INTERNATIONAL SOCIETY OF SIX SIGMA PROFESSIONALS

Fuel Supply for the State of Florida During Hurricane Evacuation

Ernesto L. Garcia C., PhD

Appaloosa Engineering LLC

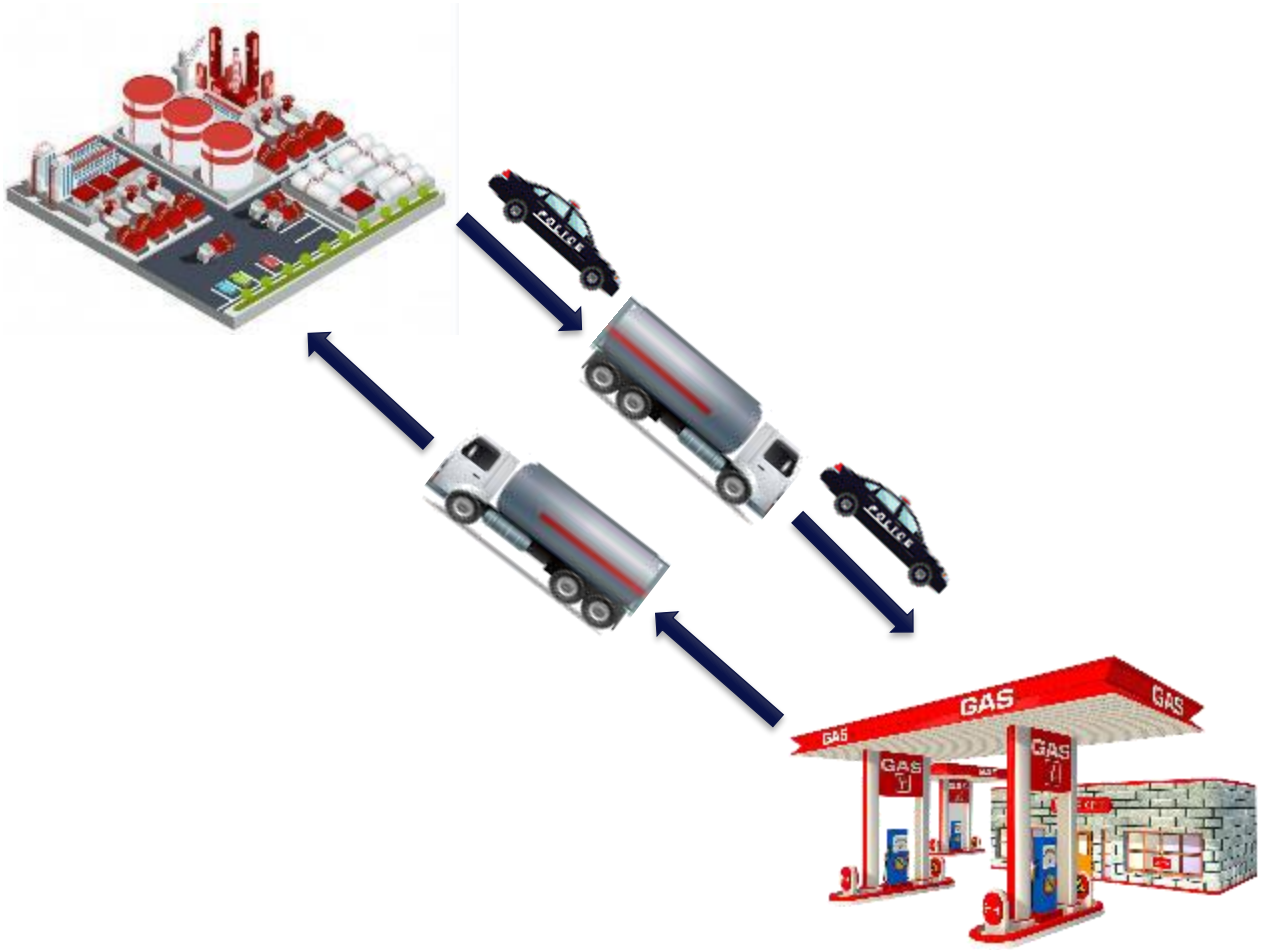
Statement for the Project

Provide the Florida Department of Transportation (FDOT) with fact-based recommendations to improve the State's rack-to-retail fuel capacity in the context of a hurricane evacuation leveraging existing infrastructure and commercial fuel industry capabilities.

