these lanes. These three sub-hypotheses were supported as odds ratios confirmed how evacuees with experience (contraflow or evacuation), people with dependents, or passengers requiring extra stops) demonstrated a high likelihood to switch to contraflow when provided information about the availability of services (e.g., gas, restrooms, food) along the route.

H6- The presence of police officers increases the likelihood of evacuees switching to contraflow routes. This hypothesis was weak and not statistically supported as the probability of

switching to contraflow motivated by the presence of the police was not higher than the probabilities of being indifferent or not switching.

All of these findings show how each element can factor into an evacuee's decision on whether to switch to contraflow lanes or not. In more realistic scenarios, the different factors should have been considered jointly to determine the relative significance and the combined effect of their different levels. However, this would have required an extremely large sample. Nonetheless, the analysis performed in this study demonstrated the importance of providing the evacuees with full information about what to expect on upcoming contraflow sections, whether exit locations, other entries, or services. These factors can by themselves alter evacuees' behavior around contraflow entries, and thus have some effect on the anticipated contraflow usage.

Congestion levels and congestion information along regular and contraflow lanes were not considered independently. These factors were combined in different scenarios. Respondents' behaviors towards congestion and information scenarios were used to construct a conditional logit model that can be used to predict choice probabilities for contraflow vs. regular lanes under different circumstances. Results from the model analysis revealed the significance of both congestion and information factors on willingness to use contraflow lanes. Better congestion conditions on the contraflow lanes attracted evacuees to these lanes. The greater the flow improvement on the contraflow lanes, the more likely it is for evacuees to switch to these lanes. Possible unfamiliarity or discomfort on evacuation routes (Wolshon, 2001) did not seem to prevent evacuees from switching to contraflow lanes. Even in instances of medium to high congestion, evacuees will spread almost evenly among lanes (even slightly higher ratios for contraflow lanes), which demonstrates an overall acceptance and willingness to benefit from the extra capacity this contraflow strategy offers. However, as congestion on both lanes increases, willingness to switch lanes decreases, where gridlock conditions result in evacuees mostly sticking to their regular lanes.

Information about downstream traffic conditions, in turn, influences evacuees' route choice behavior. Detailed information conveying distance to downstream congestion encourages evacuees to switch to the routes with farther upcoming traffic. At medium congestion levels (C C scenarios), downstream traffic congestion information has a major influence on evacuees' decision to switch to contraflow lanes or not. However, when congestion along regular lanes

increases, evacuees will mostly still be willing to switch to the less congested lanes even if they are expecting upcoming traffic, since they would still be saving some congestion time. Again, according to the model, evacuees will not abstain from using the less familiar contraflow lanes, as long as they provide some congestion improvement.

The study further examined the effect of background characteristics on the contraflow switching behavior. The model demonstrates a slightly lower tendency for people living in coastal areas to use contraflow lanes. On the other hand, people with previous evacuation experience can be expected to be less motivated than people without experience to use contraflow lanes at medium congestion levels, and more optimistic about their benefits with greater congestion on regular lanes. However, the overall acceptance for contraflow strategies is dominant across segments of the population.

6.1. Contribution of the thesis

This research constructed a model that enabled prediction of willingness to switch to contraflow lanes given congestion and information levels along regular and contraflow lanes. Previous literature mostly overlooked evacuees' behavior in the context of the different factors accompanying the availability of contraflow lanes. This study tests evacuees' overall willingness to use contraflow lanes. The constructed model indicated that information about traffic conditions on the regular and contraflow facilities influences the choice between these facilities. When transportation agencies monitor traffic conditions and provide information at route choice points, traffic can become more balanced between the two. Information however needs to be more accurate. For instance, simply stating that congestion is ongoing ("Congestion Ahead") did not offer additional knowledge to the driver and thus did not affect their choice. On the other hand, information bringing details on the distance to congestion helped drivers make more informed decisions. As demonstrated by Zhanf and Levinson (2008) previously, the better the quality and accuracy of the information, the more likely it is to affect drivers' route choices. While most people switched based on information, many were not affected or even switch contrary to the information indication. This might be due to different factors: people might have misunderstood the information, did not pay attention to it, did not consider it seriously with the flowing traffic in front of them, found it incomplete, or simply ignored information provided to them. Consequently, designs should take into account the probability of people ignoring the messages. Otherwise, the message conveyed needs to be clear and understood and familiar to the

drivers of the area. In addition, it needs to include information as detailed as possible for evacuees to be able to benefit from them.

