FLEET AND FUEL STRATEGIES FOR TRANSPORTATION RESILIENCE[1]

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ABSTRACT: The state of Florida, including the Tampa Bay region, is considered one of the most vulnerable areas in the United States to hurricanes and severe tropical weather. A particular vulnerability stems from the fact that Tampa Bay receives all of its petroleum—gasoline and diesel—through Port Tampa Bay, which can be impacted by hurricanes and tropical storms, as well as other disasters. If the port is unable to receive ships due to hurricane wind or storm surge, fuel cannot be delivered to the area, and transportation is impeded. One promising way to avoid this reduction in transportation functionality is to diversify the fuels used. This paper summarizes previous fuel challenges and vulnerabilities experienced by key Tampa Bay fleets after the area's most recent tropical event—Hurricane Irma in 2017—in order to explore ways to improve the resilience of Tampa Bay to natural disasters. Some of these strategies include maintaining emergency fuel supply, prioritizing fuel use, developing innovative real-time resource sharing mechanisms, strategically placing the assets around the region to assist with the recovery, investing in backup generators, planning for redundancies in fuel supply networks, and diversifying fuel sources by incorporating alternative fuel vehicles into the fleet.

Keywords: alternative fuel, electric vehicles, fuel management, hurricanes, resiliency

ESTRATEGIAS DE FLOTA Y COMBUSTIBLE PARA LA RESILIENCIA EN TRANSPORTACIÓN

RESUMEN: El estado de la Florida, incluyendo la región de la Bahía de Tampa, se considera una de las áreas más vulnerables en los Estados Unidos a los huracanes y al clima tropical severo. Una vulnerabilidad particular se deriva del hecho de que la Bahía de Tampa recibe todo su petróleo - gasolina y diésel–a través del Puerto de la Bahía de Tampa, que puede verse afectado por huracanes y tormentas tropicales, así como por otros desastres. Si el puerto no puede recibir a los barcos debido al viento huracanado o marejada ciclónica, no se puede entregar combustible al área y se obstaculiza la transportación. Una manera prometedora de evitar esta reducción en la funcionalidad del transporte es diversificar los combustibles utilizados. Este artículo resume los desafíos y vulnerabilidades de combustible experimentados anteriormente por flotas clave de la Bahía de Tampa después del evento tropical más reciente del área –Huracán Irma en el 2017– con el fin de explorar maneras de mejorar la resiliencia de la Bahía de Tampa debido a los desastres naturales. Algunas de estas estrategias incluyen mantener el suministro de combustible de emergencia, priorizar el uso de combustible, desarrollar mecanismos innovadores para compartir recursos a tiempo real, ubicar estratégicamente los activos en la región para ayudar con la recuperación, invertir en generadores de respuesta, planificar redundancias en las redes de suministro de combustible y diversificar las fuentes de combustible mediante la incorporación de vehículos de combustible alternativo a la flota.

Palabras clave: combustible alternativo, vehículos eléctricos, gestión de combustible, huracanes, resiliencia

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INTRODUCTION

Since 2000, seven major hurricanes—Category 3 or higher—have made landfall in Florida, with some years experiencing several major hurricanes and tropical storms. Hurricanes and tropical storms often bring high winds, storm surge, and coastal and inland flooding. It has been noted that hurricanes are increasing in frequency, intensity, and duration and are projected to intensify in the future (Kossin et al. 2020). The 2017 Atlantic hurricane season was one of the costliest seasons in recorded history with Hurricanes Harvey, Maria, and Irma causing $265 billion in damages (NOAA 2020). In addition to infrastructure damage, hurricanes and other severe storms are also known to disrupt the supply of essential resources, underscoring the need for effective strategies to address these challenges.

Florida's transportation systems are in a uniquely vulnerable position in terms of fuel supply. Approximately 90 percent of Florida's petroleum fuel—gasoline and diesel—is delivered exclusively via waterborne cargoes through five of the state's seaports (EIA 2014). Since Florida is not connected to the Colonial Pipeline system, which transports petroleum products from Houston to the Port of New York and New Jersey, the state's petroleum supply is entirely dependent on its seaport operations. A small amount of petroleum product is brought into the state by tanker trucks from the Colonial Pipeline terminal in Bainbridge, Georgia. At the same time, seaport operations may be significantly disrupted by hurricanes and other natural disasters, posing a risk to the delivery of critical fuel supplies. Tampa Bay is not an exception. If Port Tampa Bay is unable to receive ships due to excessive storm surge, fuel tankers cannot deliver fuel to areas of critical need within the Tampa Bay area.