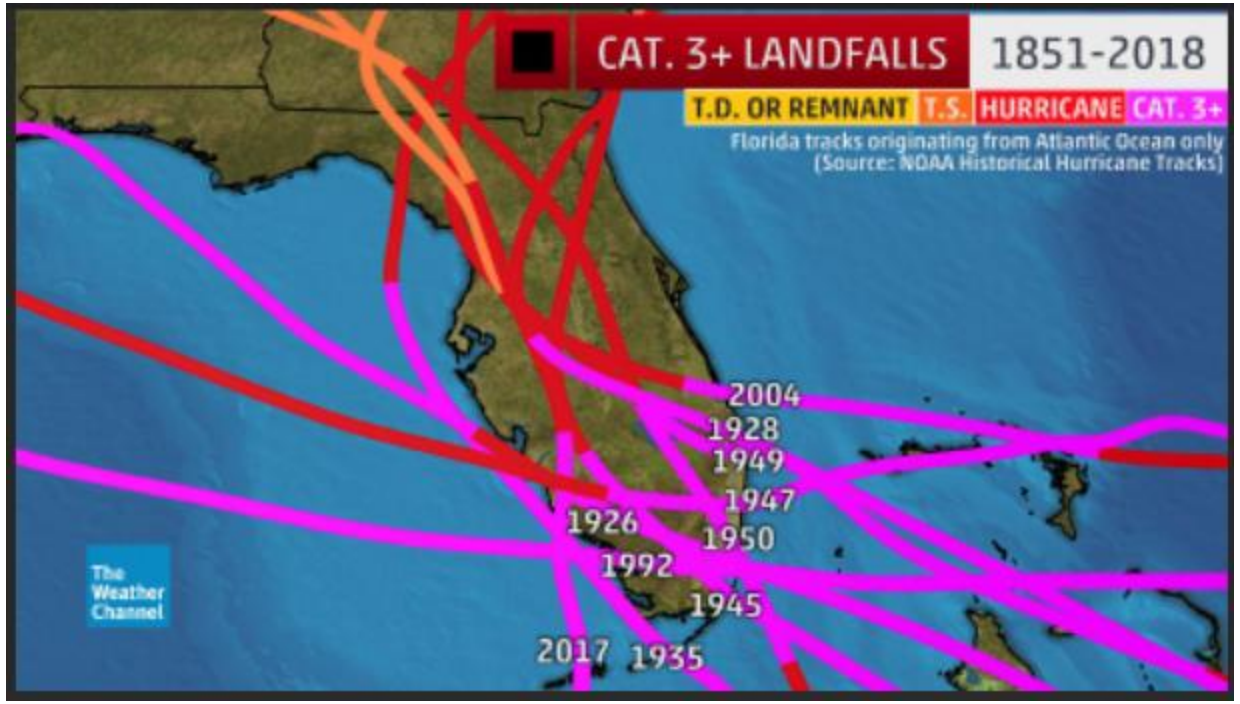
Scope: Consider only main evacuation routes and retail fuel providers ½ mile around those evacuation routes.

Scope: Florida Evacuation Routes

General Process



Measure Phase: How they come



Majority of hurricanes category 3+ impact Florida from South to North

Sources in references.

