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Investigating changes in trends of traffic crashes due to COVID-19 Pandemic in Florida's freeways

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INVESTIGATING CHANGES IN TRENDS OF TRAFFIC CRASHES DUE TO COVID-19 PANDEMIC IN FLORIDA'S FREEWAYS

By

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THESIS/DISSERTATION CERTIFICATE OF APPROVAL

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DEDICATION

This thesis is dedicated to:

The Almighty God.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The COVID-19 pandemic outbreak caused a shift in traffic patterns that have in turn influenced a change in traffic accident trends. Due to stay-at-home orders that were issued across the United States, transportation agencies reported low traffic demands on highways after the pandemic outbreak. Low traffic volumes are associated with relatively higher speeds that are linked to increased severity of crashes. Several states reported an increase in fatal crashes after the outbreak of the COVID-19 pandemic. This paper evaluates the traffic crash trends on three interstates in Florida (I-10, I-75, and I-95) and sheds light on what happened before, during, and after the implementation of lockdown orders. It also assesses traffic crashes for the period after the lockdown orders were lifted.

Crash data for the period from 2018 to 2021 was collected from Signal Four Analytics and the crash frequencies were analyzed. Traffic volume and traffic speed data were obtained from the Regional Integrated Transportation System (RITIS) for the four years and analyzed.

Results show an overall reduction of 20% in total crashes for the period from March to December 2020 compared to a similar period in 2019, and an increase of 4% in total crashes for the period from March to December 2021 compared to a similar period in 2020. Comparing monthly crash counts in 2020 versus those in 2019, it has been observed that the month of April 2020 experienced the most significant increase in the proportion of single-vehicle crashes (hence the greatest decrease in the proportion of multivehicle crashes), increase in the proportion of run-off crashes, and the decrease in the proportion of rear-end crashes. Annual average 15-minute traffic speeds were observed to be higher in 2020 compared to 2018, 2019, and 2021, especially during the AM and PM peak periods.

This study's findings can inform transportation agencies on how and where to allocate resources aimed at enhancing safety due to a dramatic and unexpected change in mobility trends similar to those caused by the COVID-19 lockdown.

Keywords: COVID-19; traffic crashes; freeways; traffic safety

CHAPTER 1: INTRODUCTION

Background

The Coronavirus disease that emerged in 2019 (COVID-19) has been the worst pandemic of the twenty-first century so far. Since this novel pandemic was found to spread rapidly all over the globe, various nonpharmaceutical interventions were considered to slow down the spread of the disease. These nonpharmaceutical interventions aimed to limit person-to-person interaction, which is the main cause of the spread of the virus. The countermeasures imposed to limit the spread of the coronavirus included social distancing, contact tracing, quarantine of exposed persons, school closures, business closures, closure of restaurants and bars, and stay-at-home orders. For example, in Florida, the first executive order was signed on March 01, 2020, directing the Florida Department of Health to issue a public health emergency following the COVID-19 outbreak. On March 09, 2020, the Governor declared a state of emergency for the entire state, and *stay-at-home* orders came into effect on April 01, 2020 (Secretary of State, 2020).

These measures, imposed to slow down the spread of the disease, dramatically changed peoples' lives, and led to a decrease in social and economic activities, hence reducing the number of trips that individuals needed to make (World Trade Organization, 2020). Due to the decrease in the number of person trips following the travel restrictions and stay-at-home order, there was a rapid drop in traffic demand. Traffic demand has a strong correlation with highway safety (Martin, 2002; Retallack & Ostendorf, 2020). The COVID-19-induced drop in traffic demand has eased congestion which is intuitively expected to result in a lower number of crashes. While the crash frequency might have decreased, some media channels (Calvert, 2020; Huetter, 2020) reported an increase in more severe crashes, partly due to drivers being able to drive at a relatively higher speed on emptier highways. These reports are based on field observations and anecdotal evidence.

Therefore, there is a need to conduct a systematic research study to examine the changes in crash trends due to COVID-19 and recommend effective countermeasures that would address such issues in case a similar crisis occurs in the future.

While the COVID-19 crisis was unfolding around the globe and in the United States, the state of Florida was not an exception. This consequently led to several responses from several governmental and business entities. Table 1 shows a list of some significant statewide chronological events that unfolded in Florida right after the COVID-19 outbreak in the state. In less than two weeks, the state moved from normalcy to closing most of the economic and social activities, causing a plunge in trips on Florida highways. The series of events shown in Table 1 is important as it can inform the timeline to demarcate the before-and-after data needed to analyze the change in traffic and crash patterns due to the outbreak of the COVID-19 pandemic in the state.

Table 1: Events Following the Outbreak of COVID-19 in Florida (Source: Office of the Governor of Florida)

Date-2020	**Event**
1-Mar	First COVID-19 cases (2 cases) in Florida confirmed
9-Mar	State of Emergency declared
13-Mar	Statewide closure of schools
15-Mar	Theme parks ordered to close
17-Mar	Bars and nightclubs were ordered to close for 30 days
1-Apr	Statewide 30 days *stay-at-home* order issued
4-May	Phase 1 of reopening begins
5-Jun	Phase 2 reopening begins, except for South Florida
25-Sep	Phase 3 reopening begins

Problem Statement

The rate of traffic crashes on a roadway should correlate directly to the amount of traffic on roadways. For this reason, high traffic conditions should be accompanied by high crash rates whereas low traffic conditions should be accompanied by low crash rates. During the COVID-19 pandemic, media and police reports have shown that the number of crashes generally decreased, but the rate of fatalities and injuries increased. The number of fatalities and injuries also went up in several places in the United States. To improve traffic safety on roadways during circumstances such as the COVID-19 pandemic period, it is important to understand the trend of traffic crashes in such conditions; this will help transportation authorities know what to expect in such situations and act accordingly to reduce traffic crashes and their impacts on road users and the environment.

Study Objectives

This study investigates the change in the pattern of traffic crashes on freeways during the outbreak of COVID-19. The study aims to present a comparative analysis of traffic crashes from March to December 2020 with the corresponding similar periods in the previous two years (i.e., 2018 and 2019), and the following year (2021). The study divides traffic crashes based on crash types, crash severity, single-vehicle crashes, and multivehicle crashes. Each category was analyzed to explore the impacts of the COVID-19 on different crash categories. The analysis also incorporates pertinent traffic data such as vehicle speeds and traffic volume to establish the association of crash patterns with prevailing traffic conditions.

Study Benefits

The results of this study will increase awareness of traffic behavior in low volume conditions. With this knowledge, transportation authorities will understand in detail how traffic behaved on freeways during the pandemic outbreak and how this behavior differs from that before and after the outbreak. Researchers can also use the findings of this research to develop prediction models that can be used to forecast the resulting traffic operations and safety patterns in the case similar events in the future occur. This readiness will furthermore help them act accordingly in response to any negative changes in traffic safety on freeways.

With further research, this work could be extended towards other facilities such as arterial roads, local streets, and intersections, thereby increasing the coverage of the knowledge on traffic safety to a broader part of the roadway transportation system.

Study Approach and Overview

This thesis contains 6 chapters. Chapter 1 introduces the problem to be studied and provides an overview of the research problem and the study's objectives. Chapter 2 reviews the literature relevant to the study. This includes a discussion on the COVID-19 pandemic, its progression, and its impacts on transportation in Florida. It also discusses methodologies for crash analysis that may be relevant to the study. Chapter 3 focuses on the methodology adopted to perform the study. This includes a description of the study area and study period, data sources, and description of the analyses done to attempt to answer the research problem. Chapter 4 presents the results of the preliminary analysis and discusses the results and their implications. Chapter 5 presents the results

of the detailed analysis and gives a discussion of these results. Chapter 6 concludes the thesis with important highlights on the findings of the study.

CHAPTER 2: LITERATURE REVIEW

COVID-19 Pandemic

Generally, pandemics are known globally as diseases that spread rapidly across the world shortly and they are also generally rare events that are complex to manage. For instance, about a hundred years ago, there were three worldwide outbreaks of the Influenza pandemic in the 20th century. These pandemics were identified by their origin as Spanish flu, Asian flu, and Hong Kong flu which occurred in 1918, 1957, and 1968, respectively (Kilbourne, 2006). Moreover, one of the recent pandemics before the COVID-19 pandemic was the 2009 H1N1 influenza virus known as swine flu which first appeared in Mexico and the United States (U.S.) in March and April 2009 (Al Hajjar & McIntosh, 2010). Apart from the worldwide recognized pandemic, there have been epidemics such as dengue fever, Ebola, and measles which spread to several places worldwide but are more limited than pandemics because are only concentrated in a few countries or regions of the world.

The novel Coronavirus disease (COVID-19) pandemic originated in Wuhan City, China, where it was first identified, in December 2019. The pandemic was found to spread rapidly through person-to-person contact. Since the outbreak of this pandemic at the end of the year 2019, many challenges have arisen ranging from the lack of knowledge, experience, and readiness during the early beginning of the outbreak. As the virus spread quickly from person to person, the World Health Organization (WHO) and the Centers for Disease and Control Prevention (CDC) initiated guidelines that were believed to help slow down the spread of the disease (World Health Organization WHO, 2020). Although the specific mechanism for the transmission of the virus was unknown during the early outbreak, almost all countries used social distancing and stay-at-home or shelter-in-place orders as the strategies to contain the spread of the disease.

In the U.S., the first confirmed case of coronavirus was reported on January 9, 2020, in Washington (Holshue et al., 2020), and in Florida, the first cases were reported on March 1, 2020 (Cutway, 2020). Since the first confirmed case, the U.S. government, the federal, state, and local authorities set the guidelines that varied over time and the pattern of spread of the virus. One of the early actions included international travel restrictions, closure of schools, business, voluntary *stay-at-home* requests, and restrictions on large public gatherings. As the disease continued to spread across the country, all the U.S. states imposed mandatory *stay-at-home* orders and lockdown quarantines. In Florida, the first executive order was declared on March 01, 2020, directing the Florida Department of Health to issue a public health emergency following the COVID-19 outbreak. A week later, the Governor declared a state of emergency for the entire state on March 09, 2020, followed by the closure of the schools, beaches, theme parks, restaurants, and bars. Finally, on April 01, 2020, the state issued the mandatory *stay-at-home* order (Secretary of State, 2020).

Observed Impacts of COVID on Road Transportation

These restrictions were imposed to limit and slow down the progression of the virus. However, these restrictions have dramatically changed people's lives and ways of living. The impacts of these restrictions were experienced in the transportation systems including a sudden change in traffic patterns and driving (Global Alliance of NGOs for Road Safety, 2020; Shilling & Waetjen, 2020a). Traffic changes that have been observed across different states include a decline in vehicle-miles traveled (VMT), a decline in traffic volume, an increase in travel speed, and an increase in the number of non-motorist road users. These changes in the traffic pattern have also resulted in a shift in traffic crashes.

In this unprecedented period, almost all countries experienced a drop in traffic volume on the roadways. For instance, Australia experienced a drop in the number of trips per household by 50% since March 30, 2020, following the lockdown measures imposed by the Australian government to combat the spread of the disease (Beck & Hensher, 2020). While there was a significant reduction in the number of household trips, the private trips remained fairly constant and public transportation dropped significantly. This drop in the use of public transport has occurred due to people's distrust of hygiene conditions of public transportation and thus choosing to use private cars instead (Beck & Hensher, 2020). In North Carolina, traffic volume decreased significantly by 40% following the shutdown (NCDOT, 2020a) whereas Florida recorded almost half (47.5%) drop in traffic volume following the restrictions to contain the spread of the coronavirus (Parr et al., 2020).

The significant reduction in traffic volumes affects other traffic flow parameters including travel speed. During the outbreak of the novel coronavirus, different states observed an increase in travel speed due to the drop in traffic volumes during the pandemic. California recorded an 87% increase in the number of citations for overspeeding (100 mph) from March 19 to April 19, 2020, compared to a similar corresponding period in 2019 (Caltrans, 2020). In New York City, commercial vehicles have been able to drive at average speeds 20% higher than last year (Huetter, 2020). The Massachusetts state officials reported that more than 271 citations and 111 warnings were issued for overspeeding in April 2020 (Wilson, 2020). In North Carolina, a slight increase in travel speed was observed during peak hours on weekdays (Carter, 2020a).

The changes that have been observed in the traffic operation parameters have also resulted in the shift in traffic crash patterns. Research shows that there has been a decrease in overall crash numbers but a relative increase in the severity of injuries and death (Yasin et al., 2021). As

expected, the number of traffic crashes indeed decreased due to lower traffic volumes on majority of the roadways in the U.S. In California, crashes on state highways were reduced by 50% per week except during inclement rain events (Shilling & Waetjen, 2020b). North Carolina observed a similar trend of about a 50% decrease in total crashes following the shutdown (Carter, 2020b). Other states in which drop in traffic crashes were observed include Louisiana (where there was insignificant drop in fatal crashes) and Ohio (where higher crash severities were observed) (Barnes et al., 2022; Stiles et al., 2021). Although the total number of crashes seemed to be on a decreasing trend, the crash rate was on an increasing trend in many cities. Reckless driving, which could potentially be due to reduced traffic congestion as a result of shutdowns, may have increased the risk of crashes. In Virginia, speed-related fatalities made up approximately 48% of total traffic fatalities during this pandemic period, which is a higher percentage than the 5-year average of 41% (Lockwood et al., 2020). The Massachusetts State Department of Transportation reported a 100% increase in the fatality rate in April 2020 compared to April 2019 despite a 50% drop in traffic volume on major highways due to the COVID-19 pandemic. The state officials reported speeding as one of the causes of the higher fatality rate (Wilson, 2020).