THE ROLE OF ALTERNATIVE FUELS IN TRANSPORTATION RESILIENCE

Resilience in the transportation sector can be defined as the ability to withstand small to moderate disturbances without loss of service, to maintain minimum service during severe disturbances, and to quickly return to normal service after a disturbance (DOE 2014). Transportation resilience efforts traditionally focus on protecting infrastructure (e.g., bridges, roads, and structures), overlooking the role of vehicles and fuels. Additionally, government programs and funding do not always provide incentives for prevention and planning efforts. For example, funding by the Federal Emergency Management Agency (FEMA) is disproportionately directed toward recovery efforts after a catastrophic event rather than planning and preparing prior to a disaster.

Recent natural disasters demonstrated the value of transportation fuel diversification for ensuring resilience. After Hurricane Sandy in 2012, Atlantic City (NJ) relied on a fleet of 190 Compressed Natural Gas (CNG) minibuses, called Jitneys, to provide public transportation, assist with evacuation and recovery efforts, transport medical patients, and assist with other essential functions. While the supply chain disruptions caused shortages in petroleum fuel–diesel and gasoline–, the CNG supply was uninterrupted by the storm. Similarly, after Hurricane Harvey hit Houston (TX) in 2017, causing shortages in conventional fuels, the underground natural gas pipeline network was largely unaffected. As a result, the Metropolitan Transit Authority of Harris County (METRO) was able to provide transit service using CNG buses without interruptions. In the fall of 2015, during large wildfires in the Sierra Nevada Mountains (CA) that caused power outages and evacuations of residents, Pacific Gas and Electric (PG&E) employed a plug-in hybrid electric truck with exportable power capabilities to power a shelter for two days until electrical service was restored. These are just a few notable examples of alternative fuels and alternative fuel vehicles (AFVs) proving valuable for providing critical services after natural disasters while conventional fuels were in short supply. Recognizing the role that alternative fuels can play in improving transportation resilience, governments at the federal, state, and local levels are dedicating more efforts and funding toward research and demonstration in that area. The Initiative for Resiliency in Energy through Vehicles (iREV), created by the National Association of State Energy Officials (NASEO) in partnership with the U.S. Department of Energy (DOE) Clean Cities program, assists states and municipalities in learning how AFVs might be incorporated into their emergency preparedness and response planning. Another example is DOE funding $1 million to Cummins, Inc., to develop H2Rescue, a hydrogen fuel cell truck that will travel to disaster relief sites and provide power, heat, and water (DOE 2020).

Achieving transportation resilience can be viewed through a five-pronged approach to fuel management involving five essential components: (1) ensuring redundancy (e.g. the use of multiple fuels, fuel delivery methods, and multi-purpose vehicles); (2) maintaining fuel storage nearby that can be used when the supply is cut off; (3) maintaining access to stored fuel during and after the disaster (e.g. the storage location should be easily accessible and uncompromised by the disaster event); (4) replenishment of fuel storage as soon as regular supply channels are restored; and (5) maximizing the efficiency of fuel use to get the most work done for a given amount of fuel (e.g. maximizing jobs done per vehicle and miles per gallon for a given job).

Various transportation fuels may have different advantages and limitations that are inherent in their supply chain and its vulnerability to natural disasters, as shown in Figure 1.

