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Impacts of COVID-19 Restrictions on Freight Transportation in Coastal and Intermodal Port Regions

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ABSTRACT

The COVID-19 pandemic resulted in significant social and economic impacts throughout the world. In addition to the health consequences, the impacts on travel behavior have also been sudden and wide-ranging. This study describes the drastic changes in human behavior using the analysis of highway volume data as a representation of personal activity and interaction. Same-day traffic volumes for 2019 and 2020 across Florida were analyzed to identify spatial and temporal changes in behavior resulting from the disease or fear of it and state-wide directives to limit person-to-person interaction. Compared to similar days in 2019, overall state-wide traffic volume dropped by 47.5 percent. Although decreases were evident across the state, there were also differences between rural and urban areas and between highways and arterials both in terms of the timing and extent. The data and analyses help to demonstrate the early impacts of the pandemic and may be useful for operational and strategic planning of recovery efforts and for dealing with future pandemics.

INTRODUCTION

The coronavirus (COVID-19) pandemic brought unprecedented levels of disruption to countries throughout the world. As the disease spread globally, all countries were impacted to one extent or another. However, the response to the global pandemic declaration has been uneven and varied, depending on factors such as wealth, availability of health care, socialized medicine, public welfare and the extent of authoritarianism in government.

As the specific mechanisms for the transmission of the virus were largely unknown during its onset period in the United States (US) and there was a limited ability to test for infection, public officials throughout the country had few other options to limit the rapid spread of the virus than to call upon people to maintain physical distancing from one another. In the United States (US), governmental directives varied over time, beginning with voluntary stay-at-home requests and restrictions on large public gatherings then, later, to virtual state-wide lock-down quarantines. However, travel in various forms continued throughout the country. Most notable of these were activities deemed "essential" for the public good, such as for people to access food, medical care, and other basic life necessities for public health, welfare, and safety.

While the ultimate intent of these restrictions, to slow the progression of the virus and limit fatalities, will take time to assess, other effects of travel and social interaction restriction can already be studied. In this research, it was hypothesized that roadway traffic volume data could serve as a reflection of societal activity and, to an extent, the likelihood of personal interaction. Since traffic count data is objective, accurate, reliable, and collected continuously throughout cities and states it permits a basis of comparison between conditions before, during, and after the period of the initial COVID-19 detection in the US in early 2020. In this paper, the sudden and drastic changes in societal behaviors are described and assessed by using the same-day traffic volumes for 2019 and 2020 across Florida to compare spatial and temporal pattern changes resulting from the disease, fear of it, and state-wide directives to limit its spread.

More specifically, the focus of the effort was to examine the temporal relationship of key governmental requests for public isolation and travel limitations both temporally and spatially. The assessment looked differences in urban versus rural regions of the state over time as well as on different road functional classifications. Road functional class was included because it was recognized that some types or roads, urban arterials for example, tend to serve local traffic, while others, like rural freeways tend to served more distant, intercity travel Florida was thought to be particularly interesting location to examine the travel impacts of COVID-19 pandemic because of its enormous diversity and unique demographic and commercial characteristics. Among these are its numerous highly populated major metropolitan regions and rural regions; its significant percentage of elderly population; and it position as one of the most highly visited tourist and recreational locations in the world.

The paper includes several sections to highlight and summarize the primary components of this research study. First, a review of relevant literature is included to provide background and context to the study from the perspective of prior research and prior study of virus transmission, particularly through isolation and as it related to means and modes of transportation. This is followed by a description of the data and methods used to carry out the study. Then, the data collection and analyses are discussed. In particular, the FODT traffic count data collection system is described and how its output was used for this study. This is followed by a presentation and discussion of the analytical results of the research. Because of the enormous quantity of data recorded hourly over a statewide network of data recorders, the Results section focused on key statistical findings at various high levels of aggregation. Finally, the paper concludes with a discussion of what these data and results may be suggesting, especially in terms of policy guidance - both existing and future and the public response to government guidance and recommendations.

BACKGROUND

Broadly, pandemics are global disease outbreaks that spread quickly across the world. Often, they result from lack of immunity and an inability to develop and deliver vaccines to stop the disease. While the threat of pandemic has been well recognized (Yong, 2018), and guidance for pandemic planning has been developed by the World Health Organization (2019) and the Centers for Disease Control and Prevention (2007 and 2020), pandemics are complex, difficult phenomena to manage. They are rare events. Only four have occurred in the last century in 1918, 1957, 1968 and 2009 (Kilbourne, 2006; Centers for Disease Control and Prevention, 2009).

There have been epidemics such as dengue, Ebola, measles, etc, which are disease outbreaks that are more limited than pandemics in that they are concentrated in a few countries or regions of the world. With pandemics, challenges arise from the lack of knowledge, experience and readiness. The global scale overwhelms capacity to manage, respond to, contain, mitigate and recover from the disease outbreak. Characteristics of the 2019 novel coronavirus in terms of origin, transmission, contagion, lethality, containment, treatment and recovery present challenges for emergency management. A vaccine will not likely be developed in time to prevent the spread of the disease and its health and social consequences. For this reason, non-pharmaceutical interventions (U.S. Department of Health and Human Services, 2020) such as quarantine, isolation, and social distancing are most needed. Pandemics differ from other natural hazards (Kim, Francis, and Yamashita, 2017) such as hurricanes, tornadoes, flooding, earthquakes, tsunamis, volcanoes and wildfires that typically damage infrastructure as well as cause harm to people. With a pandemic, homes, buildings, roads, facilities, vehicles, and equipment are not damaged. Pandemics cause people to be sick, absent from work, and hospitalized and some die. Some infected individuals may not fully re-cooperate or may take many months to recover. The loss of income because of health care costs, not being able to work, pay taxes, or conduct business can impact households, firms, and governments. A pandemic can also affect social, cultural, educational, recreational, and other important activities. As such, a pandemic affects the health and wellbeing of people and communities.