As shown in this study, even though information plays a significant role, evacuees will be highly affected by the congestion level they observe at the contraflow entry. In an F C (F on the regular and C on the contraflow lanes) case for instance, information will not be needed since it will not be information will not of any relevance to the driver. As such, planners should try to convey information at the right time to avoid situations of highly unbalanced congestion.

This study was conducted, in part, to determine whether prior researchers' assumptions about the use of contraflow lanes/facilities were supported by the survey responses. As demonstrated by this research, people do not seem to mind switching to contraflow lanes. As such, the effect of unfamiliarity and discomfort that Wolshon (2001) talked about did not seem to affect drivers' motivation to use the contraflow lanes. Also, studies like Theodoulou (2003), assumed preference for regular over contraflow lanes; their split percentages were based on assumptions of dropped speeds used in simulations. Such studies will no longer have to rely on assumptions to determine regular vs. contraflow split percentages and can refer to specific situations and respective responses to use in their models. Other studies, like Dixit et al. (2008) when working on the assessment of the I-4 contraflow plans, would also be able to refer to our model for evacuees' preference assumptions rather than working with assumptions on the division of traffic at the contraflow entry points. Moreover, Lim (2003) would have strengthened his model had he taken into account evacuees' preferences alongside the design and geometry factors he was investigating, since evacuees' behavior factors into the effects on the examined traffic operations. Williams et al. (2007) pointed out the necessity of studying evacuee driver behavior in future research, and our study presented a first attempt to try to fill this gap in the literature.

6.2. Future research directions

This study was a first attempt towards understanding the factors behind evacuees' decisions when it comes to contraflow routes. A more generalized model that includes factors related to services, multiple entries and access to contraflow lanes would be interesting for future studies to address and try to determine how these factors interact with congestion and information factors and what compromises evacuees are willing to make in order to select their best perceived route that would enhance their evacuation experience. However, with more factors, the scenarios become more complicated and larger samples are needed.

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Appendix A

Demographic and background variables

- VEH_OWN: Vehicle Ownership – whether the household owns or leases a vehicle:

1: Yes

0: No

- NVEHL: Number of vehicles owned by household

(Continuous)

- FRFREQ: Frequency of driving on a freeway or similar type of road

1: Never

2: Less than once a week

3: 1-2 days a week

4: 3-4 days a week

5: 5 or more days a week

Recorded as a semi-continuous variable indicating the average of the range of the number of driving days per week:

- FRFREQ 2:

0: Never

0.5: Less than once a week

1.5: 1-2 days a week

3.5: 3-4 days a week

6: 5 or more days a week

- REVFREQ: Frequency of usage of reversible lanes

1: Never

2: Less than once a week

3: 1-2 days a week

4: 3-4 days a week

5: 5 or more days a week

Recorded as a semi-continuous variable indicating the average of the range of the number of days reversible lanes are used per week:

- REVFREQ 2:

0: Never

0.5: Less than once a week

1.5: 1-2 days a week

3.5: 3-4 days a week

6: 5 or more days a week

- REV_EXP: Previous usage of reversible lanes during special events:

1: Yes

2: No

3: I don't know

Recoded as a binary variable:

- REV_EXP 2:

1: Previously used reversible lanes during special events

0: Otherwise

(Note that I don't know was recoded as missing data)

- STATE: state of respondent's residence

1: Alabama

2: Alaska

3: Arizona

4: Arkansas

5: California

6: Colorado

7: Connecticut

8: Delaware

51: District of Columbia

9: Florida

10: Georgia

11: Hawaii

12: Idaho

13: Illinois

14: Indiana

15: Iowa
16: Kansas
17: Kentucky
18: Louisiana
19: Maine
20: Maryland
21: Massachusetts
22: Michigan
23: Minnesota
24: Mississippi
25: Missouri
26: Montana
27: Nebraska
28: Nevada
29: New Hampshire
30: New Jersey
31: New Mexico
32: New York
33: North Carolina
34: North Dakota
35: Ohio
36: Oklahoma
37: Oregon
38: Pennsylvania
39: Rhode Island
40: South Carolina
41: South Dakota
42: Tennessee
43: Texas
44: Utah
45: Vermont