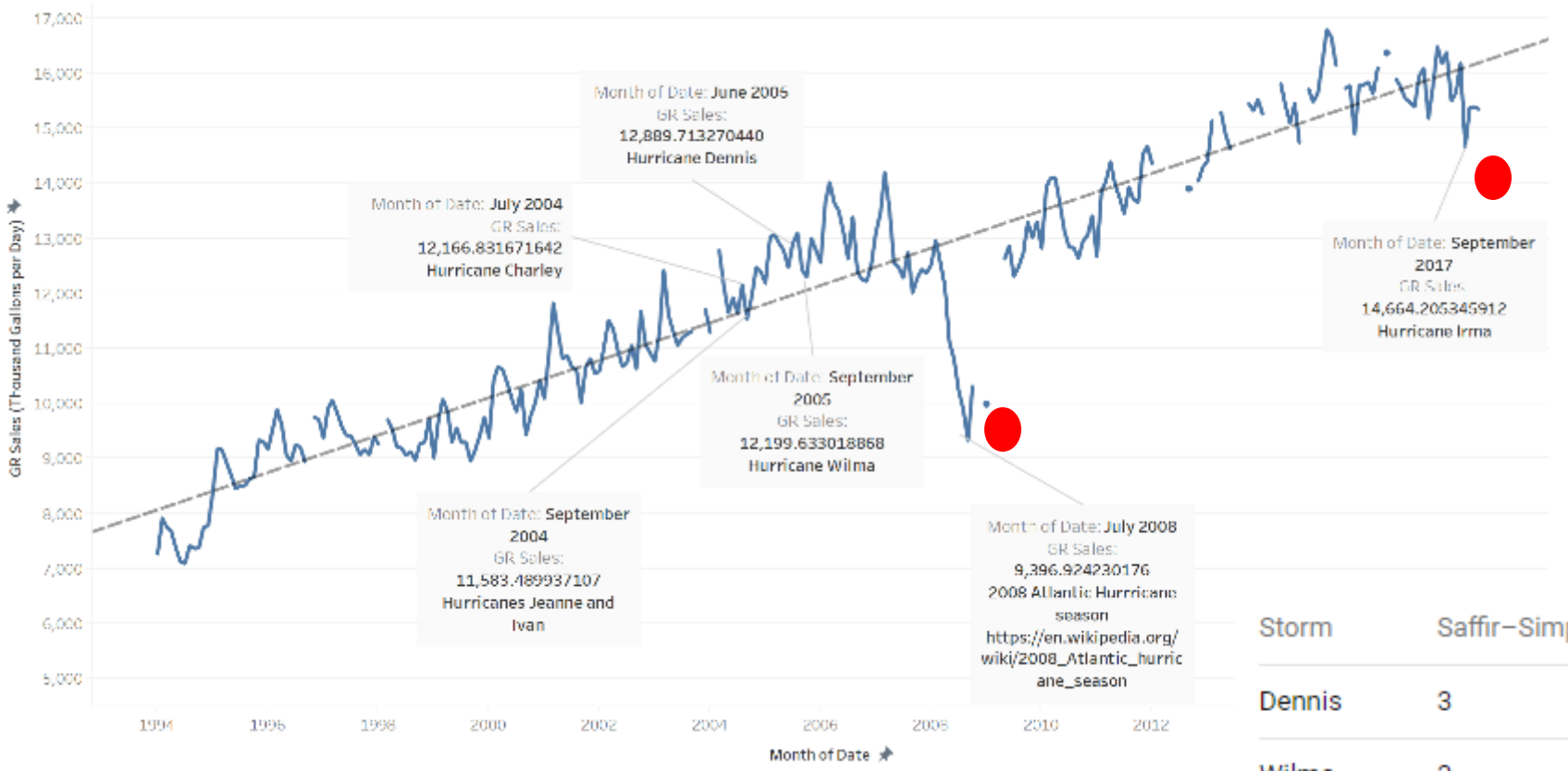
Measure Phase: Data

Data sources are listed in the references.

FDOT supplied traffic counts, and volumes as well as highway fuel consumption raw data.

Other data obtained: sources of fuel supply and commercial wholesale distribution to fuel containers; Florida Highway Patrol's emergency plans; List and capacity of gas stations ½ mile from evacuation route; interviews with fuel truck companies servicing Florida and Southern states.

Florida Total Gasoline Rack Sales Volume by Refiners and Hurricane Impacts (1996-2018)



Measure Phase:

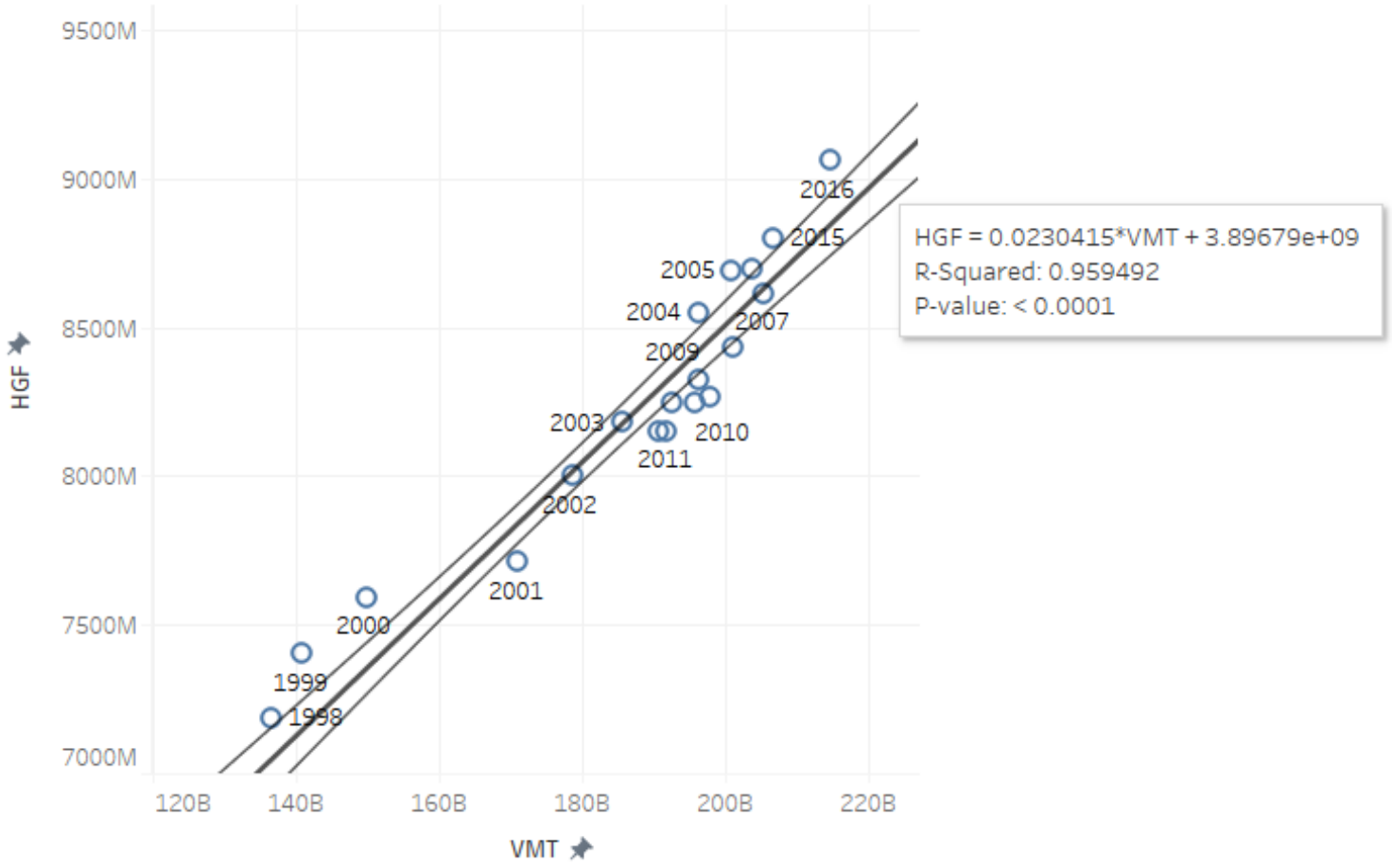
How much do they affect supply?