Among the ways that governments and health officials attempt to limit the speed and extent of pandemics is to physically separate people. In particular, quarantines - the restriction of movement of healthy persons suspected of being infected with a contagious disease, attempt to isolate and treat individuals who are, or are suspected to be, infected. Social distancing involves actions by individuals, groups, and organizations to limit contact with others through actions such as the closure of schools and businesses, shutdown of services, travel and activities and gatherings. Any particular pandemic response relies on the planning, coordination, and execution of actions involving governments (federal, state, local, tribal and territorial), businesses and industry, non-profit organizations, and community groups. Pandemic responses also rely on "whole community" approaches. In the US, this is a part of the National Incident Management System (NIMS) that includes frameworks for emergency management and response.

While guidance, training, exercises and systems for pandemic planning have been developed, there are reasons for focusing on transportation and managing travel demand. Transportation planning theories, research, methods and technologies can be incorporated into pandemic response and recovery (Baxtor, 2001; Berkoune, et al., 2012; Kim, Pant, Yamashita, 2018; Matherly, et al., 2014; Renne, et al., 2019; Zheng and Ling, 2013). It is particularly useful to apply the tactics and strategies from other events which have disrupted transportation systems (Douglass, et al., 2014; Grayson and Noona, 2010; Hambridge, Howitt, and Giles, 2017; Houston, 2006; Houston, et al., 2009, 2010; Kim, et al., 2019; Kontou, Murray-Tuite and Wernsted, 2017; Litman, 2006; Schwartz and Litman, 2008; Reggiani, 2013; Vasconez and Keheli, 2010 and Wolshon, et al., 2005). There are useful lessons for managing recovering and restarting transportation systems (Chen and Miller-Hooks, 2012). While evacuation typically involves movement of people away from hazards and threats, planning and decision-making involve tradeoffs between sheltering-in-place, travel through hazard zones, evacuating to safety and re-entry decisions; all pertinent to quarantine, isolation, and social distancing efforts.

Timely, accurate, and actionable data are required for planning and decision-making. Information on the spread of the disease across and within transportation systems (e.g., nodes, hubs, links, vehicles, operators, passengers, and users), an understanding of risk, risk tolerance and risk management (Flannery, et al., 2015; Fletcher, et al., 2014; Reggiani, 2013) is critical for strategic and operational planning. The capabilities used with events, such as hazardous material release (National Academies of Sciences, Engineering, and Medicine, 2011), infectious disease outbreaks on transit systems (Henson and Timmons, 2017), air travel (Gardner and Sakar, 2015), or management of transportation agencies during emergencies (Krechmer, et al., 2012) depends on many of the same systems, frameworks, protocols, operational procedures, and processes needed for the COVID-19 pandemic.

There are unique challenges with COVID-19. The disease has spread rapidly, forcing governments to implement historic lockdowns, shutdowns, and closures of schools and businesses. There have been significant bans on international travel with impacts on tourism, entertainment, and the cruise ship industry, impacting some states more than others. In terms of the cruise ship industry, Florida leads the nation (followed by Alaska, California, Puerto Rico, and the Virgin Islands) with over 3,000 port calls, with the largest number of jobs in this industry located in Miami (Congressional Research Service, 2020). The cancellation of flights and the closure of beaches, parks, sporting events, conferences, conventions, and other activities due to the coronavirus has had significant impacts on travel behavior. The effects on the airline industry are even more dramatic than 9/11 or the Icelandic volcano eruption in 2010 (Ulfarsson and Unger, 2014).

Evidence of the change in transportation due to the shutdown of travel has been captured by seismometers measuring planetary movements (Gibney, 2020).

In the U.S., the response to the COVID-19 pandemic has been difficult to coordinate because of the size of the country and the system of public health management. While the federal government may impose restrictions on international travel and take actions affecting airlines and cruise ships, for the most part, state and local governments manage public health emergencies. Most emergencies, from motor vehicle crashes to fires to industrial accidents, are handled locally with mutual aid from neighboring jurisdictions. Large cities have relevant experience with managing special events and incidents, including mass shootings, severe weather and more catastrophic events such as earthquakes and hurricanes. However, most jurisdictions are not well prepared for pandemics. New York, San Francisco, New Orleans, and Detroit initially asked residents to limit travel to only "essential" trips for food, medication, medical care, and work deemed to be essential (e.g. public safety, hospitals, utilities, manufacturing, food production, groceries and drug stores).

A recent study of Seattle from February 2, 2020 to March 8, 2020 found that major employment centers experienced the largest declines in visit followed by recreational and social hubs, but a decline in longer trips were replaces with more frequent short trips. Second, as commute and social trips reduced traffic, travel speeds on roadways increased and trip times feel correspondingly. Finally, the study found that visits to bulk retailers spiked while mall visits decreased. Somewhat surprisingly, the study found that visits to grocery stores decreased, perhaps due to the early nature of this study before restaurants were closed on Tuesday, March 17, 2020 (Reed and Hendrickson, 2020).