46: Virginia

47: Washington

48: West Virginia

49: Wisconsin

50: Wyoming

- COAST: Whether respondent lives in a coastal area or not

1: Yes

2: No

3: I don't know

Recoded as a binary variable:

- COAST 2:

1: Respondent knows he lives in a coastal area

0: Otherwise

(Note that I don't know was recoded as missing data)

- HURR: Whether respondent lives in an area prone to hurricanes

1: Yes

2: No

3: I don't know

Recoded as a binary variable:

- HURR 2:

1: Respondent knows he lives in an area prone to hurricanes

0: Otherwise

(Note that I don't know was recoded as missing data)

- EVAC_EXP: Previously evacuated

1: Yes

2: No

3: I don't know

Recoded as a binary variable:

- EVAC_EXP 2:

1: Respondent has previously evacuated

0: Otherwise

(Note that I don't know was recoded as missing data)

- EVAC_CONG: Congestion in previous evacuation

1: Very Congested

2: Congested

3: Not Congested

Recoded as a binary variable:

- EVAC_CONG 2:

1: Respondent who has previously evacuated experienced congestion

0: Respondent who has previously evacuated did not experience congestion

- EVAC_CONTRA: Contraflow availability in previous evacuation

1: Yes

2: No

3: I don't know

Recoded as a binary variable:

- EVAC_CONTRA 2:

1: Respondent who has previously evacuated encountered contraflow

0: Respondent who has previously evacuated did not encounter contraflow

- CONTRA_EXP: Previous usage of contraflow lanes in an evacuation

1: Yes

2: No

Recoded as a binary variable:

- CONTRA_EXP 2:

1: Respondent who has previously evacuated used contraflow in a previous evacuation

0: Respondent who has previously evacuated did not use contraflow in a previous evacuation

- CONTRA_AGAIN: Willingness to use contraflow lanes after using them in a previous evacuation

1: Yes

2: No

3: I don't know

Recoded as a binary variable:

- CONTRA_AGAIN 2:

1: Respondent who has used contraflow lanes in a previous evacuation is willing to use them again

0: Respondent who has used contraflow lanes in a previous evacuation is not willing to use them again

- CONTRA_FUTURE: Willingness to use contraflow lanes after not using them in a previous evacuation

1: Yes

2: No

3: I don't know

Recoded as a binary variable:

- CONTRA_FUTURE 2:

1: Respondent who has not used contraflow lanes in a previous evacuation is willing to use them in the future

0: Respondent who has not used contraflow lanes in a previous evacuation is not willing to use them in the future

- DR: Respondent will be the driver in a future evacuation

1: Yes

2: No

3: I don't know

Recoded as a binary variable:

- DR 2:

1: Respondent will be the driver in a future evacuation

0: Otherwise

(Note that I don't know was recoded as missing data)

- COMP: Number of accompanying people in an evacuation

(continuous)

- STOP: Whether accompanying people might influence stop frequency

1: Yes

2: No

3: I don't know

Recoded as a binary variable:

➤ STOP 2:

1: Accompanying people might influence stop frequency

0: Otherwise

(Note that I don't know was recoded as missing data)

- DEST: Whether accompanying people might influence destination choice

1: Yes

2: No

3: I don't know

Recoded as a binary variable:

➤ DEST 2:

1: Accompanying people might influence destination choice

0: Otherwise

(Note that I don't know was recoded as missing data)

- AGE: Respondent's age

(Continuous)

Recoded to group ages in cluster of groups similar to census data

➤ AGE_NG: Grouped age groups

Grouping was based on the categories used in the 2010 Age and Sex composition census brief (Howden and Meyer, 2010).