Storm	Saffir–Simpson Category	Date of landfall	Year
Dennis	3	July 10	2005
Wilma	3	October 24	2005
Irma	4	September 10	2017
Michael	5	October 10	2018

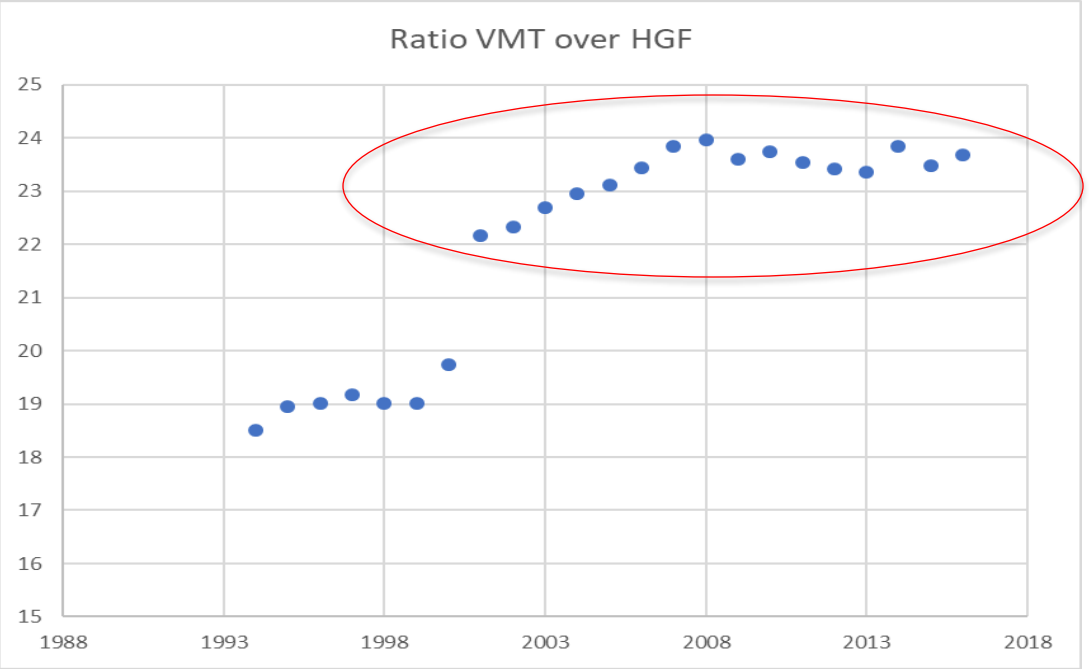
Modeling: Estimation of Fuel Consumed during a Hurricane

* Relation between Highway Fuel Used (HGF) and Vehicle Miles Traveled (VMT)

* **Note**: Data related to fuel demand at the gas stations was not available for this study. Therefore, our calculations used fuel consumption obtained from the Federal Highway Administration (Ref 8), and Vehicle Miles Traveled obtained from Florida Transportation Indicators (Ref 9).