Florida imposed statewide lockdowns, keeping beaches open in some parts of the state outside the epicenter in South Florida during spring break but urging elderly and high-risk groups to shelter in place. An article published in the New York Times found that residents in South Florida had virtually no travel while residents in the northern part of the state maintained more regular patterns of travel (Glanz et al., 2020). Directives in Florida became more restrictive over time as confirmed cases increased. By late March 2020, most non-essential activities throughout the nation came to a halt. Most primary, secondary and higher education institutions started online education and some extended spring breaks. Restaurants switched to pick-up and delivery service. There has also been growth in online shopping, telework, and virtual meetings.

In this research, statewide traffic volume data collected by the Florida Department of Transportation (FDOT) were used to assess regional surface mobility during the early onset of COVID-19. With more than 20 million residents, Florida has a large diverse population with a mix of large urban regions and small rural communities. In addition to examining different parts of the state, urban and rural locations, there are a mix of different roadway classes. As a narrow peninsula, the state provides a more comprehensible and coherent transportation network.

From an operations perspective, the data and analyses in this paper support greater understanding of how to implement quarantine and isolation controls (Graham, et al., 2008), adding to research on slowing movement of infectious disease (Gardner, 2015; Gendreau, 2015; Fletcher, et al., 2014). If the duration of the pandemic is long, there may be need for other operational strategies, such as the pre-positioning of supplies (Zheng and Leng, 2013; Rawls and Turnquist, 2010), including equipment, and other goods necessary for response and relief efforts or to ensure populations can comply with stay-at-home orders. Data on travel behavior is also relevant to recovery efforts and planning for the return to normalcy (Matherly, et al., 2014; Chen and Miller-Hooks, 2012), training and overall preparedness (Department of Homeland Security, 2013; Edwards and Goodrich, 2014; Wallace, et al., 2010) and longer-term community resilience.

DATA AND METHODS

Traffic patterns before and during the COVID-19 crisis across the State of Florida are examined using a quasi-natural experimental design of before and after, featuring traffic volume as the key variable of interest. Traffic count data from the Florida Department of Transportation (FDOT) for 262 sites were analyzed to answer the following research questions:

1. What have been the changes in overall traffic volume patterns across Florida due to COVID-19?
2. Did traffic volumes decrease more in closer proximity to the epicenter of the outbreak in South Florida compared to other counties with fewer confirmed cases (at the end of the

study period on March 22, 2020), or was the decrease in travel equally distributed across the state?

3. Did traffic decline equally in urban locations compared to rural locations?
4. Did traffic decline equally on arterials compared to interstates?
5. When did traffic change significantly? Did this vary by roadway classification or area?

The first research question was answered by examining the overall share of traffic volume growth or decrease statewide for all locations during the COVID-19 response in March 2020 compared to March 2019. The second question examined 2019 to 2020 differences in traffic counts for sites located in Broward, Miami-Dade, Monroe and Palm Beach counties compared to 2019 to 2020 differences to counties outside this area. The third question examined 2019 to 2020 differences in traffic counts for sites located in urbanized areas (as defined by FDOT) compared to 2019 to 2020 differences in rural locations. The fourth research question examined 2019 to 2020 traffic volume differences on arterial roads versus interstates. Finally, the fifth research question was addressed through an examination of the dates when statistically significant differences arose and remained consistently different between 2019 and 2020.

Data from this natural experiment helped to inform the role of state policy directives in limiting travel on actual traffic volume. Moreover, the study sought to understand if proximity to the outbreak reduced traffic greater than distant locations; everyone in the state was under the same directives from the Governor. Examining urban versus rural traffic differences informed how travel varied in different contexts. For example, while travel volumes are typically lower in rural areas, the decrease in travel may not have been as great because people may not have been as concerned about the disease due to living in a less crowded environment. Finally, comparing arterials with interstates allows for a comparison of differences between long-distance and local travel.

Traffic volumes in March 2020 were compared to base year levels in March of 2019 using paired t-test statistics generated using SPSS version 22. The comparison dates were March 1-22, 2020 and March 3-24, 2019, with matched days of the week. Wednesday and Thursday of the third week in January for 2019 and 2020 were compared against each other to test for general traffic growth or contraction. It should also be noted that the Tuesday of this week was discarded since it would have involved comparing the Tuesday after MLK Day in 2020 with the Tuesday before MLK Day in 2019 and the holiday traffic differences could have skewed the results.

The Florida Department of Transportation's (FDOT) Transportation Data and Analytics Office gathers roadway data from across the state. Volume, speed, and vehicle classification are collected hourly using telemetric monitoring stations which transmit this data through telephone or wireless communications. Bidirectional hourly traffic counts were collected, cataloged, and processed from 262 telemetric monitoring stations, shown in Figure 1. Data were collected for the 82-day period beginning January 1, 2020 and ending March 22, 2020. For comparative purposes, data were also collected for the 90 day period beginning January 1, 2019 and ending March 31, 2019. Totaled, the dataset consisted of over 2.1 million individual count observations (172 days x 24 hours x 262 sites x two directions). The data were reviewed for errors. A common error was missing data and/or sites reporting zero values. The zero values were due to road closures because of incidents, scheduled maintenance work and malfunctioning roadway sensors. Sites with three or more consecutive observations of zero values were removed. Data from 2020 were linked to data from 2019, resulting in 212 sites with consistent and error free information.

RESULTS

The research results are presented in two parts. First, traffic volume and trends are presented and discussed for the period corresponding to the early onset of the COVID-19 pandemic in Florida. Then, statistical comparisons are presented to illustrate the significance of the traffic decrease in 2020 compared to 2019.