The COVID-19 pandemic has raised concerns about traffic safety similar to other emergencies such as hurricanes (Collins et al., 2016; Sullivent et al., 2006; Wolshon et al., 2005). The ongoing novel COVID-19 pandemic has brought unprecedented changes in traffic patterns and travel behavior. However, due to its novelty, its impact on traffic safety is not clear. Therefore, this study intends to investigate the impacts of COVID-19 on traffic crashes in Florida's interstates. The study was based on the three major Florida interstates (I-10, I-75, and I-95). Total crashes, total crash frequency per 100M DVMT, and total crash frequency by the manner of collision during this pandemic were investigated and compared with the same period in 2018 and 2019. The results

from the analysis will assist agencies in understanding the early impacts of the outbreak on our transportation network in terms of safety and may be useful in operational and strategic planning for future pandemics.

Measuring Traffic Crashes

Several metrics have been used to quantify the number of crashes that occur in a given roadway facility. The Highway Safety Manual (HSM) mentions some terminologies describing the "amount" of crashes. These include crash frequency, crash severity, and crash rate.

Crash frequency is defined as the number of crashes occurring in a highway facility divided by the period in years. Crash frequency gives an overall view of the safety performance of a roadway facility. It is also easy to obtain and understand. However, it does not consider the number of vehicles using the roadway or the total distance driven by vehicles. Facilities that are used by more vehicles are expected to have more crashes than those with fewer vehicles and therefore, this metric will always be more biased towards high volume roadways.

Traffic crash rate has been defined as the average crash frequency in a period divided by the exposure in the given roadway facility. This gives the probability of a road user being involved in an accident. One weakness of using crash rate is that it involves the assumption that the number of crashes observed in a given highway facility varies linearly with the amount of exposure. However, this has been shown by several research works to not be the case (Council & Stewart, 2000).

Crash severity measures the level of injury or property damage. The ANSI Manual on Classification of Motor Vehicle Traffic Crashes defines the KABCO scale for crash severity (American National Standards Institute, 2017), which has been elaborated in Table 2 below.

Table 2: Crash severity scale as defined by the American National Standards Institute

Level	Description
K	Fatal injury: an injury that results in death;
A	Incapacitating injury: any injury, other than a fatal injury, that prevents the injured person from walking, driving, or normally continuing the activities the person could perform before the injury occurred;
B	Non-incapacitating evident injury: any injury, other than a fatal injury or an incapacitating injury, that is evident to observers at the scene of the crash in which the injury occurred;
C	Possible injury: any injury reported or claimed that is not a fatal injury, incapacitating injury, or non-incapacitating evident injury and includes a claim of injuries not evident;
O	No Injury/Property Damage Only (PDO).

Also, some state departments of transportation have guidelines on how to report vehicle damage. For example, the Texas Department of Transportation (TxDOT) developed a Vehicle Damage Guide for Traffic Crash Investigators to assist law enforcement agencies in assessing damage to motor vehicles involved in traffic crashes (TxDOT, 2015). A law enforcement officer who has observed a vehicle involved in a crash may accurately document a Vehicle Damage Rating which is a 6 alphanumeric entry describing the direction of crash force onto the vehicle, the area on the vehicle hit, and the severity of the damage received.

The Florida Department of Highway Safety and Motor Vehicles (FLHSMV) uses a scale similar to the KABCO but with numerical codes from 1 to 6 to represent injuries. These codes are elaborated further in Table 3 below.

Table 3: Injury severity scale applied by FLHSMV (source: Florida's Uniform Traffic Crash Report Manual, 2019)

Level	Description
1	None
2	Possible Injury
3	Non-Incapacitating
4	Incapacitating
5	Fatal (within 30 days)
6	Non-traffic fatality

Traffic behavior on low volume roads

Speed

The Highway Capacity Manual describes the relationship between average passenger car speed and the flow rate of the roadway facility. This is described in Figure 1 below. What can be seen is that as traffic volumes drop for a given roadway facility, then the average speed of vehicles rises to a peak value, the free-flow speed.

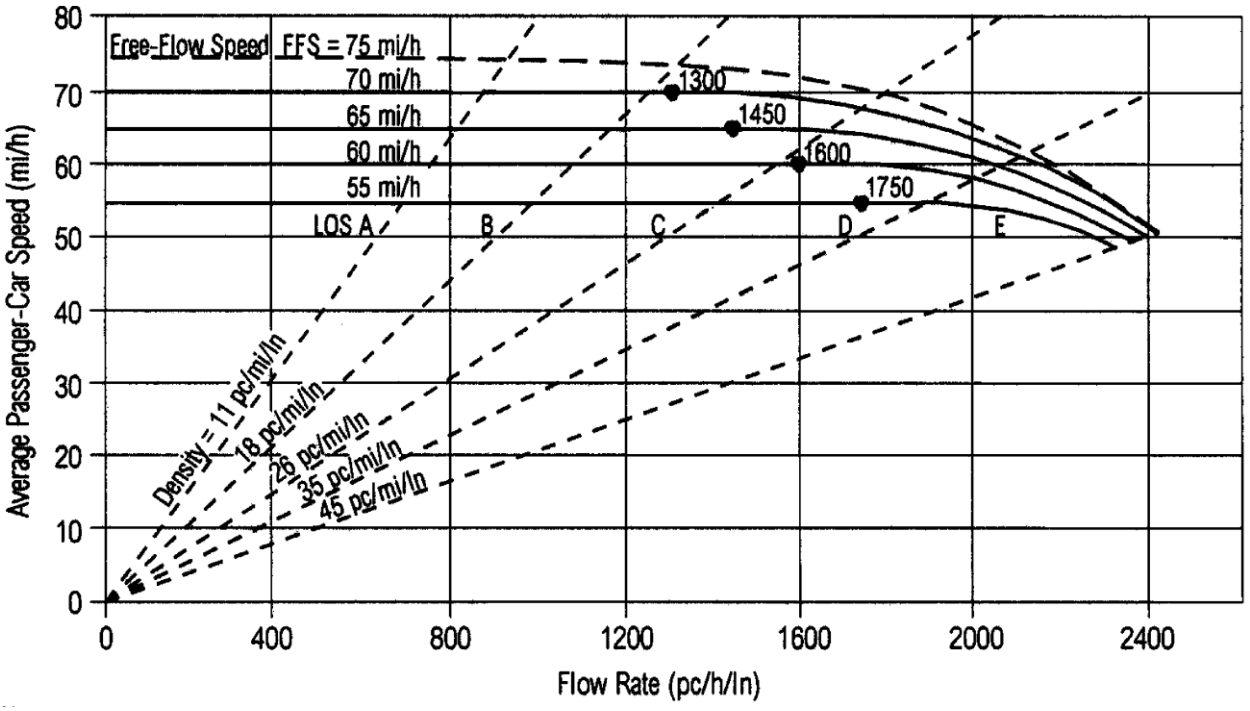


Figure 1: Speed-Flow Curves and Level-of-Service for Basic Freeway Segments (Source: Highway Capacity Manual, 2010)

Overspeeding has also been observed in several states as drivers used to driving on congested roads feel more liberated. California recorded an 87% increase in the number of citations for overspeeding (100 mph) from March 19 to April 19, 2020, compared to a similar corresponding period in 2019 (Caltrans, 2020). The Massachusetts state officials reported that more than 271 citations and 111 warnings were issued for overspeeding in April 2020 (Wilson, 2020).

Accidents

There is a plethora of research works done to evaluate the impact of high traffic volumes on crash frequencies and crash rates. It has been shown that traffic volume is the most used predictor for crash rates (number of crashes per length of roadway) in a roadway facility and an increase in

traffic volume leads to an increase in crash rate (Dorina Cadar et al., 2017). However, this relationship between traffic volume and the crash rate is not strictly linear but rather exponential (Glavić et al., 2016).

CHAPTER 3: METHODOLOGY

Study Location

The study area includes three of Florida's major interstates, i.e., I-10, I-75, and I-95. Interstate 10 (I-10) covers 362 miles in Florida, from the Florida-Alabama state line at the Perdido River (western terminus) to the Brooklyn neighborhood in Jacksonville's urban center (eastern terminus). Interstate 95 (I-95) covers 382 miles from the partial interchange with US-1 south of downtown Miami (southern terminus) to the Florida-Georgia state line at the St. Marys River (northern terminus) where it ends. Interstate 75 (I-75) covers 471 miles in Florida from south of downtown Miami to the Florida-Georgia state line.

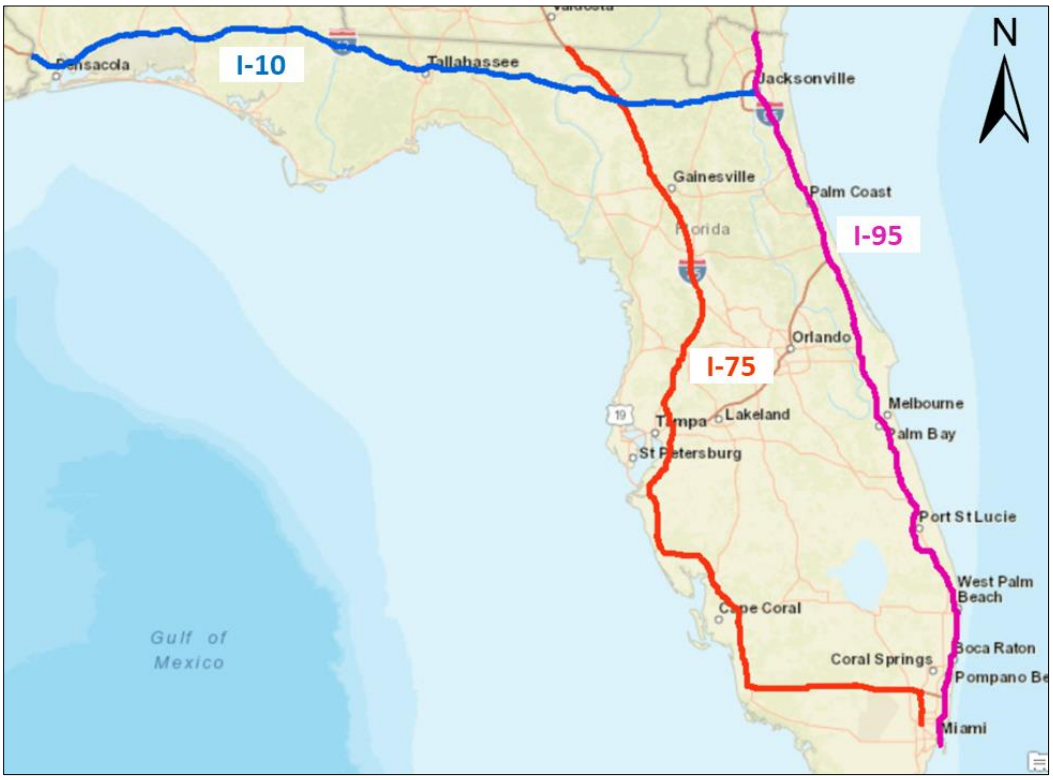


Figure 2: Study Area along Florida's Freeways (I-10, I-75, and I-95).

Data

The HSM proposes the use of crash data, facility data, and traffic volume data for meaningful and sound analyses to be made on crash analysis. Crash data should contain information on crash location, date and time, crash severity, collision type, and information on the roadway, vehicles, and people involved.

Facility data refers to the physical characteristics of the crash site. This is provided by the roadway or intersection inventory data and it has information on the lane configuration, roadway classification, and shoulder width. For intersections, this should provide information on the road names, area type, traffic control, and lane configurations.

Traffic volume data normally refers to the annual average daily traffic (AADT). Additional data may be helpful. For example, intersection total entering vehicles (TEV) and vehicle-miles traveled (VMT) give a measure of segment length and traffic volume.

Signal Four Analytics

Signal Four Analytics is a web-based geospatial crash analytical tool developed and hosted by the GeoPlan Center at the University of Florida that provides crash data with numerous crash attributes. It includes crash data for the most recent 10-year period provided by the Department of Highway Safety and Motor Vehicles (DHSMV) and citations data since 2011 that is provided by the Florida Highway Patrol (FHP). This database also includes crashes reported through long and short forms, as well as crashes that occurred in private and parking lots with their respective geographical coordinates. The analysis was based only on the crashes that occurred along the study corridors.

Regional Integrated Transportation Information System (RITIS)

RITIS is an automated data sharing, dissemination, and archiving system that includes real-time data feeds and data analysis tools such as a probe, detector, and transit data analytics. RITIS provides traffic flow information such as speed, volume, and occupancy. There are 3,751 detectors along the selected freeway corridors. The average spacing between these detectors is approximately 0.5 miles. In this study, 15-min aggregated traffic speed and 60-min aggregated traffic volume were collected for the study period.