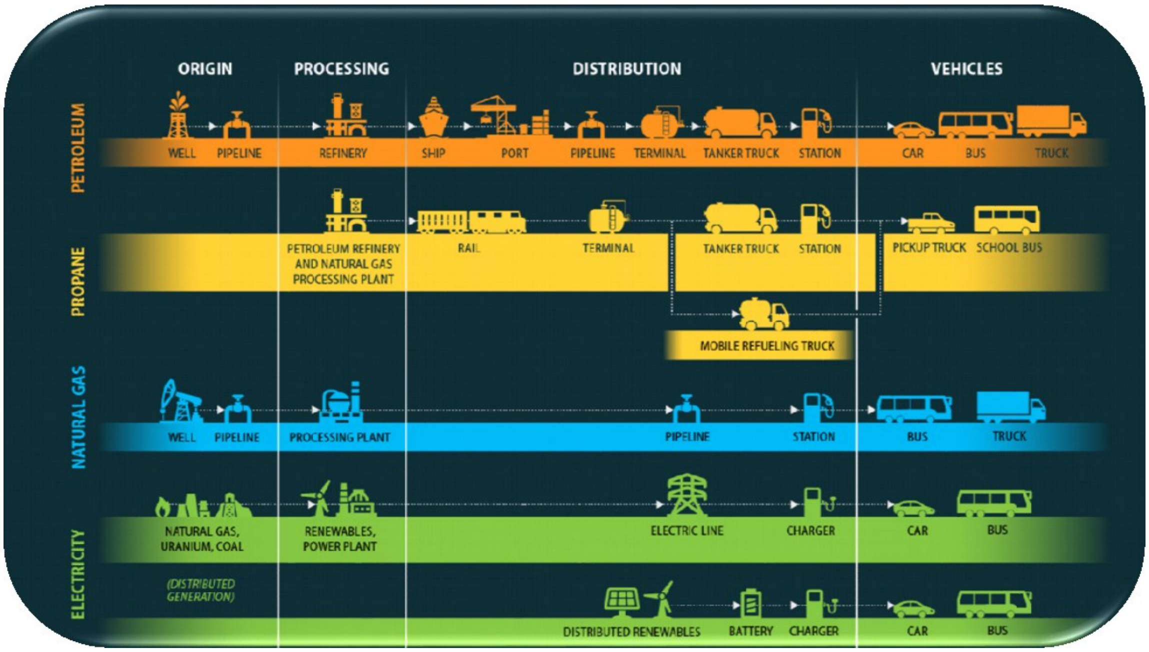

Figure 1: Transportation fuels supply chain in Florida.
Source: National Renewable Energy Laboratory (NREL)

Petroleum fuels are transported from refineries on ships through ports and then on fuel tankers to retail locations. The biggest vulnerability of the petroleum supply chain in Florida is related to port operations that can be jeopardized by major storms and hurricanes. High winds and storm surge caused by hurricanes can shut down port operations and disrupt deliveries of conventional fuels. Port Tampa Bay's vulnerability also results from the configuration of the port and waterways leading to the port. The 43-mile-long channel leading to the port requires approximately four hours for ships to cover the distance and the channel can accommodate only one-way traffic for mid-sized (or larger) cargo ships, which can create significant bottlenecks. Due to the complexity of the port channel, large cargo ships are guided through the channel by trained local pilots. In the case of an approaching hurricane with increased wave height, or poor weather conditions, pilots suspend service and ships are not able to enter or exit the port.

Propane is transported by rail to a storage terminal and then by tanker trucks to the retail locations. While rail transportation is not immune to disruptions caused by various natural or man-made disasters, rail deliveries are less affected by hurricanes and tropical storms that are the most common types of disasters in Florida. Therefore, at least in Florida, propane deliveries are less vulnerable to disruptions by natural disasters than petroleum fuels. One attractive property of propane is that, unlike petroleum fuels, it can be stored indefinitely without degrading. Additionally, just like petroleum, propane allows for mobile fueling. This makes propane a good backup emergency fuel.

Natural gas is transported though aboveground or underground pipelines. The natural gas supply chain is relatively free of choke points due to a large amount of redundancy in the system. For instance, if a stretch of pipeline needs to be shut down, there is often another series of pipelines that can deliver to the same destination. Furthermore, transmission pipelines are powered by several compressor stations. If one compressor station becomes inoperable, this would reduce gas flow through the system, but would not halt fuel delivery. Transfer from transmission to distribution pipelines takes place at the city gate, and most cities have six or more gates, providing for redundancy in natural gas supply. CNG also allows for mobile fueling.