Traffic Volume Trends

Figure 2 provides the daily traffic totals collected from the monitoring stations between March 1, 2020 and March 22, 2020. Traffic counts are shown for urban roads (123 sites), rural roads (89 sites), and combined for all roads (212 sites). Daily traffic totals from these same sites are shown for a similar period in 2019, based on the first through the fourth Sunday in March for both years. Included in the figure are the cumulative confirmed cases of COVID-19 in Florida as well as the dates of statewide directives and actions (e.g., the emergency declaration, school closures, major

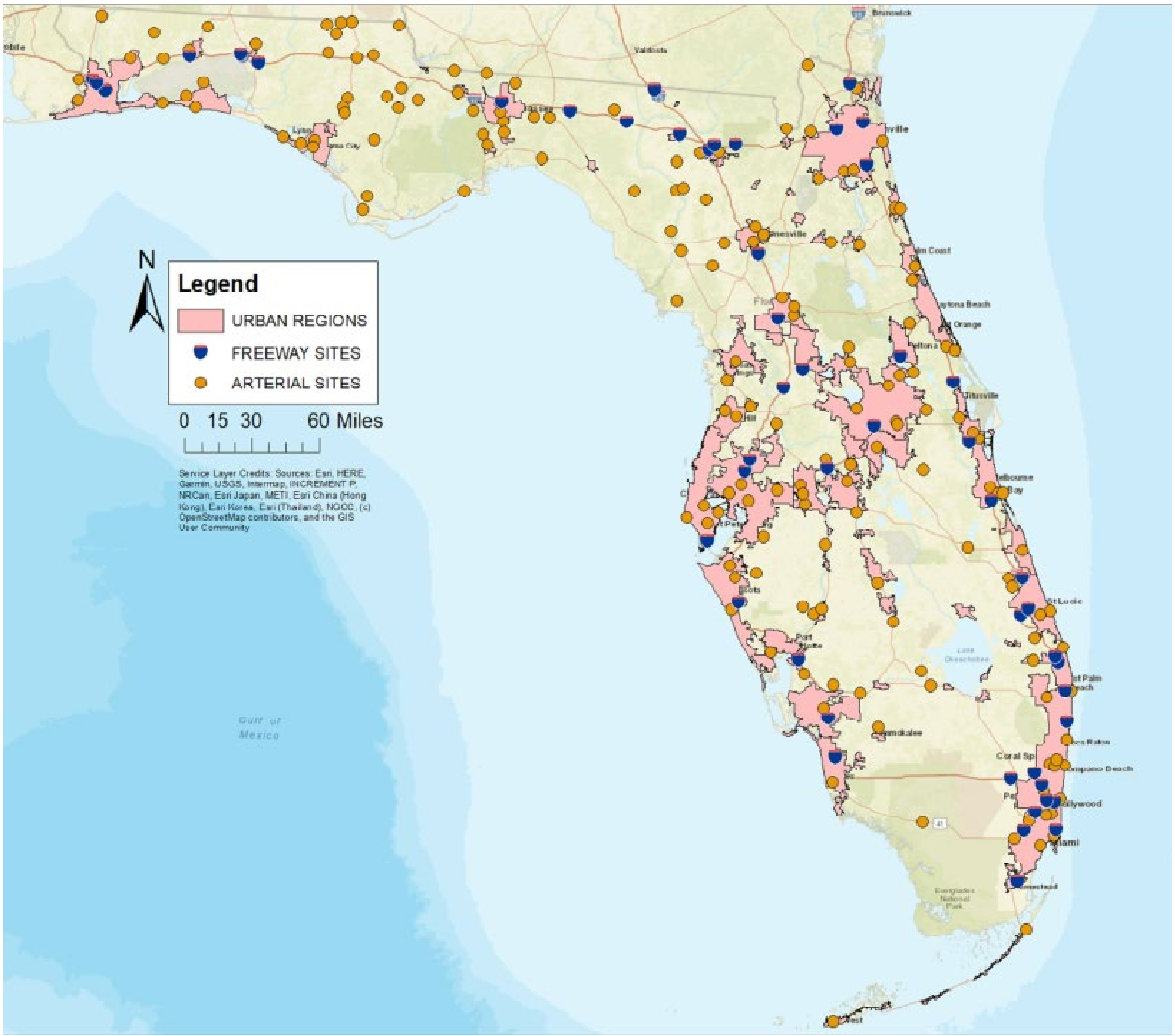

Fig. 1. FDOT telemetered traffic monitoring sites. [Base map sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community.]

theme park closures, bar closures, and restaurant closures). Traffic volumes for the first week of March 2020 remained consistent with the prior year. Governor DeSantis declared a state of emergency on March 9 when the first two cases of COVID-19 were confirmed. By March 12, traffic volumes were reduced by 3.2 percent from their 2019 levels. The following day (March 13), the governor announced the closure of schools and by Saturday, March 15, Disney World and Universal Studios' Orlando theme parks were closed.

At that time, there were 50 confirmed case of COVID-19 and traffic was reduced by 12 percent compared to 2019. By March 17, the governor closed all bars and nightclubs and on March 20, all restaurants were closed to dine-in service and traffic had decreased by 23 percent. On March 22, the last day of observation, traffic volumes across the 212 sites had dropped by an average of 47.5 percent when compared to 2019 levels and there were more than 1,100 confirmed cases of COVID-19 in the state.