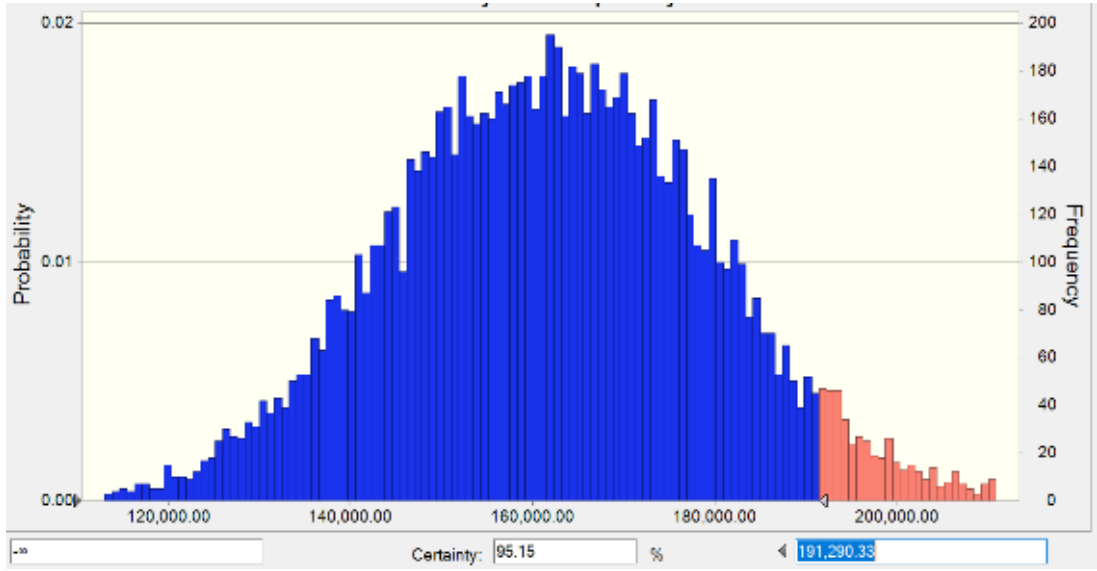
Modeling: Monte Carlo



		2001 thru 2016	2006 Thru 2016
VMT per Gallon	Xbar	**23.32**	23.63
	S	0.53	0.20
	Xbar-2S	**22.25**	**23.23**
	xbar+2S	**24.39**	**24.02**
	Max	23.96	23.96
	Min	22.17	23.37

Monte Carlo Simulation was used to estimate the amount of fuel consumed before hurricane impact.

Historical patterns of travel and fuel consumption were obtained from FDOT data.



Simulation result: Gal/hr distribution 5 days before impact

Model results

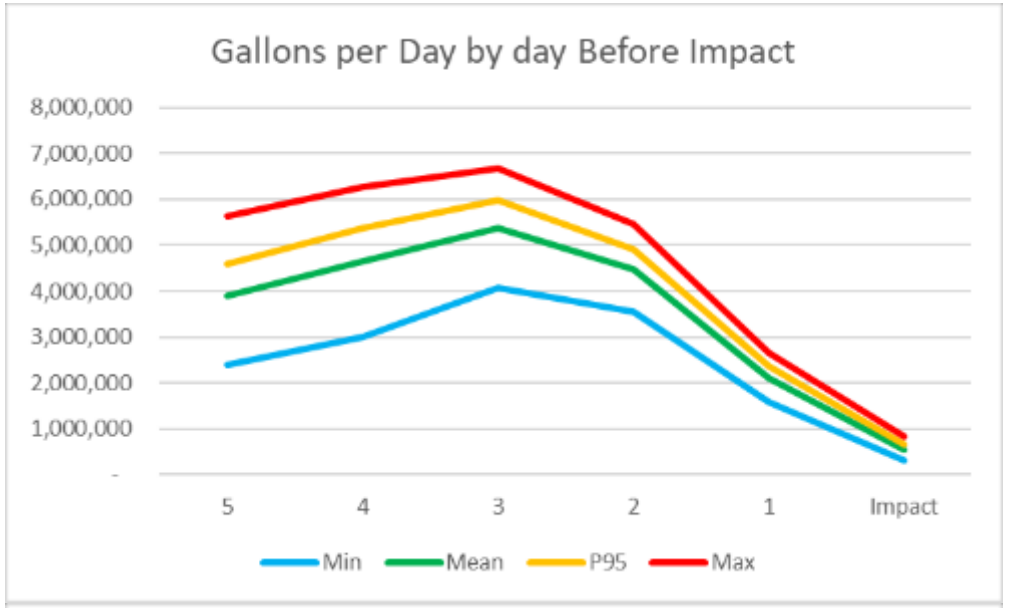
* **Note**: demand generated to evacuate Key West was included.