Electricity is distributed through aboveground or underground electric lines. Depending on whether pipelines and electric lines are underground or aboveground, and depending on the amount of redundancy, the supply of both natural gas and electricity can be less vulnerable to disruptions than petroleum fuels because these delivery channels do not rely on port operations. Additionally, electric vehicles (EVs) with exportable power can be used as mobile generators powering up critical facilities when the central electric grid is down as a result of a natural disaster.

LESSONS LEARNED FROM TAMPA BAY RESILIENCE STUDY

In 2020, the Center for Urban Transportation Research (CUTR) at the University of South Florida (USF) completed a study documenting the fuel resiliency practices implemented by public agency fleets in the Tampa Bay area. The study relied on both primary and secondary data sources that provided insight into fuel management practices and natural disaster planning and recovery operations, with a specific focus on practices stemming from Hurricane Irma, which impacted the entire state of Florida in September 2017. CUTR researchers performed a day-long workshop and conducted follow-up phone interviews with a variety of stakeholders in Tampa Bay, including representatives from the private and public sectors, local governments, transit agencies, the airport and port, local emergency operations departments, as well as electric utilities. Additionally, the researchers collected comprehensive data provided by GasBuddy on the Tampa Bay area's fuel shortage during Hurricane Irma, as well as power outage data during Irma provided by the local utility company.

The data on fuel availability demonstrated that panic buying before Hurricane Irma caused significant fuel shortages in Tampa Bay even before hurricane landfall. Eighty percent (80%) of the Tampa Bay area's gasoline stations were out of gasoline and fifty-five percent (55%) were out of diesel three days prior to hurricane impact. While diesel was more available than gasoline before and during hurricane impact, diesel availability dropped significantly after hurricane landfall. While it is not entirely clear what caused the drop in diesel availability right after landfall, it could be attributed to the fact that diesel is the fuel of choice for recovery operations, which caused a high demand after the storm, or that the diesel supply had been compromised. There might also be other reasons that necessitate more in-depth investigation. Figure 2 summarizes conventional fuel availability at public stations in Tampa Bay during Hurricane Irma.

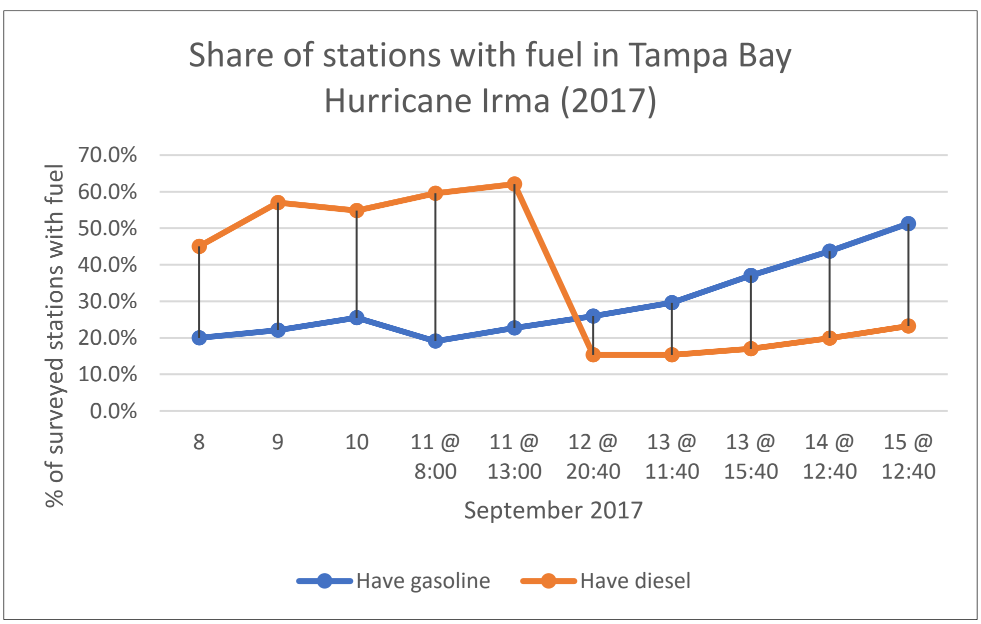

Figure 2: Share of gasoline stations with fuel in Tampa Bay – Hurricane Irma.