Vehicle-Miles Traveled (VMT) Estimations

Vehicle miles traveled (VMT) is a measure used in transportation planning for various purposes including allocation of the resources, estimation of the vehicle emissions, energy consumption, adjusting travel demand forecast, measuring traffic fatalities, etc. VMT is the function of the roadway centerline length and traffic count data over a given period. This metric is given as the product of the amount of daily traffic on a roadway segment and the length of the segment. The total VMT for the geographical area of concern can be obtained by summing all the segments' VMT (Williams et al., 2016). In this study, the daily vehicle mile traveled (DVMT) was estimated using the traffic volume extracted from the RITIS detectors. The DVMT per segment and the total DVMT for the entire interstate section were determined through Equations 1 and 2.

$$DVMT\ per\ segment = Traffic\ Volume\ \times Segment\ length \quad (1)$$

$$Total\ DVMT = \sum DVMT\ per\ Segment \quad (2)$$

Preliminary Analysis

To determine the impact of the COVID lockdown on traffic crashes, this study employs a comparative analysis of crash data after the lockdown began and makes comparisons with the crash data from the periods before and after the lockdown. A study period from 2018 to 2021 is considered for the study. The years 2018 and 2019 represent the pre-lockdown period, the year 2020 represents the lockdown period, and the year 2021 represents the post-lockdown period.

A preliminary analysis was done to observe how the trend in crashes within 2 months of the emergence of the pandemic, from March 1 to April 30, 2020, changed compared to similar periods in 2018 and 2019, and what happened in a similar period in 2021, when the lockdown orders were no longer in effect. The two months period was split into 3 phases, according to the level of movement restrictions imposed by the State Government. Phase 1 covers the period from the first confirmed case, the first executive order issued to direct the department of the public health issuing the public health emergency following the outbreak of the coronavirus and before the closing of the schools in the entire state. Phase 2 started on March 15, 2020, when all schools were closed, followed by the closure of parks (March 17, 2020), restaurants, and bars (March 20, 2020). Phase 3 covers the 30-day *stay-at-home* order which was declared on April 1, 2020.

The analysis makes comparisons of the raw number of crashes per day observed in 2020 and compares them to those that occurred in similar periods in 2018, 2019, and 2021. Furthermore, the analysis divides crash types based on the manner of collisions, severity levels, and the number of vehicles involved in a crash (single-vehicle crashes vs multivehicle crashes) and examines pattern changes in each level. Due to the low number of fatal and injury crashes being small, crash severity was grouped into two categories: fatal plus injury (FI) crashes and property damage only (PDO) crashes Since the proportion of angle crashes, rollover crashes, pedestrian crashes, and head-on

crashes are very few on freeways, this study explores the impact of the COVID-19 pandemic only on the rear-end crashes, run-off-road crashes, and sideswipe crashes.

The analysis also incorporates pertinent traffic data such as vehicle speeds and traffic volume to establish the association of crash patterns with prevailing traffic conditions.

Extended Analysis

The two-month analysis done in the preliminary analysis was extended to include the remaining 10 months. Crash numbers were aggregated monthly instead of daily to eliminate the effects of daily fluctuations in traffic patterns.

Three roadway sections were selected to observe traffic volume and speed patterns, one on I-10 (4.83 miles), one on I-75 (5.6 miles), and one on I-95 (4.4 miles). The selection of these sections required them to have homogeneous roadway geometric features throughout, and have high traffic volumes, so that changes in traffic speed may be easily noted, especially in peak hour periods. Figure 3 shows the locations of these roadway sections.

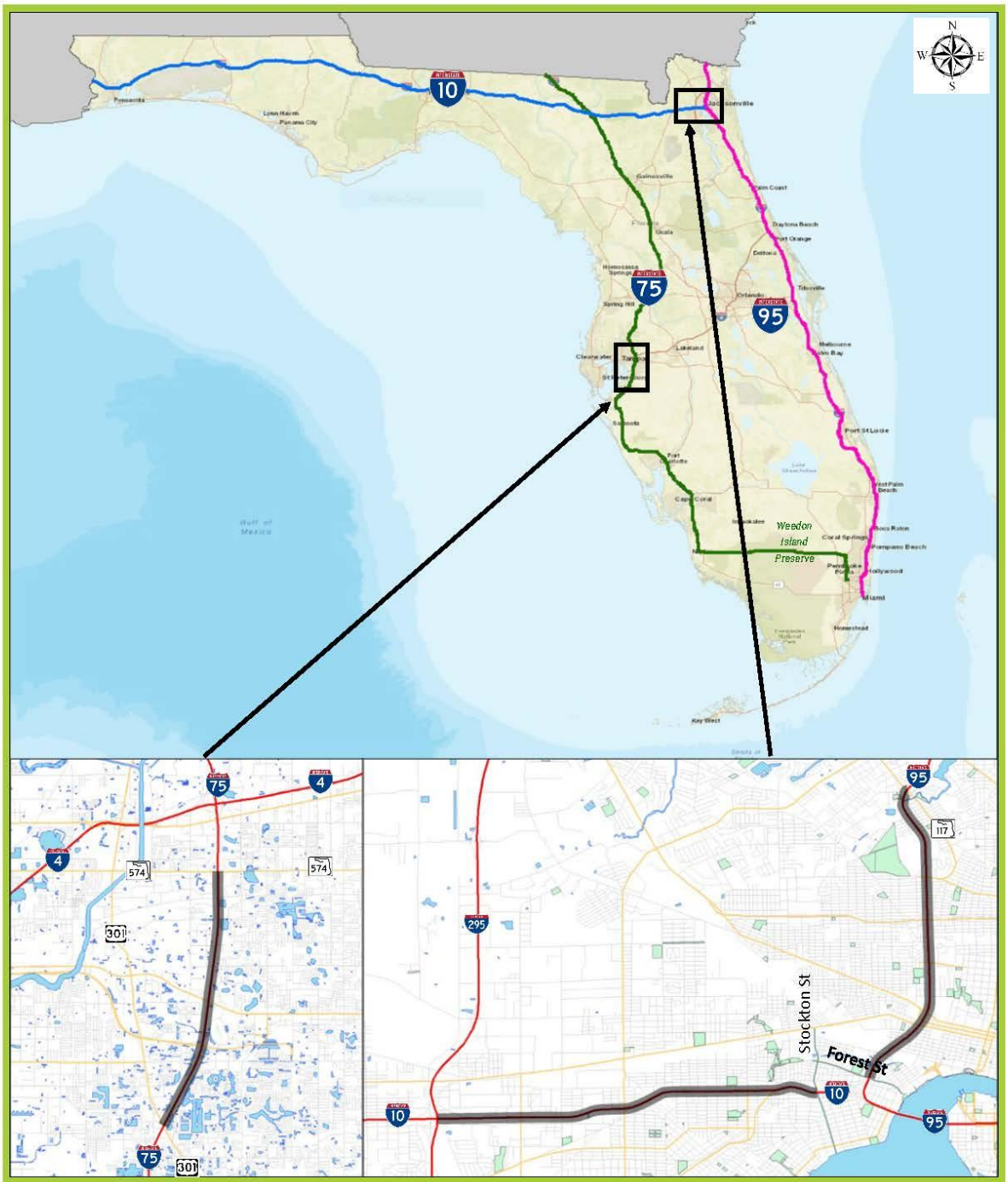


Figure 3: Road sections considered for traffic volume and traffic speed analysis

CHAPTER 4: PRELIMINARY ANALYSIS AND RESULTS

Crash Frequencies for Different Closure Phases

In Florida, the first confirmed case of coronavirus was reported on March 1, 2020. Following the first confirmed case, the state has been issuing several guidelines and orders to combat the rapid spread of the disease. For example, the first executive order was signed on March 01, 2020, directing the Florida Department of Health to issue a public health emergency following the COVID-19 outbreak. On March 09, 2020, the Governor declared a state of emergency for the entire state, and the *stay-at-home* order was declared on April 01, 2020 (Secretary of State, 2020). The transition in state legislation from the pre-pandemic to the total lockdown era was essentially a smooth transition that took about a month to complete. As a result, people's livelihoods and behaviors, including driving behaviors, would change gradually in a pattern that would mimic that transition, albeit at a slower pace.

Figure 3 presents the total crash frequency trends along the Florida interstates (I-10, I-75, and I-95) at different closing phases from the first day when the first confirmed case was reported on March 1 to April 30, 2020. Phase 1 covers the period from the first confirmed case, the first executive order issued to direct the department of the public health issuing the public health emergency following the outbreak of the coronavirus and before the closing of the schools in the entire state. Phase 2 started on March 15, 2020, when all schools were closed, followed by the closure of parks (March 17, 2020), restaurants, and bars (March 20, 2020). Phase 3 covers the 30-day *stay-at-home* order which was declared on April 1, 2020.

As presented in Figure 3, there was a decreasing trend in the total crash frequency in the three analyzed interstates, from phase 1 to phase 3. A drop in crash numbers can be observed from phase 1 to phase 2, during which (that is, in phase 2) restrictions to limiting person-to-person interaction

were beginning to being imposed.This was followed by a slight increase in crash frequency from phase 2 to phase 3. The decrease in total traffic crashes was expected due to a reduction in the traffic volume on Florida's interstates. This observation is consistent with several states including California and Virginia (Lockwood et al., 2020; Shilling & Waetjen, 2020b).

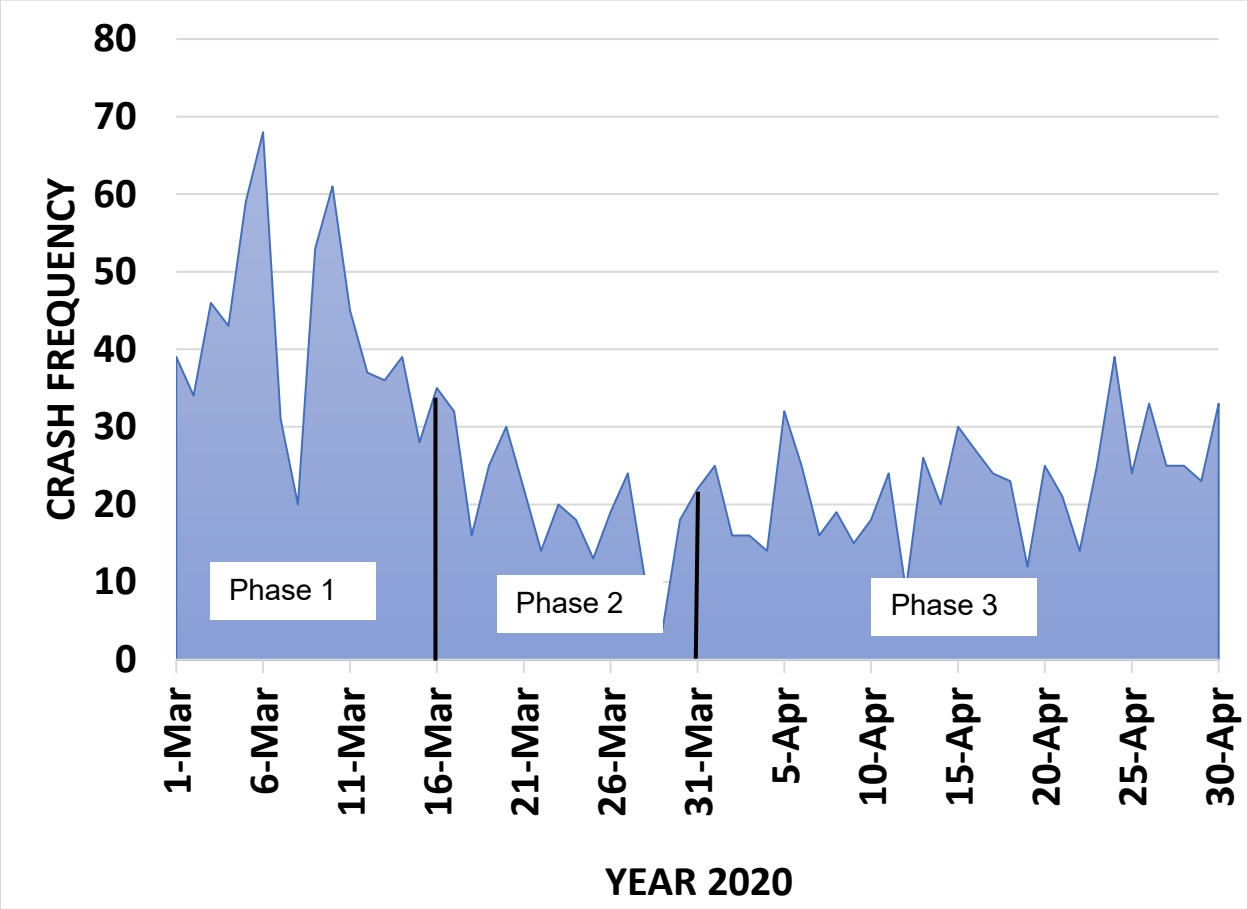


Figure 3: Daily Total Crash Frequency Trends at the beginning of the COVID-19 Outbreak in Florida's Freeways (I-10, I-75, and I-95)

Impacts on Total Crash Frequency

Table 4 below presents the comparison of total crash frequency and crash severity for March and April 2018-2020. Total crash frequency in the first two weeks of March 2020 (phase 1) increased by 22.3% compared to similar weeks in 2018 and 2019. After the complete closure of businesses and schools effective on March 15 up to March 31, 2020 (phase 2), the total crash frequency decreased by 45.3% compared to a similar period in 2018 and 2019. In April 2020 (phase 3), a 30% reduction in the total crash frequency was observed in the interstate analyzed amid the pandemic outbreak. In general, there was a reduction in the total crash frequency in 2020 compared with a similar corresponding period in the previous years 2018 and 2019. This reduction was expected due to a reduction in the traffic volume on Florida's highways following the COVID-19 pandemic outbreak.