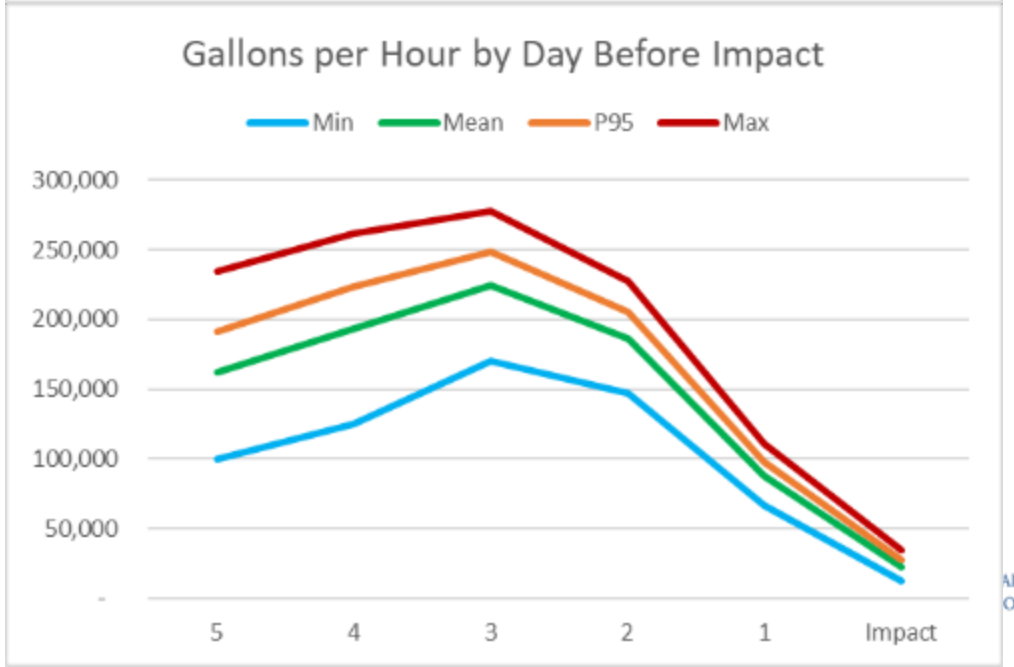
* Gallons per hour and day for all gas stations located within ½ mile of the evacuation route are presented. These data includes demand within 5 days prior to hurricane impact.

* Minimum, Average, 95 percentile and Maximum estimated values were calculated using Monte Carlo Simulation on FDOT data.

* Peak demand is expected during day 3 before hurricane impact.

* Expected demand of gas supplied by the gas stations is between 4 to 5 million gallons per day, or 200 to 225 thousand gallons per hour.





Fuel depletion estimates by gas stations per county: Monte Carlo

County	Retails within 1/2 mile	Gallon Storage	Number of Dispensers	Average Time to Empty (Hours)					
				Day 5	Day 4	Day 3	Day 2	Day 1	Impact
OSCEOLA	2	55,000	14	0.3	0.3	0.2	0.3	0.6	2.4
HERNANDO	3	60,000	18	0.4	0.3	0.3	0.3	0.7	2.7
GILCHRIST	4	75,000	9	0.5	0.4	0.3	0.4	0.9	3.3
JEFFERSON	7	144,000	31	0.9	0.7	0.6	0.8	1.6	6.4
NASSAU	7	164,000	37	1.0	0.8	0.7	0.9	1.9	7.3
DIXIE	8	167,900	35	1.0	0.9	0.7	0.9	1.9	7.4
PALM BEACH	7	186,000	35	1.1	1.0	0.8	1.0	2.1	8.2
MADISON	8	208,000	50	1.3	1.1	0.9	1.1	2.4	9.2
HAMILTON	9	215,000	57	1.3	1.1	1.0	1.2	2.4	9.5
MARTIN	10	244,000	55	1.5	1.3	1.1	1.3	2.8	10.8
LAKE	11	307,000	65	1.9	1.6	1.4	1.6	3.5	13.6
TAYLOR	16	314,000	67	1.9	1.6	1.4	1.7	3.6	13.9
PASCO	11	335,240	68	2.1	1.7	1.5	1.8	3.8	14.8
CLAY	13	353,000	65	2.2	1.8	1.6	1.9	4.0	15.6
INDIAN RIVER	14	377,000	84	2.3	1.9	1.7	2.0	4.3	16.7
FLAGLER	16	396,000	78	2.4	2.0	1.8	2.1	4.5	17.5
BROWARD	14	402,000	79	2.5	2.1	1.8	2.2	4.6	17.8
BAKER	18	403,000	76	2.5	2.1	1.8	2.2	4.6	17.8
SUWANNEE	18	442,000	80	2.7	2.3	2.0	2.4	5.0	19.6
LEVY	23	452,571	70	2.8	2.3	2.0	2.4	5.1	20.0
CITRUS	19	452,672	85	2.8	2.3	2.0	2.4	5.1	20.0
CHARLOTTE	19	488,368	137	3.0	2.5	2.2	2.6	5.5	21.6
SUMTER	20	531,000	145	3.3	2.7	2.4	2.8	6.0	23.5
ORANGE	23	598,000	141	3.7	3.1	2.7	3.2	6.8	26.5
ST. JOHNS	26	739,000	187	4.6	3.8	3.3	4.0	8.4	32.7
MANATEE	30	821,000	176	5.1	4.2	3.7	4.4	9.3	36.3
COLUMBIA	36	832,000	164	5.1	4.3	3.7	4.5	9.4	36.8
SARASOTA	34	942,000	230	5.8	4.9	4.2	5.1	10.7	41.7
ST. LUCIE	40	1,020,052	231	6.3	5.3	4.6	5.5	11.6	45.1
COLLIER	41	1,109,168	222	6.8	5.7	5.0	5.9	12.6	49.1
POLK	49	1,120,456	227	6.9	5.8	5.0	6.0	12.7	49.6
ALACHUA	44	1,131,080	217	7.0	5.8	5.0	6.1	12.8	50.0
LEE	52	1,509,840	321	9.3	7.8	6.7	8.1	17.1	66.8
VOLUSIA	51	1,967,000	246	12.1	10.2	8.8	10.5	22.3	87.0
MARION	93	2,314,063	433	14.3	11.9	10.3	12.4	26.3	102.4
BREVARD	97	2,505,448	430	15.5	12.9	11.2	13.4	28.4	110.9
HILLSBOROUGH	138	3,497,974	705	21.6	18.1	15.6	18.8	39.7	154.8
DUVAL	227	5,880,836	1142	36.3	30.4	26.3	31.5	66.8	260.2