One important lesson from past hurricanes is that fuel availability alone may not be enough to ensure that vehicles will receive fuel. Gasoline terminals and stations must have power to dispense fuel, which can be also compromised by the storm. Approximately 13%-15% percent of gasoline stations in Tampa Bay had both gasoline and power available before and during Irma. Fuel supply and power restoration may take a long time and essential fleets should be ready to compensate. Despite intensive restoration efforts, four days after Irma landfall, only half of Tampa Bay public stations had both fuel and power. At the same time, during the entire pre and post-landfall periods, approximately 5%-10% percent of stations had fuel but no power to dispense it. This emphasizes the importance of having emergency generators for ensuring uninterrupted fueling, especially for fleets performing essential functions. Figure 3 summarizes the data on fuel and power availability at public gasoline stations in Tampa Bay.

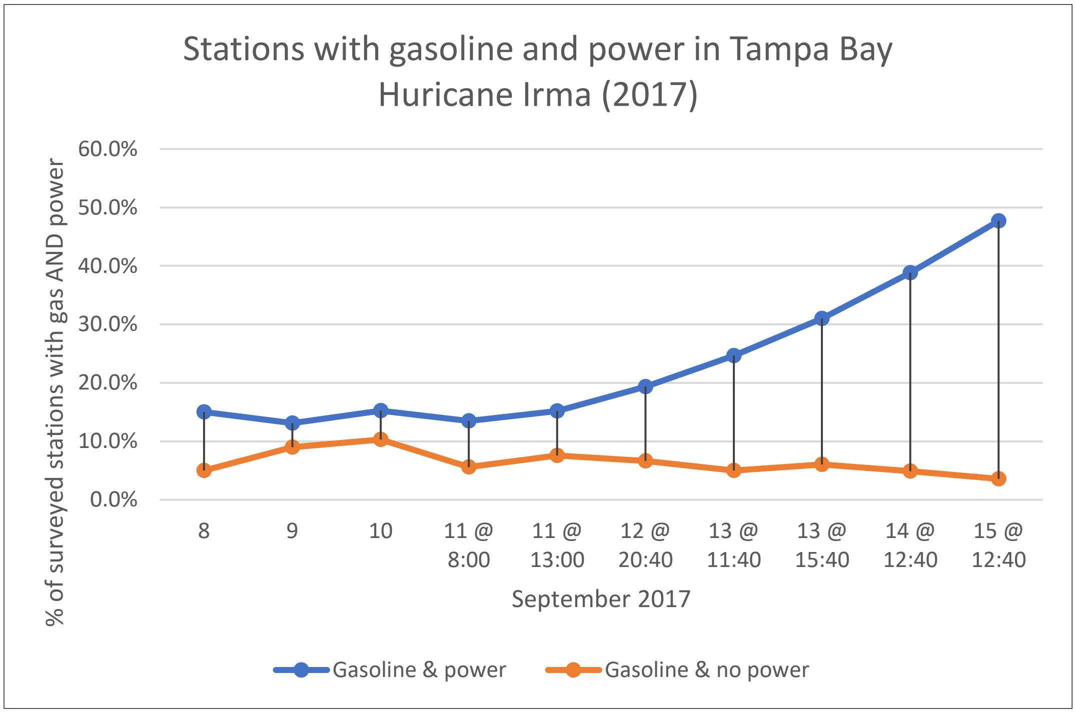

Figure 3: Stations with fuel and power in Tampa Bay – Hurricane Irma.

KEY FINDINGS AND RECOMMENDATIONS

The key findings from Hurricane Irma on fuel considerations in the Tampa Bay area and recommendations that can help improve resilience to natural disasters are summarized below:

1. *Maintain adequate fuel storage.* This amount can vary depending on the role of the fleet. Managers of essential fleets recommended having enough fuel to maintain fleet operation for 7-14 days. One thing to keep in mind is that accurately predicting the fuel burn rate for the fleet under emergency operations may be rather challenging. Fleets can consume 2 to 3 times more fuel during emergency operations.

2. *Diversify fuel supply.* This may include using alternative fuel supply channels (e.g., receiving fuel from different geographic areas and/or using multiple delivery methods) or incorporating alternative fuel vehicles into the fleet.