Table 4: Descriptive Statistics for the Crashes Occurred in Freeways (I-10, I-75, and I-95)

Period	Year	FI Crashes		PDO Crashes		Total Crashes	% Change (Total Crashes)		
		Count	Proportion	Count	Proportion		2018-19	2019-20	2020-21
March 1-15	2018	145	27.6%	380	72.4%	525	-5.9%	22.3%	11.3%
	2019	125	25.3%	369	74.7%	494			
	2020	144	23.8%	460	76.2%	604			
	2021	201	30.0%	471	70.0%	672			
March 16-31	2018	164	29.1%	400	70.9%	564	1.6%	-45.5%	70.1%
	2019	156	27.2%	417	72.8%	573			
	2020	96	30.8%	216	69.2%	312			
	2021	133	25.0%	398	75.0%	531			
April 1-30	2018	293	27.4%	777	72.6%	1070	-11.6%	-30.1%	102.5%
	2019	257	27.2%	689	72.8%	946			
	2020	169	25.6%	492	74.4%	661			
	2021	398	29.8%	940	70.3%	1339			

Impacts on Crash Severity

Crash severity was categorized into two categories: fatal plus injury (FI) crashes and property damage only (PDO) crashes. As presented in Table 4 above, FI crashes and PDO crashes reduced in 2020 compared to similar corresponding periods in 2018 and 2019, just as expected. The last two weeks of March 2020 experienced few FI crashes and a larger proportion of FI crashes compared with the similar corresponding period in 2018 and 2019. The FI crashes and proportion of FI decreased from 257 (27.2%) in April 2019 to 169 (25.6%) in April 2020 following the outbreak of the COVID-19 pandemic. The decrease in FI crashes was expected as the overall

crashes went down following the *stay-at-home* order to combat the spread of the disease. However, the decrease in the proportion of the FI crashes was not expected as most of the crashes are single-vehicle crashes which tend to be more severe. Also, the decrease in the proportion of FI crashes contradicts the observation from different states including California and Virginia (Lockwood et al., 2020; Shilling & Waetjen, 2020b) which recorded an increase in the proportion of FI crashes particularly in April 2020. It can also be seen that the trend in proportion of FI crashes in 2021 more or less resumed to that in 2018 and 2019.

Impacts on Crashes by Number of Vehicles

The outbreak of the novel COVID-19 pandemic has shown a significant increase in single-vehicle crashes i.e., crashes that involve only one vehicle including run-off-road crashes, rollover crashes, collisions with fallen rocks or debris on the road, and collisions with animals. Table 5 presents the comparison of the single-vehicle crashes and multivehicle crashes during the analysis period. As presented in Table 3, after the complete closure of businesses and schools effective on March 15, 2020, single-vehicle crashes increased to 29.8% compared to a similar corresponding period in 2018 (18.4%) and 2019 (20.9%). Single-vehicle crashes increased from 18.6% in April 2019 to 44% in April 2020. The proportion of single-vehicle crashes in similar periods in 2021 was lower than that in 2020 but did not differ significantly from the values in 2018 and 2019.

The increase in the number of single-vehicle crashes may be attributed to excessive speeds as most drivers tend to increase speeds in the absence of congestion (Lockwood et al., 2020; Shilling, 2020). It should be noted that most single-vehicle crashes involve run-off-road crashes and rollover crashes. Since the percentage of the run-off-road crashes increased significantly in April 2020 following the outbreak of the COVID-19 pandemic and the *stay-at-home* order, the increase in the

single-vehicle crashes was expected. It should be noted that an increase in single-vehicle crashes was also observed in North Carolina (NCDOT, 2020b).

Table 5: Single Vehicle Crashes and Multivehicle Crashes

Period	Year	Single Vehicle Crashes		Multivehicle Crashes		Total
		Count	Proportion	Count	Proportion	
March 1-15	2018	87	16.6%	438	83.4%	525
	2019	99	20.0%	395	80.0%	494
	2020	112	18.5%	492	81.5%	604
	2021	158	23.5%	514	76.5%	672
March 16-31	2018	104	18.4%	460	81.6%	564
	2019	120	20.9%	453	79.1%	573
	2020	93	29.8%	219	70.2%	312
	2021	107	20.2%	424	79.8%	531
April 1-30	2018	240	22.4%	830	77.6%	1070
	2019	178	18.8%	768	81.2%	946
	2020	291	44.0%	370	56.0%	661
	2021	338	25.3%	1000	74.7%	1339

Impacts on Crashes by Manner of Collision

The novel COVID-19 pandemic has also brought significant changes in the manner of collision. This study also investigates different crash types based on the manner of collisions. Since the proportion of angle crashes, rollover crashes, pedestrian crashes, and head-on crashes are very few, this study explores the impact of the COVID-19 pandemic only on the rear-end crashes, run-off-road crashes, and sideswipe crashes.

Table 6 below presents different crash types by the manner of collision. Overall, the proportion of rear-end crashes decreased following the outbreak of the COVID-19 pandemic. More specifically,

the proportion of rear-end crashes decreased to 33% in the last two weeks of March 2020 compared to the last two weeks of March 2018 (49.3%) and 2019 (51.5%). Also, in April 2020, the proportion of rear-end crashes fell to 27%, nearly half the proportion of rear-end crashes observed in previous years of 2018 and 2019. The decrease in the proportion of the rear-end crashes during the pandemic and the *stay-at-home* order may be attributed to the reduction in traffic congestion and stop-and-go movement which is the main cause of rear-end crashes.

The proportion of run-off-road crashes increased from 10.9% in April 2019 to 32.4% in April 2020 during the *stay-at-home* order amid the outbreak of the COVID-19 pandemic; it then dropped back to 16.1% in April 2021. This may be attributed to excessive speeds as most drivers tend to increase speeds in the absence of congestion (Lockwood et al., 2020; Shilling, 2020). The analysis of the sideswipe, on the other hand, showed varying trends, and the statistics indicated that there were no defined trends that show either sideswipe crashes are increasing or decreasing following the *stay-at-home* order amid the outbreak of the novel coronavirus disease.

Table 6: Crash Types by Manner of Collision

Period	Year	Rear-end Crashes		Run-off-road Crashes		Sideswipe Crashes	
		Count	Percentage	Count	Percentage	Count	Percentage
March 1-15	2018	251	47.8%	45	8.6%	74	14.1%
	2019	250	50.6%	65	13.2%	114	23.1%
	2020	311	51.5%	60	9.9%	147	24.3%
	2021	273	40.6%	115	17.1%	164	24.4%
March 16-31	2018	278	49.3%	66	11.7%	66	11.7%
	2019	295	51.5%	78	13.6%	116	20.2%
	2020	103	33.0%	57	18.3%	78	25.0%
	2021	277	52.2%	51	9.6%	95	18.0%
April 1-30	2018	438	40.9%	145	13.6%	163	15.2%
	2019	479	50.6%	103	10.9%	216	22.8%
	2020	183	27.7%	214	32.4%	105	15.9%
	2021	566	42.3%	216	16.1%	305	22.8%

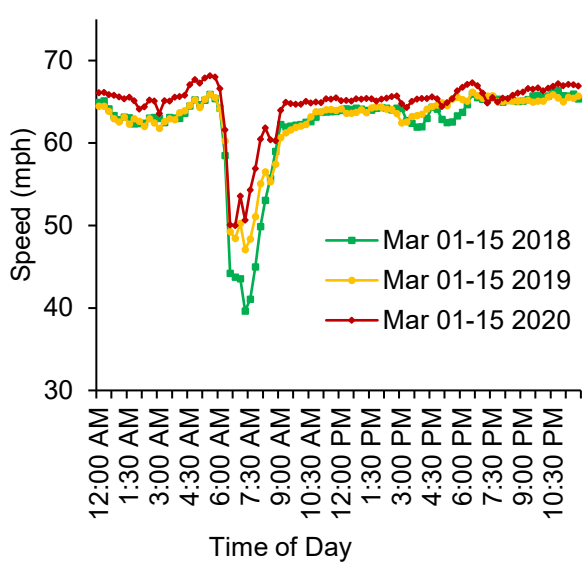
Impacts of COVID-19 on Vehicle Speed

The exploratory analysis of the speed data along the study corridors indicated that, overall, the average speeds during the pandemic (March and April 2020) are higher than the average speeds during the same period in the previous years i.e., 2018 and 2019. Figures 4 (a), (b), and (c) show the average weekday 15-min speed in one of the roadway sections on I-10. The average speeds in the first half of March across the three years i.e., 2018-2020 had peak hours as presented in Figure 4 (a). This indicates that there was no noticeable change in the travel speed during the first half of March 2020, because it was the early days of the imposed restrictions and the traffic did not change

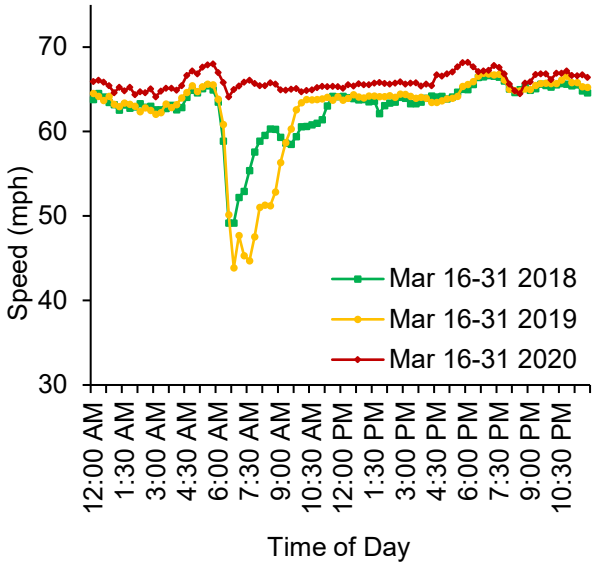
significantly. While the average speeds across the three years for the first half of March are below the speed limit in this section (55 mph), the average speeds during the year 2020 are significantly above the speed limit for the second half of March and the month of April.

While there was a noticeable change in the travel speed for the first half of March across the three years, the second half of March and the month of April 2020 had a significantly different pattern of travel speed compared to the corresponding period in the previous years 2018 and 2019 as presented in Figures 4 (b) and 3 (c). While the second half of March and April for 2018 and 2019 had peak hours, the same corresponding period in 2020 had no peak hours. As presented in Figures 4 (b) and 4 (c), the average speed for the second half of March and the month of April 2018 and 2019 was below the average speed during the peak hours while for the corresponding period in the pandemic era, the average speed was constantly the same across the day and higher than the speed limit.

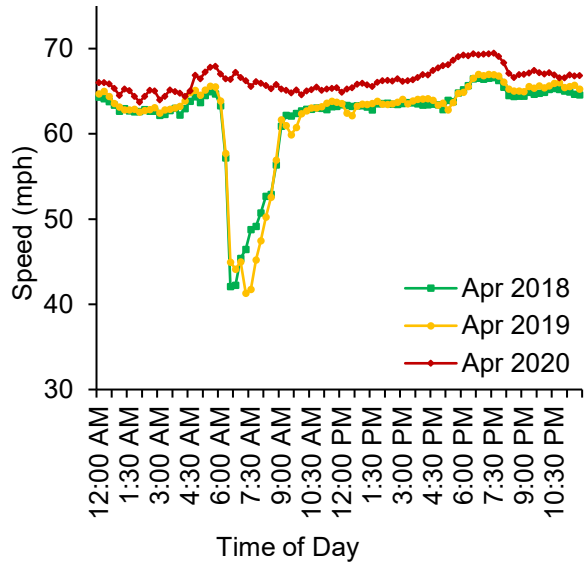
These trends were similar across the other two interstates, i.e., I-95 and I-75. For example, in Figure 4(d), it can be inferred that the average speeds in 2020 are constantly above the average speeds compared to the average speed in 2018 which are below the speed limit. While the average speed limit in this section is about 65 mph, the average speeds for 2020 are above the speed limit most of the time in the day. This observation may concur with the findings in this study where the proportion of single-vehicle crashes was observed to be abnormally high; that is, the cause for the higher proportion of single-vehicle crashes may be attributed to a significant increase in traffic speed.



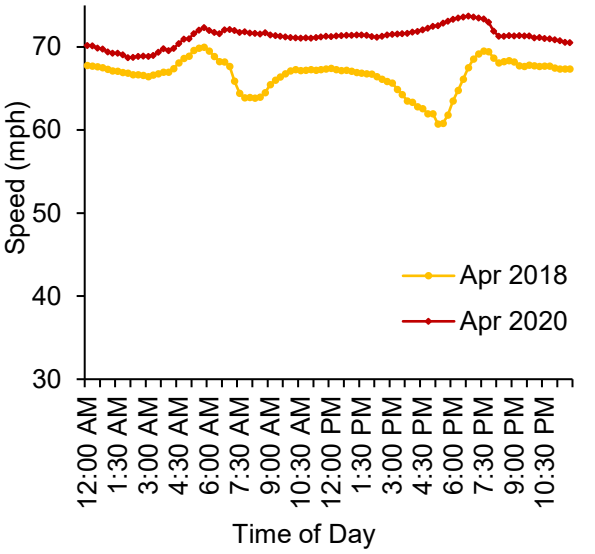
(a) March 01-15 (I-10)



(b) March 16-31 (I-10)



(c) April 01-30 (I-10)



(d) April 01-30 (I-95)

Figure 5: 15-minutes Average Weekday Speed.