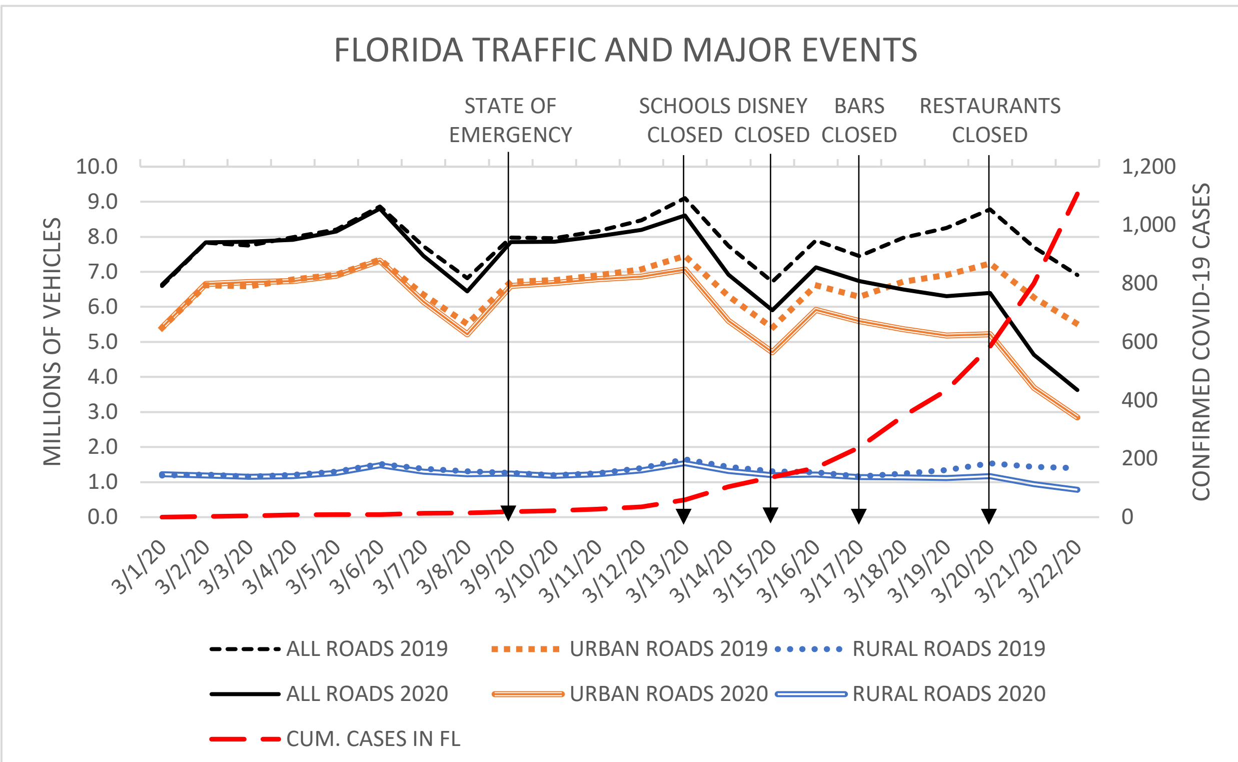

Fig. 2. Florida traffic, urban and rural roads, March 2020 and 2019 and COVID-19 reported cases.

Total urban traffic volume was approximately five times greater than rural volumes and constituted a larger proportion of the overall trend observed in Figure 2. The figure reveals that urban traffic was subject to large weekday/weekend variations, ranging from a Friday high of over 7 million vehicles per day (vpd) to a Sunday low of just 5.2 million vpd.

The weekly variations in rural traffic was not as pronounced, ranging from a Wednesday high of 1.54 million vpd to a Sunday low of 1.15 million vpd. Urban traffic begins to decline from 2019 levels on March 7 with a three percent drop; however, the percent drop decreases to 1-2 percent after March 8 (which had a 5.3 percent drop) until March 12. After March 12 (three percent drop), the percent drop generally increased until reaching 48.3 percent on the last day of the study. In terms of percentage drops, decreases in traffic on rural roads began on March 12 (4.4 percent drop), with increasingly large percentage drops starting March 18, when rural roads showed a nine percent decrease in traffic. By the end of the study period, rural roads had decreased by 44.3 percent.

Among the other findings from the analysis of traffic trends was that the 48 detector locations on freeways consistently carried more traffic than the 164 detector sites on arterial roadways. Overall, freeway traffic decreased by 52.4 percent when compared to 2019 traffic and arterials were reduced by 40.6 percent. The impact of COVID-19 on freeway traffic appeared to begin earlier than on arterial roadways.

Figure 3 shows the percent decrease in traffic observed during the study period in 2020 compared to the same period from the prior year. The figure was partitioned to show total traffic and urban and rural roadways. The figure includes cumulative COVID-19 cases and major directives and actions taken to reduce travel. Overall, the figure suggests similar trends between decreases in traffic and confirmed cases of COVID-19 within the state. In general, the decrease in traffic was nominal until the Governor's state of emergency declaration. The decreases, along with the confirmed cases of COVID-19, grew exponentially until the end of the study period. Furthermore, urban weekday/weekend variations narrowed over the study period. Starting on March 18, rural traffic rapidly reduced and the decrease aligned with urban traffic.