Times to fuel depletion for gas stations by county were calculated.

A heat map shows the counties that must be monitored closely (in red)

Analysis Phase: How is the supply of fuel?

* Fuel is received by marine deliveries and the Colonial Pipeline. The ports are concentrated in Central Florida (Tampa, Port Manatee, Canaveral), South Florida (Port Everglades, Miami, Palm beach), Northeast Florida (Jacksonville), and Florida Panhandle (Pensacola, Niceville, Freeport, Panama City) –Ref 1 pp. 75-78

* Central and South Florida represent 85% of the expected supply for 2018. Since 1926 all major hurricanes have impacted central or south Florida –Ref 3. This implies that, in case of impact, we need to store at least 2, and ideally 3 days of fuel supply for evacuation in case one of these port centers closes –Ref 4, p. 11.

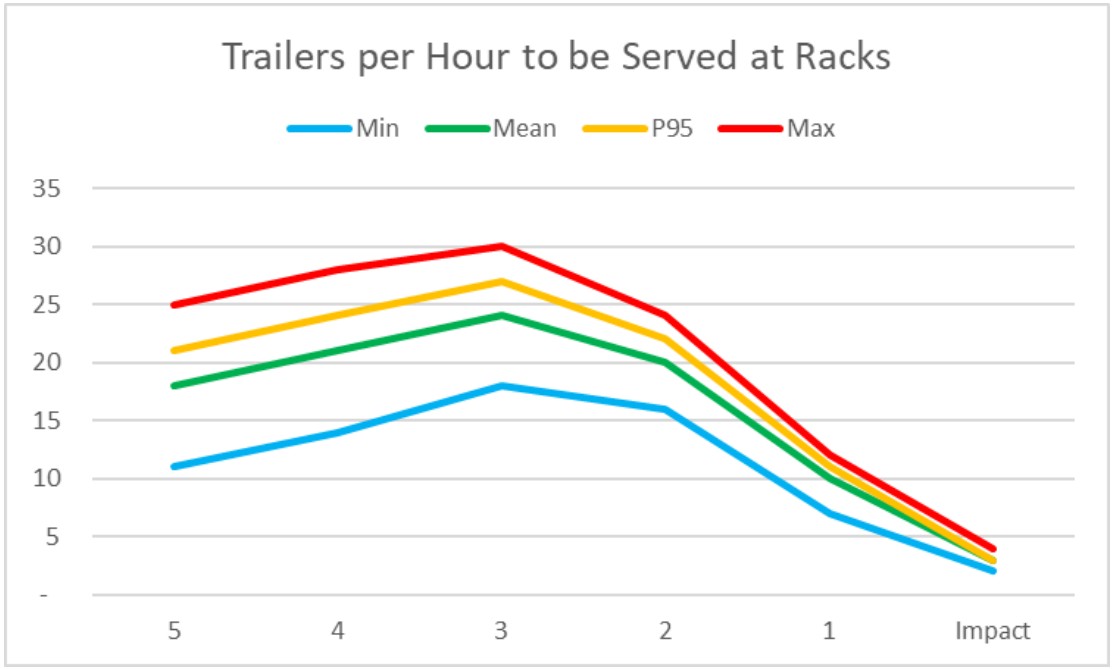
Port Zone (Ref 1 and 2)	Percent	Cumulative Percent	2018 Estimated Supply (Gal/Day)
Central Florida	48%	48%	7,629,598
South Florida	37%	85%	5,924,385
Northeast Florida	11%	96%	1,736,023
Florida Panhandle	4%	100%	709,993
Total	100%		16,000,000.00

Note: This table does not consider the supply capacity of the Colonial Pipeline.