Impacts of DVMT on Crashes

Figures 5 through 7 present the total crash frequency trends and the total crash frequency per 100M DVMT for March and April 2018-2020 for two of Florida's interstates (I-10 and I-75). As can be observed from Figures 6 and 7, the total crash frequency trends and the total crash frequency per 100M DVMT are almost the same for 2018 and 2019. This indicates that the regular period and the lockdown period can have similar traffic crash patterns. Figure 8 shows a different pattern of the total crash frequency and the total crash frequency per 100M DVMT compared to previous years 2018 and 2019. The total crash frequency decreased since March 15, 2020, after the complete closure of schools, restaurants, bars, and all other non-essential activities. Although the crash frequency decreased due to the decrease in traffic volume, the crash rate (i.e., crashes per 100M DVMT) increased since March 15, 2020, as presented by the orange-colored line in Figure 8.

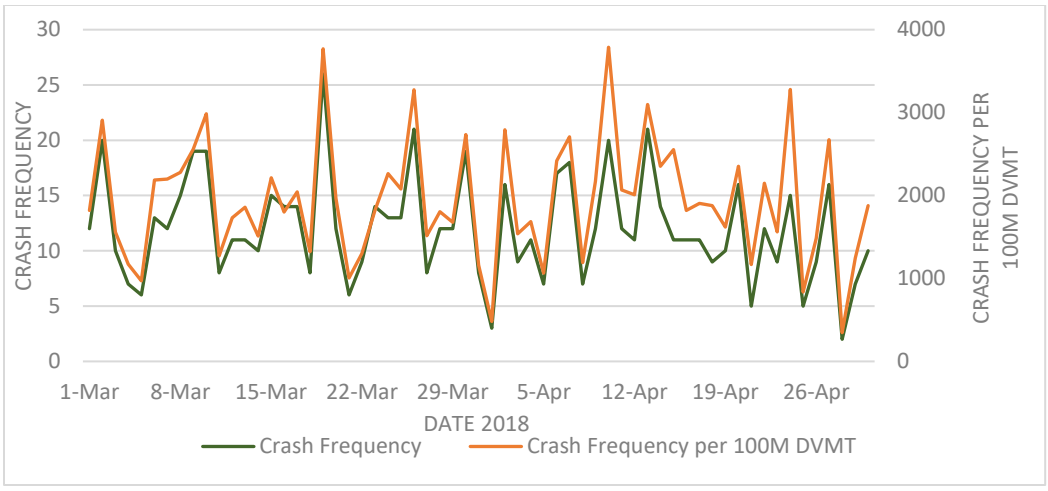


Figure 5: Daily Crash Frequency and Crash Frequency per 100M DVMT for 2018

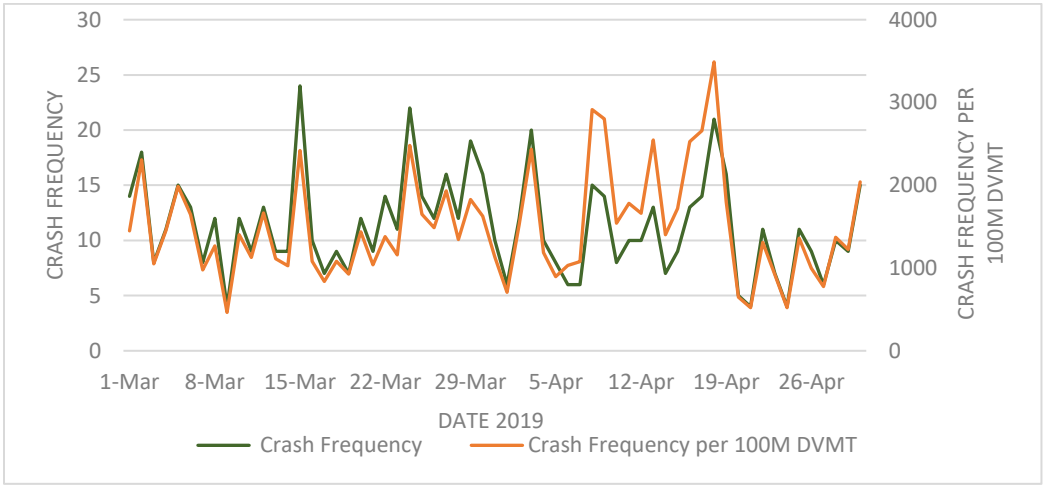


Figure 6: Daily Crash Frequency and Crash Frequency per 100M DVMT for 2019

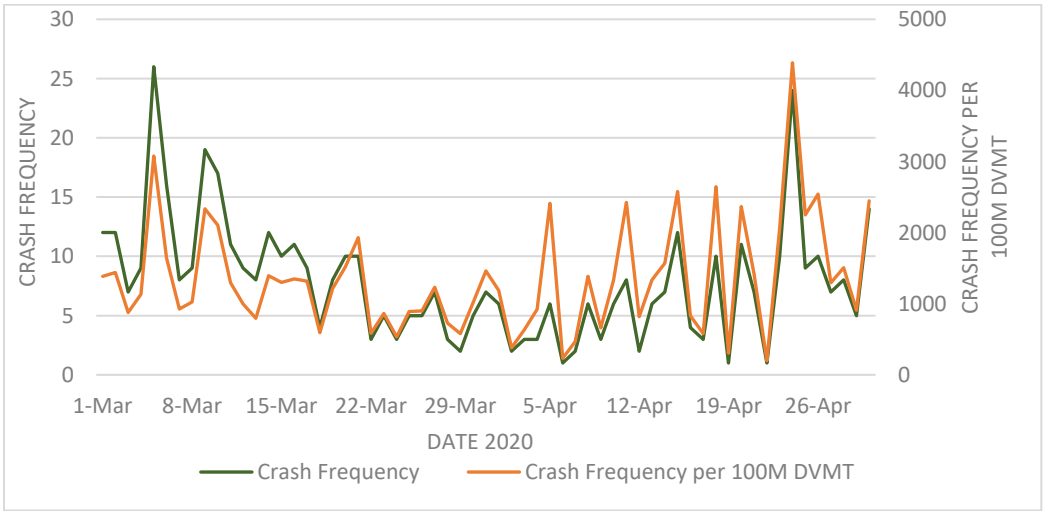


Figure 7: Daily Crash Frequency and Crash Frequency per 100M DVMT for 2020

CHAPTER 5: ANALYSIS & RESULTS

Impacts on Total Crash Frequency

Figures 8 through 10 show the crash frequencies for I-10, I-75, and I-95 from 2018 to 2021, on monthly basis. The total number of crashes dropped in 2020 compared to the other three years, especially in March and April. During these two months, traffic was lowest and therefore, the number of crashes dropped with it. It then started increasing until around July, a point from when it matched values of corresponding months in 2018 and 2019. At this point, most of the state had entered Phase 2 of reopening and therefore drivers were getting back on the road.

On I-10, the monthly crash frequency by month rose from January to May, dropped to October, and then rose to December, whereas in 2019, it trended upward from January to December. However, in 2020, the number of crashes rose from January to February and then dropped in March and in April, where only 93 crashes were recorded - the lowest number of crashes for any month from 2018 to 2021. Crash frequency then began rising steadily until October and then dropped slightly in November and December. For five consecutive months, from March to July, the number of crashes recorded on I-10 was lowest in 2020 than in any other similar period in 2018, 2019, and 2021. For the first half of 2021, the number of crashes rose back to values similar to those in 2019 but then started going down in the second half to the lowest value of 115 in December.

On I-75, the number of crashes started high at 624 in January (the highest in the four years), dropped to 445 in February, and then fluctuated between 370 and 540 for the rest of the year. In 2019, crash frequency started with a low count of 365 and trended upward for the rest of the year, following closely the 2018 trend. In 2020, the number of crashes began at 408 in January and 417 in February but then dropped in March (329 crashes) and in April (221 crashes). It then began rising in May and kept on up to 459 in November and then dropped to 390 in December. Like on

I-10, the crash frequency was lowest from March to August in 2020 than in similar periods in 2018 and 2021. Unlike I-10 though, crash frequency in 2021 trended upward from 324 in January to 462 in December.

The trend of crash frequency on I-95 is similar for most of the study period. January 2018 had the highest crash count for the study period (2,131 crashes). It then dropped to 1,712 in February and fluctuated between 1,500 and 1,900 crashes for the rest of the year. In 2019, it started at 1,537 crashes in January, and fluctuated between 1,400 and 1,900, trending upwards for the rest of the year to 1,895 crashes in December. The first two months of 2020 had 1,653 and 1,617 crashes respectively, but then there was a drop to 1,116 crashes in March and 717 crashes in April. Crash frequency then began rising in May and kept on up to 1,740 crashes in October and then dropped to 1,406 in November and 1,293 in December. For the first half of 2021, the number of crashes rose back to values similar to those in 2019 but then started going down in the second half to a count of 1,263 crashes in December.