Statistical Analyses

To test for general traffic growth/contraction, traffic volumes on two days in January 2020/2019 were compared. These days were the Wednesday and Thursday of the third week January; Tuesday, Wednesday, and Thursday are the most similar (Rakha and Van Aerde 1995). In this study Tuesday was excluded due to Martin Luther King Day falling in different weeks for 2019 and 2020. The results of the paired t-test among 226 sites indicated that the volumes were not statistically different (p > 0.28). This suggests that the differences in volumes were not due to overall decreasing trend in traffic due to the COVID-19 pandemic event and associated responses.

All Roadways

Data for all roadways, including freeways and arterials (212 traffic count locations) across the state were analyzed with a paired t-test to compare traffic volumes for each day from March 1, 2020 to March 22, 2020 to a reference day in March 2019 corresponding to the same day of the week (i.e., March 1, 2020 was the first Sunday of the month compared to March 3, 2019, which was the first Sunday of March in that year) .

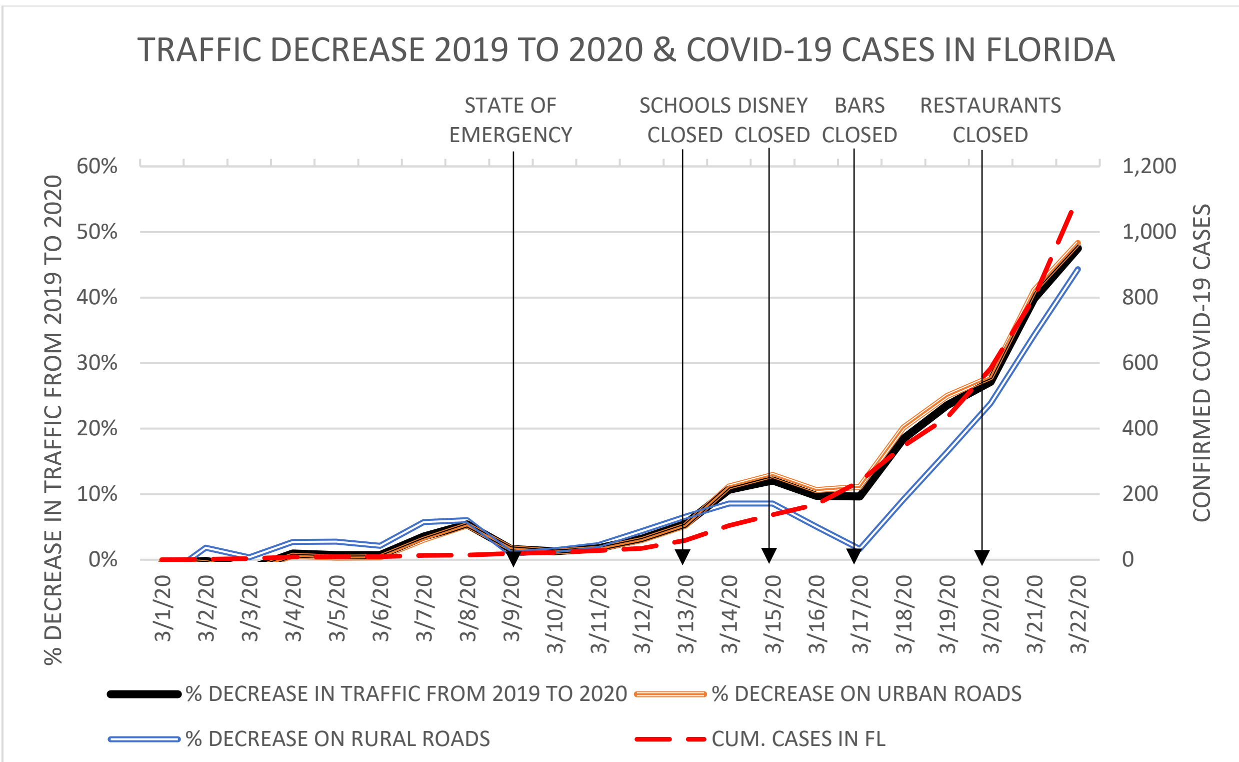

Fig. 3. Percentage of 2019-to-2020 Traffic Decrease and Cumulative Confirmed COVID-19 Cases in Florida

As reported in Table 1, traffic on Sunday and Monday, March 1 and 2 showed no statistically significant differences compared to the reference day in 2019. March 3 and 4, 2020 were the first days that traffic volume declines were statistically significant compared to the 2019 reference day (see Table 1). However, the p-values were .009 and .029, respectively, and the traffic decline was not statistically significant on March 5 and 6, 2020 compared to each of their reference days in the prior year. Starting on Saturday, March 7, 2020 and continuing to March 22, 2020, each day demonstrated a statistically significant difference compared to the reference day for 2019.

South Florida vs. Outside of South Florida

The concentration of COVID-19 cases during this study period was located in Broward, Miami-Dade, Monroe, and Palm-Beach counties, considered as "South Florida" in this study. As shown in Table 1, for all roadways combined, statistically significant volume changes were noted on March 7, 8, and 12-22 in South Florida. Outside of South Florida, statistically significant volume changes were present earlier and on more days: March 3, 5-8, 10-22.

Urban vs. Rural

Data for all roadways, including freeways and arterials, were examined and compared by urban versus rural location, as defined by FDOT (FDOT, 2018). All urban roadways (123 traffic count locations) showed no difference from the 2019 reference day for traffic volumes from March 1 – 6, 2020, with the exception of Tuesday, March 3, 2020. On that day, traffic decline was statistically significant. Starting Saturday, March 7 through the last day of the analysis on March 22, 2020 traffic decline was statistically significant for all urban roadways (see Table 1).