1: Ages 18-44

2: Ages 45-64

3: Ages ≥ 65

- N5: Number of household members less than 5 years' old

(Continuous)

- N17: Number of household members between 5 and 17 years' old

(Continuous)

- N24: Number of household members between 18 and 24 years' old

(Continuous)

- N44: Number of household members between 25 and 44 years' old
(Continuous)

- N64: Number of household members between 45 and 64 years' old
(Continuous)

- N80: Number of household members between 65 and 80 years' old
(Continuous)

- N81: Number of household members greater than 80 years' old
(Continuous)

- GENDER

1: Male

2: Female

3: Other

Recoded as a binary variable:

➤ GENDER 2:

1: Male

0: Female

(Note that other was recoded as missing data)

- MAR: Marital Status

1: Single

2: Married

3: Widowed

4: Divorced

Recoded as a binary variable:

➤ MAR 2:

1: Married

0: Otherwise

- ED: Highest Level of Education Completed

3: No school (3)

1: Some school, no degree (1)

2: High school graduate (2)

4: Some college, no degree

5: Associate's degree, occupational

6: Associate's degree, academic

8: Bachelor's degree

9: Master's degree

10: Professional degree

11: Doctoral degree

12: Other

Recoded to group the educational level:

➤ ED 2: Grouped educational levels

1: No school / Some school, no degree/ High school graduate

2: Some college, no degree / Associate's degree, occupational /Associate's degree, academic

3: Bachelor's degree / Master's degree / Professional degree /Doctoral degree

• RACE:

1: Caucasian/White

2: Asian

3: Pacific Islander

6: Hispanic

7: African American/Black

8: American Indian

9: Multi-racial

4: Other

5: I don't know

Recoded as a binary variable:

➤ RACE 2:

1: Caucasian/White

0: Otherwise

(Note that other was recoded as missing data)

Attribute Factors Variables

• SERV: Likelihood to switch to contraflow with available services along contraflow

1: Extremely likely

2: Somewhat likely

3: Neither likely nor unlikely

4: Somewhat unlikely

5: Extremely unlikely

Recoded as a binary variable:

➤ SERV 2:

1: Respondent likely to switch with the availability of services (extremely likely or somewhat likely)

0: Otherwise

- EXIT: Exit access from contraflow lanes

2: Exit from contraflow lanes a little past desired location (within 5 miles)

3: Exit from contraflow lanes well beyond desired location

4: Exit from contraflow lanes a little before desired location (within 5 miles)

5: Exit from contraflow lanes well before your desired location

1: Exit from contraflow lanes exactly at desired location

Recoded as a series of binary indicators that reflect the answer in addition to combination of answers since respondents were given the option of choosing different options

➤ EXIT 1:

1: Respondent willing to switch to contraflow to exit at its desired exit

0: Otherwise

➤ EXIT 2:

1: Respondent is willing to exit from contraflow lanes a little past its desired location (within 5 miles)

0: Otherwise

➤ EXIT 3:

1: Respondent is willing to exit from contraflow lanes well beyond its desired location

0: Otherwise

➤ EXIT 4:

1: Respondent is willing to exit from contraflow lanes a little before its desired location (within 5 miles)

0: Otherwise

➤ EXIT 5:

1: Respondent is willing to exit from contraflow lanes well before its desired location

0: Otherwise

➤ EXIT 2,4:

1: Respondent is willing to exit from contraflow lanes within 5 miles of its desired exit

0: Otherwise

➤ EXIT 4,5:

1: Respondent is willing to exit from contraflow lanes anywhere before its desired exit

0: Otherwise

➤ EXIT 2,3:

1: Respondent is willing to exit from contraflow lanes anywhere past its desired exit

0: Otherwise

➤ EXIT_ALL:

1: Respondent is willing to exit from contraflow lanes anywhere

0: Otherwise

- POL: Likelihood to switch to contraflow with available police at entrance

1: Much more likely

2: Somewhat more likely

3: Neither likely nor unlikely

4: Somewhat less likely

5: Much less likely

Recoded as a binary variable:

➤ POL 2:

1: Respondent likely to switch with the availability of police (extremely likely or somewhat likely)

0: Otherwise

- ENTRY: Likelihood to switch to contraflow with congested entrance

1: Extremely likely

2: Somewhat likely

3: Neither likely nor unlikely

4: Somewhat unlikely

5: Extremely unlikely

Recoded as a binary variable:

➤ ENTRY 2:

1: Respondent likely to switch with congested entry (extremely likely or somewhat likely)

0: Otherwise

- MULT: Choice with a second entry available

1: Definitely first

2: More likely first

3: Second

4: Not use either

5: Evaluate each at a time

6: Other

➤ MULT 2:

1: Respondent likely to use first or second entry when multiple entries are available (definitely first, more likely first, second)

0: Otherwise

- DET: Likelihood of detour to avoid contraflow lanes

1: Extremely likely

2: Somewhat likely

3: Neither likely nor unlikely

4: Somewhat unlikely

5: Extremely unlikely

Recoded as a binary variable:

➤ DET 2:

1: Respondent likely to detour to avoid contraflow lanes (extremely likely or somewhat likely)

0: Otherwise

Other Variables

SOURCE: Survey source

1: Amazon Mechanical Turk

2: Email

3: Social Media

4: Word of Mouth

5: Other

Added Variables

These are variables that were added in the survey for the purpose of the analysis

DEPENDENTS:

1: for household with kids younger than 17 and people older than 65 (N5, N17, N80 and/ or N81>0)

2: Otherwise

exp2:

1: if respondent has experienced any type of reversible or contraflow lanes in the past (REV_EXP>0, REVFREQ>1, and/or CONTRA_EXP>0)

0: Otherwise

Appendix B

Table 33: L-R Chi Square Values and Significance for Models Incorporating Individual Characteristics (1)

	No Characteristics	Characteristic 1: Contraflow Experience: exp 2	Characteristic 1: Vehicle Ownership: VEH_OWN 2	Characteristic 1: Freeway Experience: FRFREQ 2	Characteristic 1: Living in a coastal area: COAST 2	Characteristic 1: Living in a hurricane prone area: HURR 2	Characteristic 1: Previous Evacuation Experience: EVAC_EXP 2
Source	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare
<i>LOS_R</i>	626.138***	627.917***	86.061***	132.418***	510.755***	476.574***	435.498***
<i>Information_R</i>	72.443***	70.327***	4.859	28.395***	52.753***	38.61***	51.829***
<i>LOS_C</i>	622.436***	624.403***	65.602***	141.137***	489.402***	461.634***	412.71***
<i>Information_C</i>	56.447***	59.484***	1.405	16.36***	48.771***	50.421***	30.314***
[Characteristic 1]* <i>LOS_R</i>		2.96	0.01	3.187	5.424	5.128	3.628
[Characteristic 1]* <i>Information_R</i>		1.575	0.532	0.786	2.706	6.36*	0.238
[Characteristic 1]* <i>LOS_C</i>		3.169	0.764	3.383	2.721	6.372*	4.208
[Characteristic 1]* <i>Information_C</i>		4.876	2.128	1.058	0.534	2.997	2.542
[Characteristic 2]* <i>LOS_R</i>							
[Characteristic 2]* <i>Information_R</i>							
[Characteristic 2]* <i>LOS_C</i>							
[Characteristic 2]* <i>Information_C</i>							
-2*LogLikelihood	4012.4365	3995.3348	4005.352	4005.8457	3993.0847	3998.8632	4001.0523
-2*LogLikelihood difference		17.1017	7.0845	6.5908	19.3518	13.5733	11.3842
DF²		8	8	8	8	8	8
Critical Chi-Square		15.51	15.51	15.51	15.51	15.51	15.51

*** indicates $p < 0.001$ ** indicates $p \leq 0.01$ * indicates $p \leq 0.05$

²DF for each model as compared to the No Characteristics model is equal to the number of restrictions or the number of added independent interaction terms.