The colonial pipeline can supply 6.3 Million Gal/day. Ref 1 p. 77 However, when a hurricane hits Texas and/or Louisiana, the pipeline has closed for several days. Ref 5.

Analysis Phase: How many fuel trucks?

* With trucks transporting 9,500 gallons per trip (Ref 6), the expected number of trucks to be served every hour at the depots (racks) ranges from 7 to a peak of 27 during day three before hurricane impact.
* Estimating a cycle time of 7 hours (1 for loading, 1 for unloading, and 5 per round trip) we need a fleet of 168 trucks to satisfy average demand during day three.
* If the cycle time increases to 10 hours we will need a fleet of 336 trucks.



Supply Preparedness Conclusions:

- In case of hurricane impact in South and/or Central Florida, establish a transportation chain using the Colonial Pipeline (if available) and the rest of the port centers. This might imply transportation times of 6+ hours South and Northbound.
- Guarantee a supply of 4 to 6 million Gal/day for all gas stations around ½ mile of evacuation route during the week prior to hurricane impact*.
- There are around 1300 gas stations within ½ of the evacuation route. These gas stations have a total storage capacity of 32,000,000 gallons of gasoline fuel.
- The storage capacity of the port zones is estimated to be around 483,000,000 gallons.
- The retail stations within ½ mile of the evacuation route represent less than 7% of the total rack storage capacity for the State.

Recommendations for implementation (from interviews with stakeholders)

- Cooperation – Continue and expand industry and state cooperation before, during and after a hurricane event
- Fuel Visibility – Develop/improve system of reporting for wholesale and retail industry to provide visibility of availability and on-hand amounts
- Escorts – Continue escorting fuel delivery vehicles by FHP and look to expand return escorting as needed
- Traffic Control – Implement traffic control measures on/off evacuation routes and in/out of retail fuel stations
- Backup Power Generation – Continue and expand the use of backup generators at retail fuel stations
- Unattended Fuel Stations – Implement steps that facilitate industry use of unattended fuel stations
- Temporary Stand-Alone Fuel Tanks – Maximize the use of stand-alone fuel tanks

Thank you for your time

References

1. East Coast and Gulf Coast Transportation Fuel Markets. A report prepared by ICF international for EIA. February 2016. https://www.eia.gov/analysis/transportationfuels/padd1n3/pdf/transportation_fuels_padd1n3.pdf

2. Florida Total Gasoline Rack sales Volume by Refiners. US Energy Information Administration. https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=A103R13121&f=M

3. A history of strong hurricanes in Florida -- from Great Miami to Andrew and Wilma. By Dave Bartkowiak Jr. Posted: 11:01 AM, September 08, 2017Updated: 8:48 AM, May 24, 2018. https://www.clickondetroit.com/weather-center/national-weather/a-history-of-strong-hurricanes-in-florida-from-great-miami-to-andrew-and-wilma

4. Florida State's Energy Emergency Response to 2004 Hurricanes. United States Department of Energy, June 2006. www.oe.netl.doe.gov/docs/fl2004energy.pdf

5. Harvey shuts down major fuel pipeline supplying East Coast.By Jethro Mullen. August 31, 2017: 4:19 AM ET. http://money.cnn.com/2017/08/30/investing/colonial-pipeline-harvey-gas-lousiana-texas/index.html

6. https://www.fueloyal.com/learn-fuel-truck/. **Size and Volume of The Fuel Truck: "**A Semi fuel truck can hold 9,000 to 11,500 gallons of fuel. If the fuel truck has 3 axle trailer the regulations for hauling are not allowing fuel transportation that is over 8,500 gallons even if it have 9,500 gallon capacity. The fuel truck with 4 axle trailer has 11,500 gallon capacity and can haul maximum 105,000 pounds when it is fully loaded"

7. Hurricanes and tropical storms hitting FL: https://en.wikipedia.org/wiki/List_of_Florida_hurricanes_(2000%E2%80%93present) and Map of hurricanes category 3+ hitting Florida: map of hurricanes trajectory in florida - Bing images

References, cont.

8. Federal Highway Administration. Policy and Government Affairs, Office of Highway Policy information: Highway motor fuel use (Tables MF-27). https://www.fhwa.dot.gov/policyinformation/statistics
9. Florida Transportation Indicators: http://floridatransportationindicators.org/
10. Vehicle counts by day, hour and county. Data provided by FDOT
11. FDOT evacuation route. QGIS file provided by FDOT
12. Datalytics Irma. Excel file provided by FDOT
13. Data on interstate and state roads for Florida. GIS data on http://www.fdot.gov/statistics/gis/
14. Active fuel facilities (retail stations). GIS data file provided by FDOT