The change in traffic for all rural roadways (89 traffic count locations) was not as clear. The t-test showed that traffic decline on all rural roadways was statistically significant on March 3, 4, 7, 8, 12-16, and 18 – 22, but no statistically significant differences on March 1-3, 6, 9-11 and 17 (see Table 1).

The study examined urban freeways (33 traffic count locations), urban arterials (90 locations), rural freeways (15 locations) and rural arterials (74 locations). Tests of statistical significance between urban freeways and urban arterials failed to show a statistically significant difference with the exception of March 3 and 11, 2020. On March 3, 2020 traffic on urban arterials was less (statistically significant) than 2019 whereas traffic on urban freeways was not. On March 11, 2020 the opposite was the case with traffic on urban freeways showing lower traffic compared to 2019 while urban arterials showed no statistically significant difference (see Table 1).

The most striking difference in the analysis was apparent when comparing rural arterials to any other type of roadway classification. Rural arterials (74 traffic count locations) across Florida showed no statistically significant differences in traffic volume from March 1 – 15, 2020 compared to the reference day in 2019, with the exception of March 13 ($p = 0.046$). On March 16, 2020, declines in traffic volume became statistically significant on rural arterials and remained significant through the last day of the analysis on March 22, 2020. Data for rural freeways, which had the fewest number of traffic count locations (N=15) showed a sporadic pattern of differences. Rural freeways showed significant declines on March 4 – 8, 10 – 15, and 19 – 22, 2020 compared to the reference day from 2019 (see Table 1).

Freeways vs. Arterials

Data for all freeways (48 traffic count locations) demonstrated the same pattern as all roadways with the exception of March 3, 2020. On that day, data for all freeways was not statistically significant compared to the reference day in 2019. However, data for all arterials (164 traffic count locations) showed statistical significance on March 3, however, there was no significant difference in traffic on March 4-6, 2020 compared to the reference day in 2019. The data for Saturday and Sunday, March 7 and 8, 2020 demonstrate a statistically significant decrease in traffic compared to the previous year, but traffic for all arterials was not statistically different on March 9 – 11, 2020 compared to each of the prior reference year dates. Traffic decline for all arterials became statistically significant compared to the 2019 reference day March 12 through March 22, 2020 (see Table 1).

Date of Consistent Difference

For the purposes of this study, *consistently different* was considered at least three consecutive days of statistically significantly different traffic volumes with less than two consecutive days of not significantly different traffic volumes. Using this definition of consistently different, Table 1 indicates when the traffic volumes began to be consistently different. Any shading indicates a statistically significant difference at the $p < 0.05$ level. Darker shading indicates the consistently significantly different time period.

When considering all road types together for all of Florida, the first date of consistently different traffic was Saturday, March 7. The date was the same when considering just the freeways. However, while arterials show a statistically significant drop on that date, consistency did not arise until Thursday, March 12 (5 days later).

For all urban roadways, the first date of consistently different traffic was also Saturday, March 7, 2020. However, when considering only urban freeways, the first date was Wednesday, March 11, 2020. For arterials, the first date was a day later, March 12, 2020.

For all rural roadways, March 12, 2020 was the first date of consistently different traffic, later than that for urban areas. Freeways had less than 20 observations and are not discussed here due to low sample size. Rural arterials showed a noticeable four-day lag in the start date of consistently different traffic (March 16).

Finally, the first date of consistency varied whether the roadways were located in South Florida or outside of this area. For South Florida, the start date is March 12, 2020 considering all road types, while outside of this area, the start date is a week earlier – March 5. Freeways are not compared here due to low sample size within South Florida. For arterials, the start date outside of south Florida is March 12, two days earlier than within south Florida.

CONCLUSIONS

Five research questions were examined in this study. The first question (*What have been the overall changes in traffic volume patterns across Florida due to the COVID-19?*) indicated that traffic volumes by March 22, 2020 dropped by 47.5% of the volume that it was at the same point in 2019. Moreover, as shown in Figure 2 above, traffic declined in March 2020 corresponding with the Governor's state of emergency declaration, school, restaurant and bar closures. Figure 3 above revealed that during the study period, the traffic decline followed similarly shaped trends with the increase in confirmed COVID-19 cases throughout the State of Florida.

The second research question (*Did traffic decrease more in closer proximity to the epicenter of the outbreak in South Florida compared to other counties with fewer confirmed cases (at the end of the study period on March 22, 2020), or did state policies encouraging less travel reduce travel equally across the state?*) found that the traffic decline outside of South Florida was statistically noticeable before that of South Florida. This finding indicates that people in the epicenter in South Florida continued to travel more early on despite being at a higher threat. However, traffic both inside and outside South Florida noticeably dropped after schools closed.

The third research question (*Did traffic decline equally in urban locations compared to rural locations*?) found significant variation between the decline. Urban areas across the state experienced significant decline several days before rural areas. Because the data is just based on traffic volume and not trip purpose it is impossible to determine if the difference was related to a greater feeling of indifference, initially, among rural residents compared to urban dwellers. Another plausible explanation could be that college students and tourists needed to travel via rural locations on their way home to shelter. Further research should be conducted to identify when and why people traveled before they sheltered.

The fourth research question (*Did traffic decline equally on arterials compared to interstates?*) found that traffic on highways accounted for about two-thirds of the total volume and corresponding decline, but traffic decline on arterials was not consistently different until five days after freeways. This may indicate that people reduced travel for longer trip purposes, such as work trips, but continued to make local trips for nearly an extra week. However, again, the data from this study cannot draw conclusions on trip purpose, thus such data should be collected in future research on this topic.