3. *Stage assets before landfall.* Relocating vehicles to higher elevation areas pre-landfall to preserve the vehicles and ensure easy access to critical assets needed for recovery after the event is a key step in hurricane preparation, especially for fleets tasked with performing essential functions.

4. *Plan for worst-case scenarios*. From a standpoint of ensuring resilience, it is always better to overestimate the impact and consequences of the hurricane.

5. *Implement effective communication and resource sharing procedures that allow fleets to share fuel and other critical resources.* While some fleets (especially public fleets) maintain contacts with neighboring fleets and may share fuel and other resources such as vehicles, this practice is usually not formalized and involves personal relationships and initiative. Implementing a more robust system that tracks resource availability in real time (by means of an online tool) and sharing resources would benefit the community.

6. *Implement a fuel prioritization system to allocate limited resources in the most efficient way.* While some fleets in Tampa Bay are already doing this, expanding the practice to all essential fleets in the area would significantly improve resilience.

7. *Invest in emergency generators.* Emergency generators can be powered by conventional fuels or alternative fuels. Certain alternative fuels (e.g., CNG) may prove to be more resilient to fuel supply interruptions than conventional fuels (e.g., diesel), thus providing an advantage in terms of the ability to ensure uninterrupted emergency operations. Certain alternative fuels (e.g. CNG and propane) can also be stored longer than diesel or gasoline and therefore simplify logistics.

FURTHER STEPS

While the described cases and analysis were mainly focused on the Tampa area, the findings, lessons learned, and recommendations can be relevant to other areas facing similar challenges related to ensuring resilience during natural disasters (not only hurricanes). Addressing the demonstrated vulnerabilities of a region may involve coordinated efforts at both local and state levels to incorporate alternative fuels and fuel management practices into the resiliency planning process. Additionally, developing a web-based tool for real-time tracking of critical resources within a given area and facilitating the sharing of limited resources between essential (public) fleets can significantly improve an area's resilience to natural disasters.

USF is currently working on a pilot resource tracking/sharing tool that aims to (1) share necessary information between fuel providers and fleet users, and (2) provide recommendations on fuel resource allocation. This tool expects to have access to real-time states from each fuel provider such as operational status, fuel inventory level, and projected demand and supply. It will also collect real-time information of each fleet vehicle's location, fuel level, and projected duties (e.g., routes and services). Then, the tool will synthesize these real-time data and share the necessary pieces across fuel providers and fleet users to inform operation decisions.

The proposed tool will include a customized decision supporting component on the optimal resource allocation from the fuel providers to the fleet users. It will prioritize fleet users and ensure that the limited fuel resources can be allocated to high-priority fleets (e.g., emergency vehicles) in a timely manner. Further, it will analyze real-time states of both fuel providers and users and optimize the spatial-temporal assignments of the fleet users to the fuel providers (i.e., advising a fleet user to access a specific fuel provider during a specific time window). The optimization decisions aim to minimize disunities in activities (e.g., travel distances and waiting times), while maximizing the expected benefits for associated fueling activities.

CONCLUSIONS

While transportation resilience has traditionally focused on infrastructure and assets, fuel resources are an important consideration for planning and preparing for natural disasters. Previous hurricanes and storms have demonstrated how port disruptions can affect fuel supply in the Tampa Bay area. Hurricane Irma (2017) forced Port Tampa Bay to remain closed for about five days, causing area fuel shortages. In addition, massive power outages also resulted from Irma that lasted for almost a week.

Public fleets in Tampa Bay employ various strategies to ensure hurricane preparedness, including maintaining an emergency fuel supply, prioritizing fuel use, strategically placing assets around the region to help with recovery, investing in backup generators, and planning for redundancies in fuel supply networks. While these efforts proved to be rather successful during previous events, they can be improved by incorporating alternative fuels and other fuel diversification strategies into resilience planning at the state level. Additionally, developing more efficient communication between public fleets and a procedure for sharing resources in the case of an emergency can significantly improve a region's resilience to natural disasters. Finally, implementing a system to accurately track fuel usage during hurricanes will help with emergency planning and effective resource allocation during natural disasters.

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