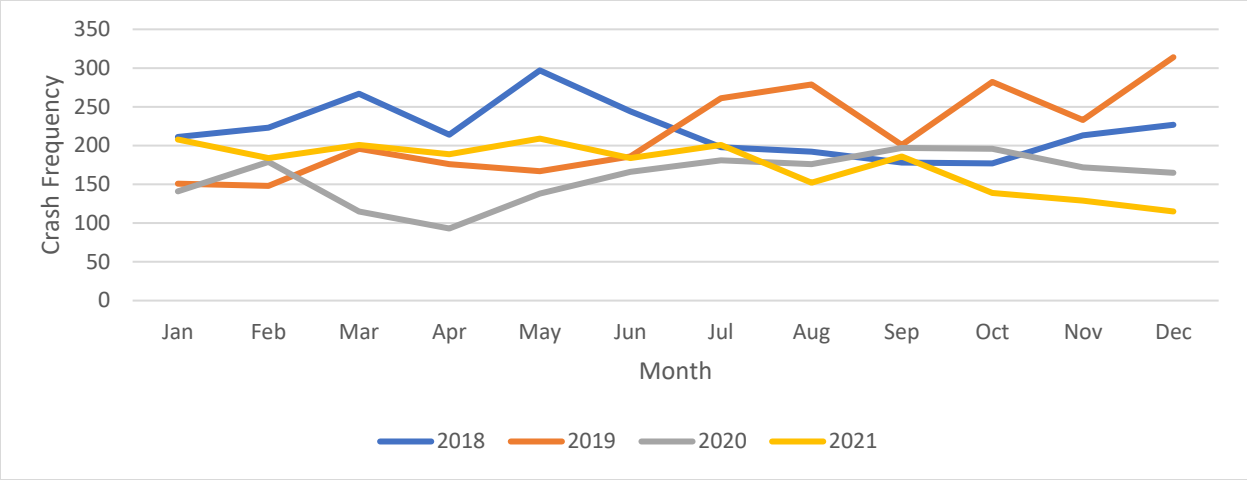


Figure 8: Monthly crash frequency for I-10

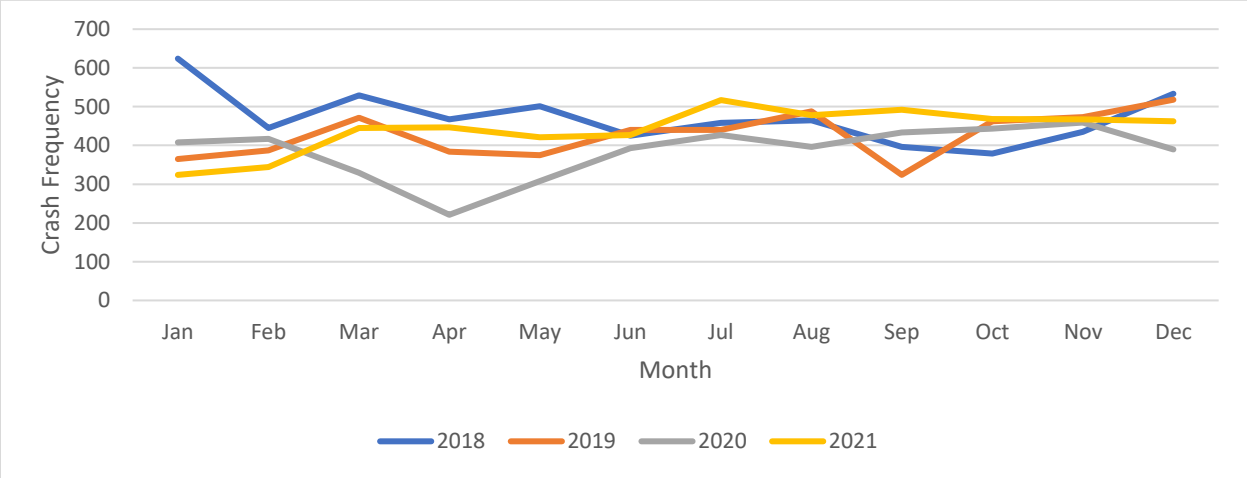


Figure 9: Crash frequency for I-75

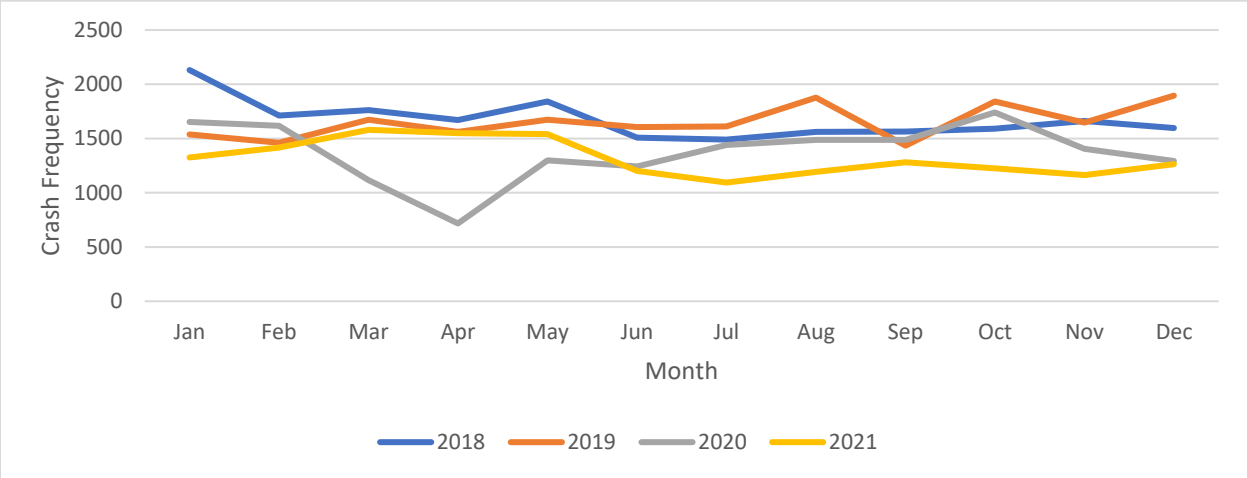


Figure 10: Crash frequency for I-95

Impacts on Crash Severity

Figures 11 through 13 show the proportions of FI crashes on I-10, I-75, and I-95 from 2018 to 2021, on monthly basis. There is no common pattern in the proportion of FI crashes by month from the graphs. The plots of the proportion of FI crashes by month for the years 2018 and 2019, there are 2 main peaks – one in April and the other in August-September The proportion of FI crashes in 2020 started at 18% in January and rose to 35% in March. It then dropped in April to 25%, unlike the increase in the proportion of FI crashes in the same months in 2018 and 2019. It rose in May and dropped further in June to 23%, from where it rose for the next 3 months to 31% in September and dropped to 26% in December. In 2021, the proportion of FI crashes went down for the first three months from 26% in January to 19% in March, then rose to 30 % in August, and dropped to 25% in December.

On I-75, the proportion of FI crashes in the first 4 months of 2020 followed a trend similar to that in 2019, ranging between 24% and 28%. However, from May to December 2020, the proportion of FI crashes rose to 30% and stayed above 29% (with the highest value of 32% in December); in the same period in 2019, the proportion of FI crashes was mostly below 25% except for July (32%). FI crashes were the highest in 2020 with an annual average of 30%.

The proportion of FI crashes didn't vary much in 2018 and 2019, ranging between 23% and 26% in the two years. The proportion of FI crashes in 2020 had a trend that followed closely that of 2019 except for February and April which had low values of 19% and 21% respectively. This proportion in 2021 ranged between 21% and 22% from January to May and then rose steadily to 26% in July, which then followed a trend close to that of the year 2020 up to December.

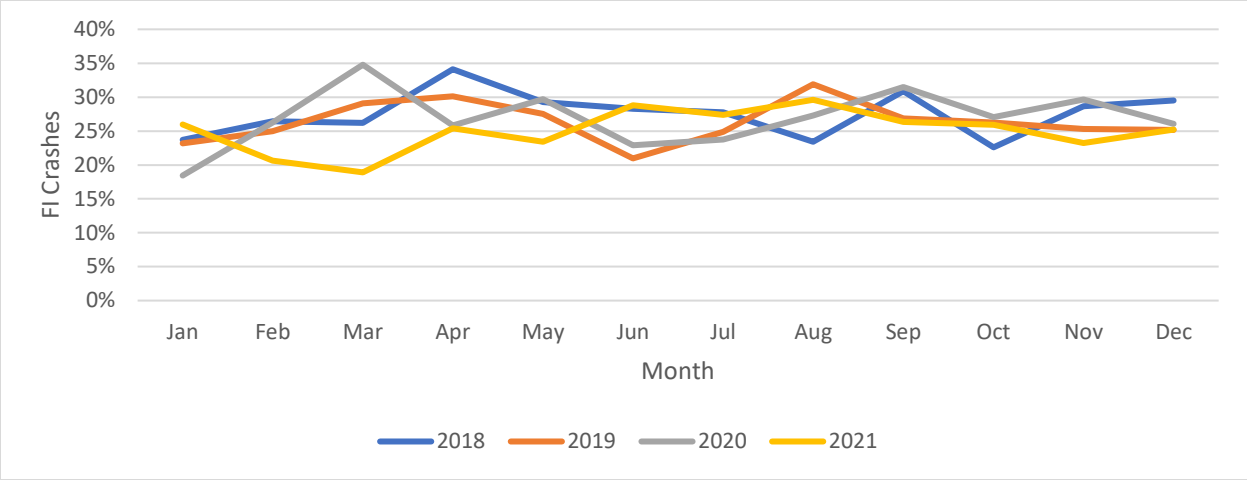


Figure 11: Proportion of FI crashes on I-10

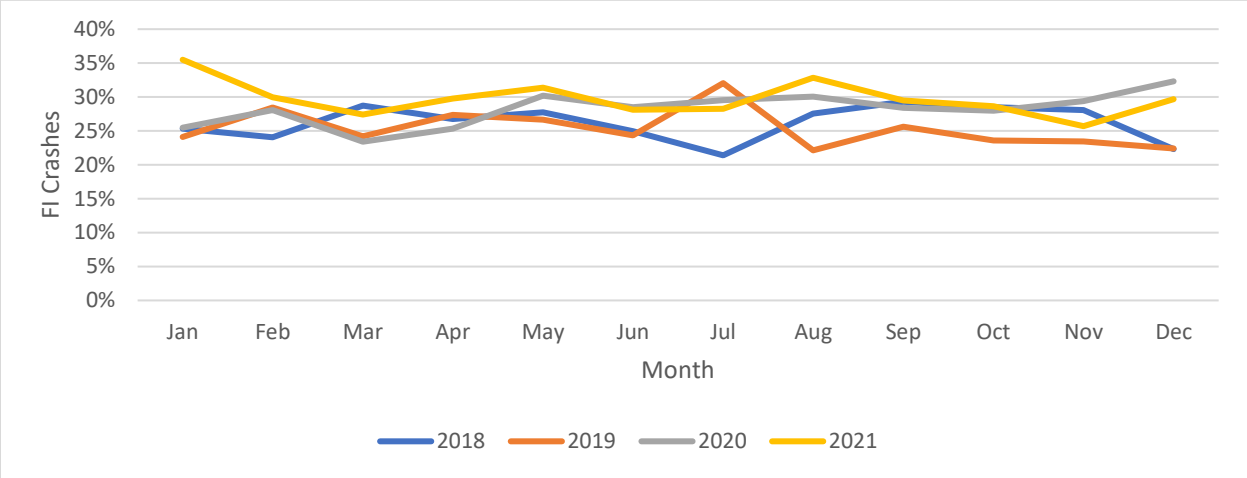


Figure 12: Proportion of FI crashes on I-75

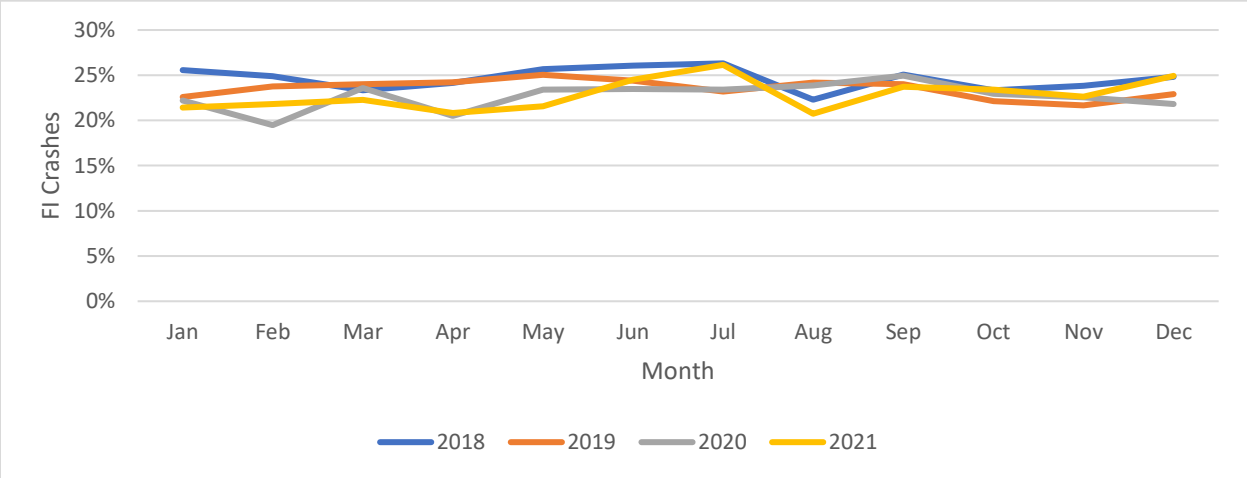


Figure 13: Proportion of FI crashes on I-95

Impacts on Crashes by Number of Vehicles

Figures 14 through 16 show the proportion of single-vehicle crashes on I-10, I-75, and I-95 from 2018 to 2021, on monthly basis. On I-10, for the years 2018 and 2019, the proportion of single-vehicle crashes has been decreasing, after which it increases to a peak value in the May-June period. In 2020 however, the proportion of single-vehicle crashes in January was the lowest (29.8%). It then increased gradually to a value of 49.5% in April, dropped in May, and then remained between 40% and 50% up to September, after which it dropped in the last 3 months. The proportion of single-vehicle crashes in 2021 followed a pattern similar to that in 2019.

On I-75, from January to March, the proportions of single-vehicle crashes in 2020 ranged between 23% and 27%, which is not very far from the proportion in 2018 and 2019. However, the value jumped to 45.7 % compared to 24.2 % and 23.7% in April 2018 and April 2019 respectively. This value remained consistently higher than the values in the previous two years for the rest of the months up to December when it dropped to 23.85% in 2020 compared to 25.14% and 23.55% in December 2018 and December 2019 respectively. In 2021, this proportion had a trend close to that in the first two years.

On I-95, the proportion of single-vehicle crashes had a trend similar to that of I-75, with its value being significantly high in 2020 compared to the other 3 years. In 2018 and 2019 the value was lowest in the first quarter of the respective years (12% in March 2018 and 13% in February 2019). It gradually increased to May/June, after which it dropped smoothly to December. The highest values in the two years were 24% in May 2018 and 22% in August 2019. The year 2020 started with comparatively low proportions of single-vehicle crashes as compared to the 2 previous years (14%, 16%, and 18% in January, February, and March respectively). It then rose sharply to the yearly peak value of 41% in April and May, from where it remained above 28% up to November

and finally dropped to 22% in December. 2021 had values of under 20% up to May, followed by a rise to 27% in May. It then dropped gradually to 17% in December.