Finally, the fifth research question (*When did traffic change significantly? Did this vary by type of roadway or area?*)found that urban arterials experience consistently different volumes a day after urban freeways and rural arterials had a four day lag compared to urban arterials.

The analysis demonstrates that overall traffic volumes decreased significantly over the period with the greatest declines occurring later in the study period, suggesting that a multiplicity of factors contributed to increasing effects the change in travel behavior. In Florida, the issuance of the emergency declaration started the reductions in travel but other actions such as school closings, shutdown of theme park operations, and the shuttering of bars and restaurants were associated with increased travel reductions. Whether the reduction in travel demand was due to the closure of activities and trip generators or a function of increased fear arising from the increased lethality of the coronavirus requires further exploration.

The data and findings are useful in considering both the timing as well as the cumulative effects of orders and actions designed to increase social distance and limit contact to reduce the spread of the pandemic. It would be interesting to determine if starting some of the actions such as restaurant and bar closings earlier would have resulted in steeper increases in trip reduction. Clearly there was a lag between urban and rural areas and more investigation as to reasons and motivations for the slower reaction was warranted. Such knowledge could be useful in messaging especially if the protective action decision-making is transferable to other hazards and threats.

Among the most important unanswered questions of this research pertain to the ultimate effect of reduced travel: was it successful in reducing sickness and fatalities from the coronavirus? Time will tell. This will require more direct correlation between trip reduction and reduction in infection, transmission and lethality for the coronavirus. It requires additional data to better isolate those travelers who sheltered in place and reduced travel linked to health outcome data.

More research is needed with data and analytical tools for investigating the relationships between infectious disease, containment strategies, and travel behavior. Feedback mechanisms and systems which use traffic volume as a proxy for compliance with emergency orders would be useful to both strategic and operational planning and emergency management. Additional efforts to integrate traffic data systems to support response and recovery from pandemics beyond this initial analysis hold promising returns for transportation and community resilience.

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Table 1. Two-Tailed Significance of Traffic Volume Differences*

		All Florida			Urban			Rural		S. FL		Non-S. FL		
Comparison Dates	**Day**	**All**	**Fwy**	**Art**	**All**	**Fwy**	**Art**	**All**	**Art**	**All**	**Art**	**All**	**Fwy**	**Art**
03/01/2020 - 03/03/2019	Sun	0.374	0.099	0.175	0.899	0.204	0.027	0.125	0.134	0.594	0.313	0.136	0.016	0.272
03/02/2020 - 03/04/2019	Mon	0.741	0.660	0.973	0.305	0.244	0.874	0.140	0.662	0.643	0.591	0.990	0.915	0.900
03/03/2020 - 03/05/2019	Tue	0.009	0.391	0.000	0.003	0.150	0.000	0.773	0.186	0.215	0.307	0.032	0.773	0.000
03/04/2020 - 03/06/2019	Wed	0.029	0.005	0.782	0.163	0.057	0.675	0.049	0.869	0.060	0.216	0.133	0.014	0.399
03/05/2020 - 03/07/2019	Thu	0.117	0.316	0.144	0.486	0.998	0.098	0.041	0.861	0.274	0.530	0.003	0.015	0.074
03/06/2020 - 03/08/2019	Fri	0.115	0.063	0.917	0.360	0.510	0.504	0.159	0.197	0.640	0.960	0.018	0.003	0.789
03/07/2020 - 03/09/2019	Sat	0.000	0.000	0.002	0.000	0.000	0.000	0.010	0.950	0.032	0.133	0.000	0.000	0.007
03/08/2020 - 03/10/2109	Sun	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.064	0.002	0.033	0.000	0.000	0.000
03/09/2020 - 03/11/2019	Mon	0.020	0.016	0.777	0.026	0.052	0.233	0.498	0.069	0.152	0.484	0.055	0.033	0.775
03/10/2020 - 03/12/2019	Tue	0.007	0.011	0.292	0.019	0.063	0.153	0.168	0.341	0.400	0.998	0.002	0.002	0.203
03/11/2020 - 03/13/2019	Wed	0.001	0.002	0.140	0.004	0.015	0.113	0.058	0.943	0.155	0.814	0.001	0.002	0.142
03/12/2020 - 03/14/2019	Thu	0.000	0.000	0.002	0.000	0.001	0.003	0.004	0.314	0.024	0.389	0.000	0.000	0.003
03/13/2020 - 03/15/2019	Fri	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.046	0.003	0.207	0.000	0.000	0.000
03/14/2020 - 03/16/2019	Sat	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.123	0.000	0.000	0.000	0.000	0.000
03/15/2020 - 03/17/2019	Sun	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.523	0.000	0.000	0.000	0.000	0.000
03/16/2020 - 03/18/2019	Mon	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.047	0.000	0.000	0.000	0.000	0.000
03/17/2020 - 03/19/2019	Tue	0.000	0.000	0.000	0.000	0.000	0.000	0.439	0.017	0.000	0.000	0.000	0.003	0.000
03/18/2020 - 03/20/2019	Wed	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
03/19/2020 - 03/21/2019	Thu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
03/20/2020 - 03/22/2019	Fri	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
03/21/2020 - 03/23/2019	Sat	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
03/22/2020 - 03/24/2019	Sun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	**212**	**48**	**164**	**123**	**33**	**90**	**89**	**74**	**33**	**23**	**176**	**37**	**139**