Example: For the model considering exp 2, interaction terms are between:

- exp 2 (1/0): one independent level and each of:

- *LOS_R (C/E/F): two independent levels*
- *Information_R (Congestion Ahead, Congestion Ahead 10 miles, Congestion Ahead 5 miles): two independent levels*
- *LOS_C (C/E/F): two independent levels*
- *Information_C (Congestion Ahead, Congestion Ahead 10 miles, Congestion Ahead 5 miles): two independent levels*

Which results in a total of: $1*2+1*2+1*2+1*2= 8$ independent interaction terms = 8 DF

Table 34: L-R Chi Square Values and Significance for Models Incorporating Individual Characteristics (2)

	No Characteristics	Characteristic 1: Driver: DR 2	Characteristic 1: Need to stop : STOP 2	Characteristic 1: Destination: DEST 2	Characteristic 1: DEPENDEN TS	Characteristic 1: GENDER: GENDER 2	Characteristic 1: Marital Status: MAR 2
Source	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare
<i>LOS_R</i>	626.138***	524.359***	620.065***	622.071***	604.999***	619.451***	593.162***
<i>Information_R</i>	72.443***	57.044***	72.47***	73.47***	67.51***	70.734***	70.639***
<i>LOS_C</i>	622.436***	484.667***	620.933***	619.634***	606.347***	612.099***	585.461***
<i>Information_C</i>	56.447***	44.427***	56.008***	56.673***	55.316***	55.948***	55.775***
[Characteristic 1]* <i>LOS_R</i>		3.608	1.12	0.181	2.498	1.242	0.505
[Characteristic 1]* <i>Information_R</i>		0.252	0.096	0.709	2.201	0.015	0.68
[Characteristic 1]* <i>LOS_C</i>		7.749*	0.519	0.173	4.777	0.494	0.159
[Characteristic 1]* <i>Information_C</i>		0.719	0.062	0.318	1.352	0.793	0.539
[Characteristic 2]* <i>LOS_R</i>							
[Characteristic 2]* <i>Information_R</i>							
[Characteristic 2]* <i>LOS_C</i>							
[Characteristic 2]* <i>Information_C</i>							
-2*LogLikelihood	4012.4365	3999.1716	4008.3527	4005.8095	4003.0984	4004.8492	4007.5876
-2*LogLikelihood difference		13.2649	4.0838	6.627	9.3381	7.5873	4.8489
DF		8	8	8	8	8	8
Critical Chi-Square		15.51	15.51	15.51	15.51	15.51	15.51

*** indicates $p < 0.001$ ** indicates $p \leq 0.01$ * indicates $p \leq 0.05$

Table 35: L-R Chi Square Values and Significance for Models Incorporating Individual Characteristics (3)

	No Characteristics	Characteristic 1: Race: RACE 2	Characteristic 1: Educational Level: ED 2	Characteristic 1: Age grouped: AGE_NG	Characteristic 1: Contraflow Experience: exp 2		
					Characteristic 2: Living in a coastal area: COAST 2		
Source	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare	L-R ChiSquare		
<i>LOS_R</i>	626.138***	529.942***	135.634***	110.127***	507.778***		
<i>Information_R</i>	72.443***	41.907***	5.531	18.912***	50.222***		
<i>LOS_C</i>	622.436***	525.105***	108.284***	139.806***	487.858***		
<i>Information_C</i>	56.447***	44.483***	9.761**	2.622	52.222***		
[Characteristic 1]* <i>LOS_R</i>		3.694	5.731	9.677*	2.426		
[Characteristic 1]* <i>Information_R</i>		3.184	1.219	4.763	2.149		
[Characteristic 1]* <i>LOS_C</i>		2.86	1.255	12.066*	2.62		
[Characteristic 1]* <i>Information_C</i>		0.16	1.024	7.884	4.674		
[Characteristic 2]* <i>LOS_R</i>					4.922		
[Characteristic 2]* <i>Information_R</i>					2.833		
[Characteristic 2]* <i>LOS_C</i>					2.239		
[Characteristic 2]* <i>Information_C</i>					0.685	Compared to model with exp 2 only	Compared to model with COAST 2 only
-2*LogLikelihood	4012.4365	4002.5637	3999.3073	3987.4701	3977.3794		
-2*LogLikelihood difference		9.8728	13.1292	24.9664	35.0571	17.96	15.71
DF		8	8	16	16	8	8
Critical Chi-Square		15.51	15.51	26.3	26.3	15.51	15.51

*** indicates $p < 0.001$ ** indicates $p \leq 0.01$ * indicates $p \leq 0.05$