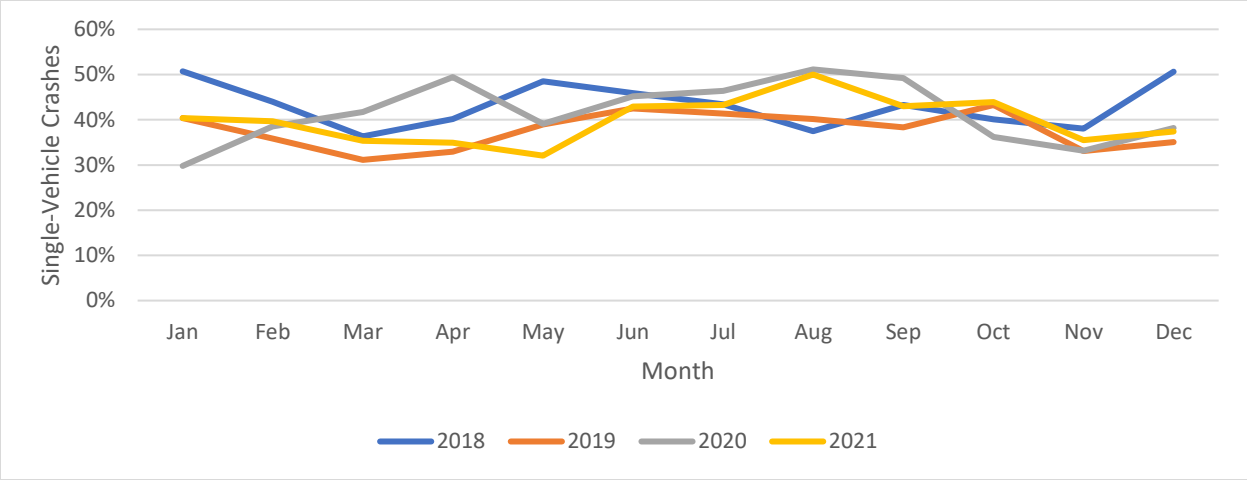


Figure 14: Proportion of single-vehicle crashes on I-10

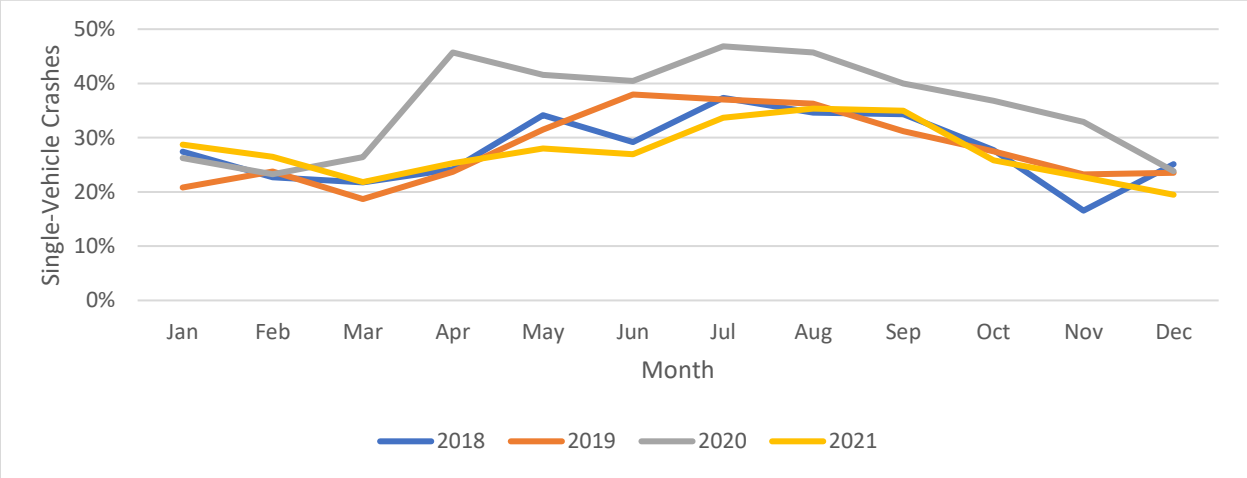


Figure 15: Proportion of single-vehicle crashes on I-75

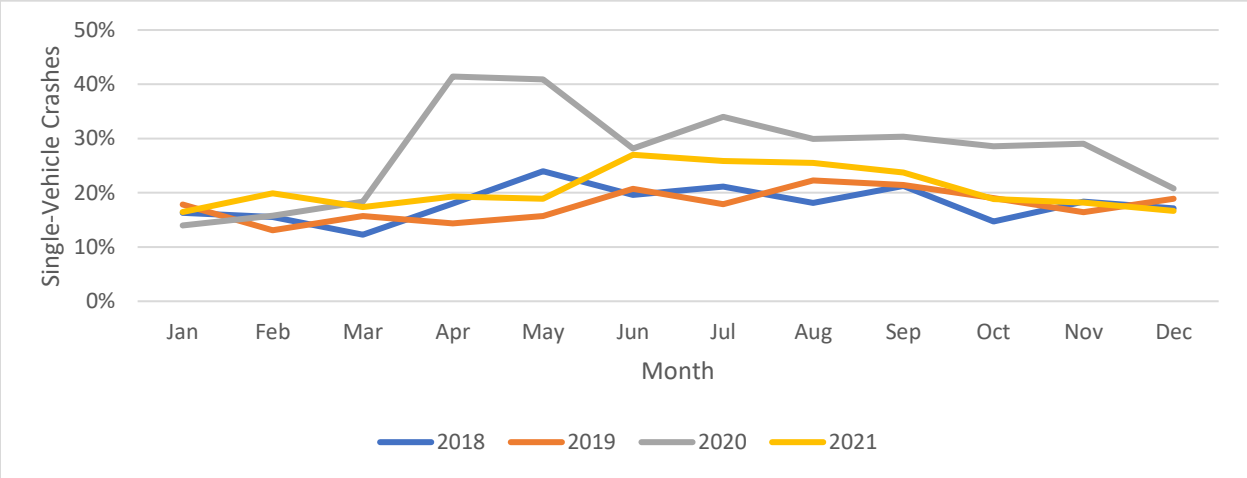


Figure 16: Proportion of single-vehicle crashes on I-95

Impacts on Crashes by Manner of Collision

Figures 17 through 19 show the proportion of run-off crashes for I-10, I-75, and I-95 from 2018 to 2021, on monthly basis. Overall, there has been a rise in the proportion of run-off crashes and a drop in the proportion of rear-end crashes in 2020 compared to similar periods in 2018, 2019, and 2021, at least for April when the lockdown began. For I-10, the years 2018 and 2019 saw a drop in the proportion of run-off crashes from January to March, followed by a period of increase in run-off crashes proportion up to the yearly peak values of 36% in May 2018 and 31% in June 2019 respectively. The proportions dropped slightly for the following couple of months until October 2018 and September 2019 when they dropped sharply to 15% and 16% respectively. They then fluctuated for the remaining months of the respective years up to the final values in December, of 34% and 25% in 2018 and 2019 respectively. The year 2020 saw a similar pattern from January to December as the 2 previous years, with some minor differences. January had the yearly low value of 16% which then rose gradually up to the peak value of 36% in August and then dropped for the remaining months up to the values of 20% and 24% in November and December 2020 respectively. 2021 had a pattern similar to the previous years but most similar to that of 2019.

I-75 and I-95 had similar trends in the proportion of run-off crashes in that for all four years, the value started low for the first few months and peaked in the July-September period. It would then drop for the remaining months. However, there was a dramatically higher proportion in 2020 compared to the other three years, with the sharpest rise being observed from March to April (14% to 35% for I-75, 10% to 28 % for I-95). This proportion was then significantly higher for the months from April up to November (for 2020, compared to 2018, 2019, and 2021), after which it dropped to 14% and 13% in December 2020 for I-75 and I-95 respectively. For the year 2021, the proportion of run-off crashes had a trend similar to that in 2018 and 2019 for all 12 months. These

observations align with the observations from the comparison of crash frequency by the number of vehicles involved; not much of a difference for I-10 for the four years but a sharp increase from April 2020 for I-75 and I-95. Considering the drop in traffic volume after the lockdown was enforced, drivers were less exposed to high traffic flows which made single-vehicle crashes and run-off crashes more likely to occur than in similar periods in the previous years. This correlation between single-vehicle crashes and run-off crashes is also an observation that has been noted before (Dissanayake et al., 2014).

The proportion of rear-end crashes had a somewhat inverse trend compared to the proportion of run-off crashes. For I-10, the proportion of rear-end crashes did not change much across each year; however, there was a sharp drop from March 2020 (33%) to April 2020 (15%) with a quick rebound in May 2020 (36%) – a pattern that did not occur for the other three years. For I-75 and I-95, the proportion of rear-end crashes would generally rise from January to March, and then drop smoothly to a low point between July and September, before going back up in the remaining months. What is clear though is that this proportion was significantly low in 2020 compared to the other three years, especially from April. Since run-off crashes on freeways are more common in congested conditions due to stopping shock waves (Davis et al., 2021), this observation is consistent with the low traffic volumes caused by the lockdown.

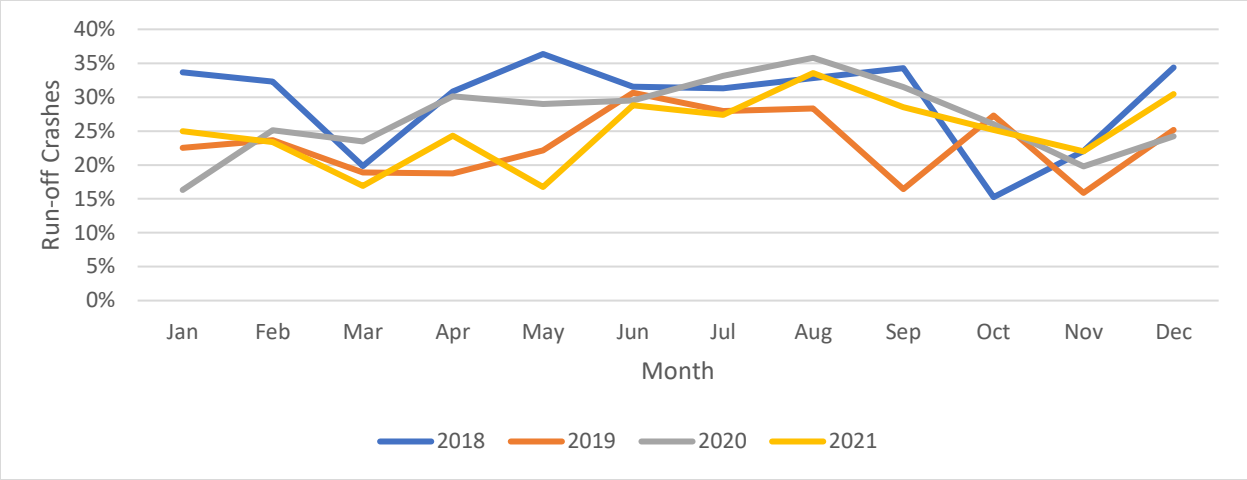


Figure 17: Proportion of run-off crashes on I-10

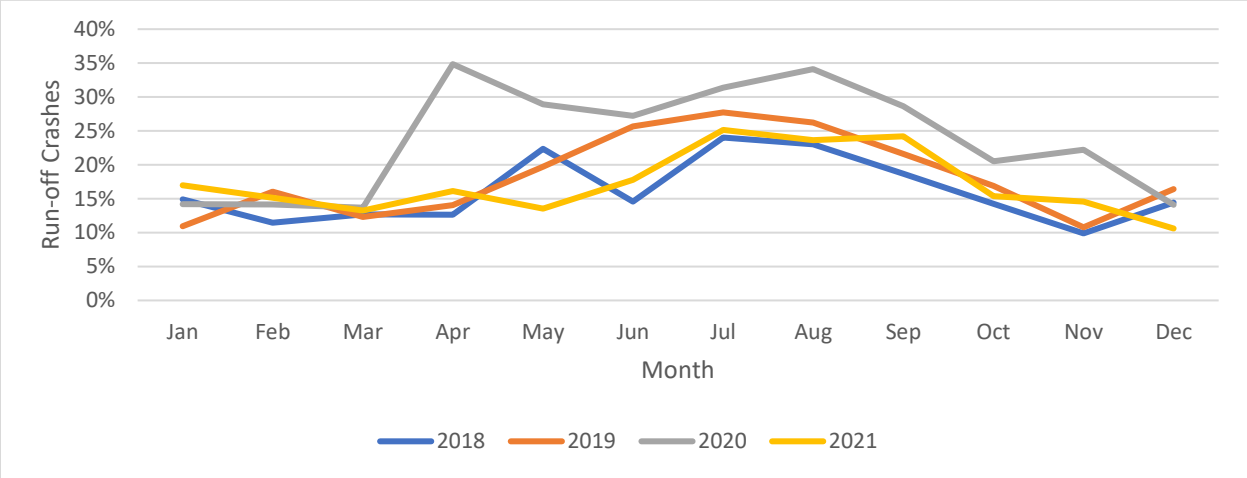


Figure 18: Proportion of run-off crashes on I-75

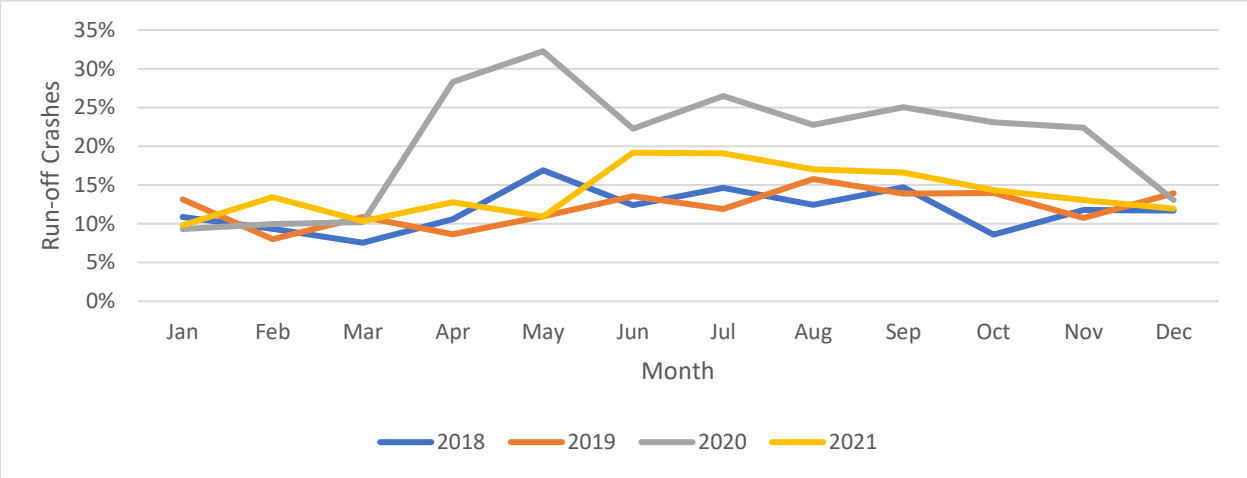


Figure 19: Proportion of run-off crashes on I-95

Impacts on Vehicle Speed

Figures 20 through 22 show the15-minute annual average vehicle speeds on I-10, I-75, and I-95 from 2018 to 2021. As the results of the preliminary analysis suggest, average speeds have been observed to be generally higher in 2020 than for the other three years. From the average weekday 15-minute speed, a common feature for all trendlines is the presence of two periods of local minimum average speeds. These local minima coincide with the AM and PM peak traffic periods at which traffic volumes are at maximum. As a result of people not commuting as before, it is to be expected that enforcement of lockdown protocols should lead to an increase in average speeds, especially during these peak periods, as in these situations, drivers encounter less traffic than they would in ordinary traffic conditions. This is what can be observed in the mean speed graphs aggregated on monthly basis. For I-10 for instance, the average 15-minute speed graphs for March for all four years reveal the AM and PM peak periods at around 6:00 a.m to 8:00 a.m and 3:15 pm to 5:15 pm respectively (though the latter is not as clear). During these peak periods, the graphs dip, signifying a decrease in average speed. For April, the pattern across the 24 hours remains the same for 2018, 2019, and 2021, but that of 2020 loses the AM and PM peak dips that were present in the previous month. This happened for the following couple of months before when the peak period dips started to appear again (I-10 in August, I-75 in September, and I-95 in August).

For off-peak periods, observations of the average 15-minute speeds in 2020 vary for the three roadway segments. For I-10, the average speed in 2020 was consistently higher than that of the other three years for all off-peak periods. The speeds in 2021 however were the lowest compared to those in the previous years. This suggests that the speeds on I-10 rose during the onset of the pandemic and stayed high in 2020 but dropped in 2021. On I-75, speeds in 2020 have been lower than those for the previous two years for most of the off-peak periods. In 2021, the speeds in all

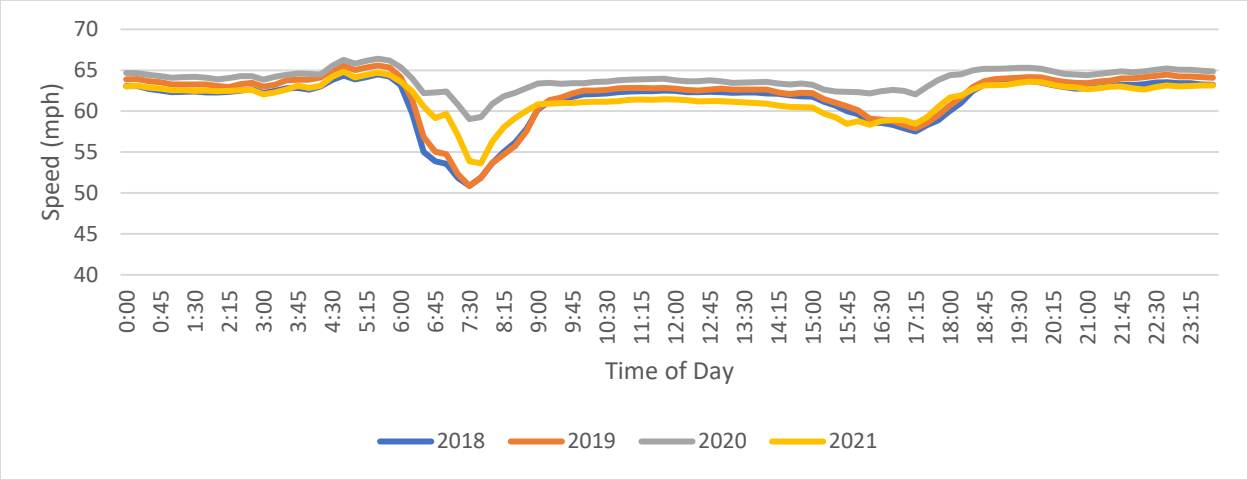


Figure 20: Annual average traffic speeds on I-10

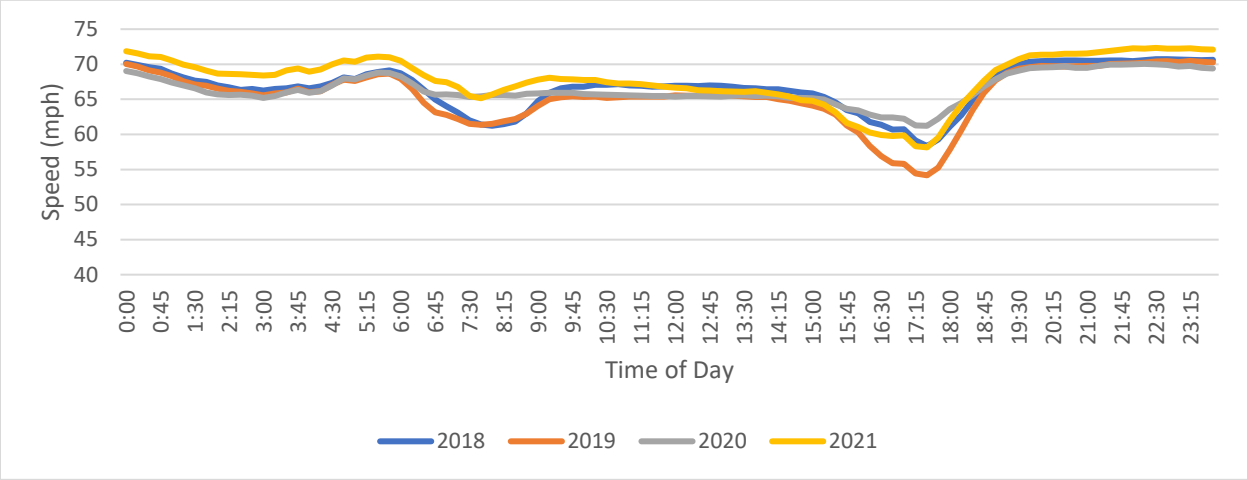


Figure 21: Annual average traffic speeds on I-75

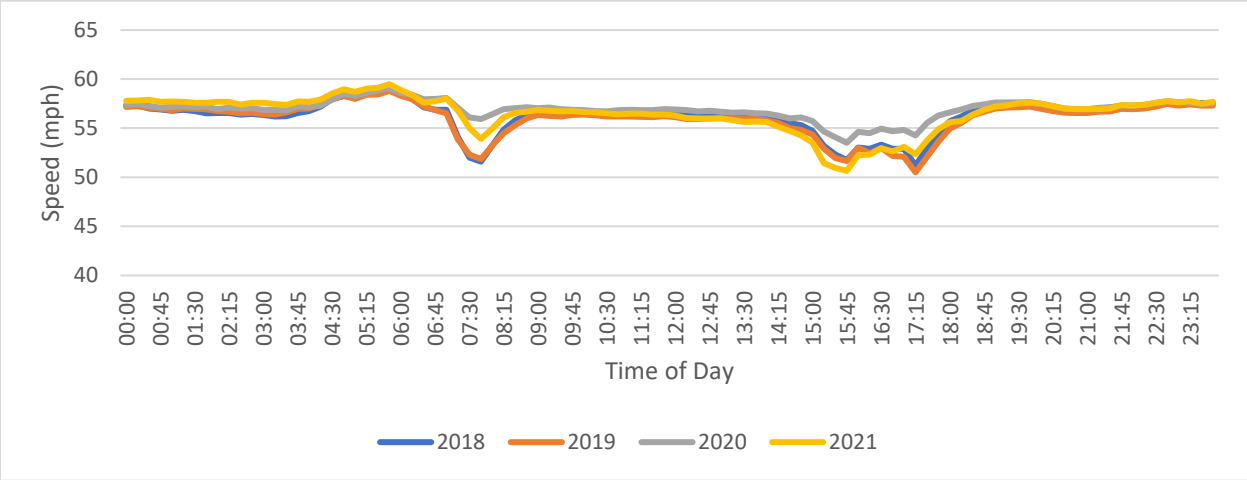


Figure 22: Annual average traffic speeds on I-95

off-peak periods went higher than in the previous three years. I-95, similar to I-10, had speeds in 2020 higher than those in the previous two years for all off-peak periods. In 2021, the speeds went down in the midday and evening off-peak periods but were higher than in 2020 for the dawn off-peak period.

Traffic conditions alone do not justify an increase in average speeds during the lockdown, especially during the off-peak periods. With roadway geometrical features not changing during the study period, driver behavior is another factor that may affect the traffic speeds. Earlier research, for example, noted significant changes in the use of alcohol and other drugs among those seriously and fatally injured from traffic crashes in 2020, with almost two-thirds of these injured individuals being tested positive for at least one active drug (including alcohol, marijuana, or opioids) between mid-March and mid-July (Thomas et al., 2020).

Impacts of DVMT on Crashes

Figures 23 through 25 show the crash rates on I-10, I-75, and I-95 from 2018 to 2021, on monthly basis. There are varying results from the three analyzed road sections. On I-10, the number of crashes per 100 million VMT dropped from around 5,600 crashes in February 2020 to 1,600 crashes in March and rose to 2,200 crashes. These crash numbers in March and April are low compared to those in 2018 (9,100 in March, 8,800 in April) and in 2019 (7,900 in March, 8,400 in April). May saw a higher crash rate of around 5,800 crashes per 100 million VMT, from where it dropped to 3,000 million VMT in December, always being significantly lower than the rates in 2018 and 2019. In 2021, the traffic crash rate was highest in January at 7,600 crashes per million VMT, from where it dropped across the year to 2,200 crashes per million VMT in December.

On I-75, the crash rates in 2020 rose from 1,200 million VMT in February to 2,100 crashes per million VMT in March and 2,200 crashes per million VMT in April. Traffic crash rate then dropped in the following two months to 1,100 crashes per million VMT in June The rates in March and April are lower than those in 2019 (3,400 in March, 3,000 in April) but higher than those in 2019 (1,400 in March, 900 in April).

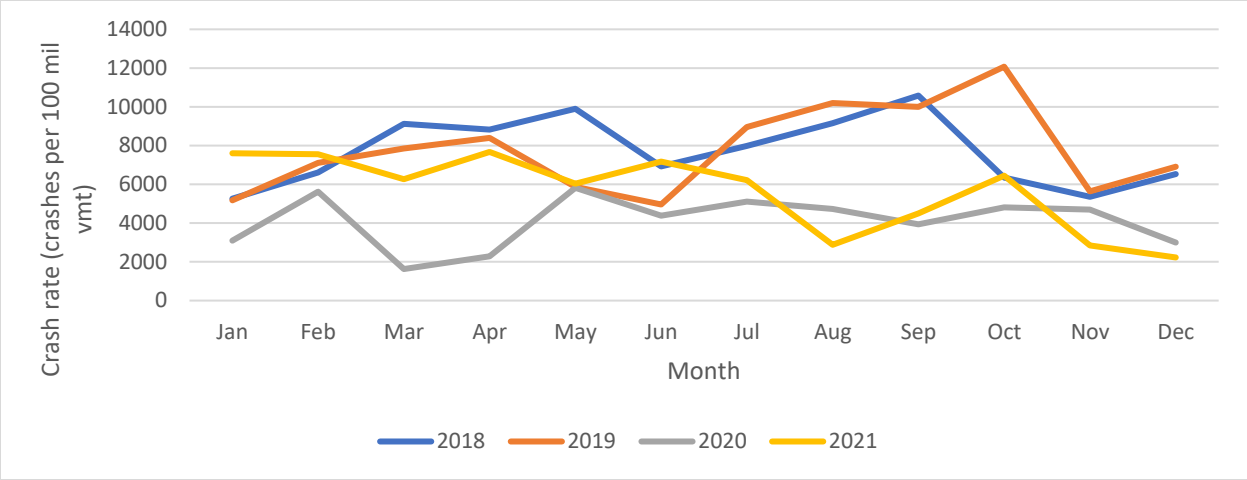


Figure 23: Crash rates on I-10

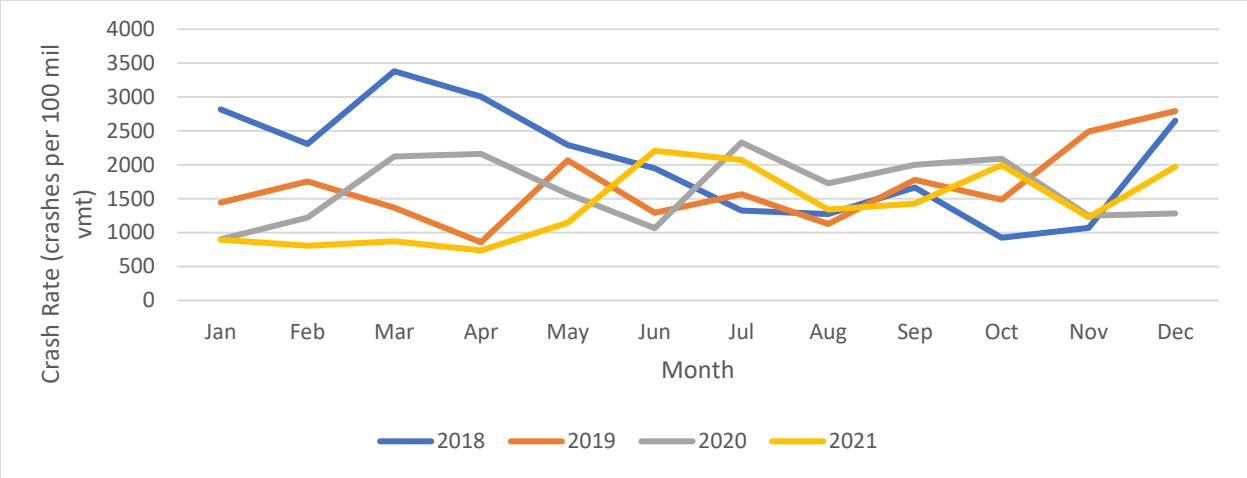


Figure 24: Crash rates on I-75

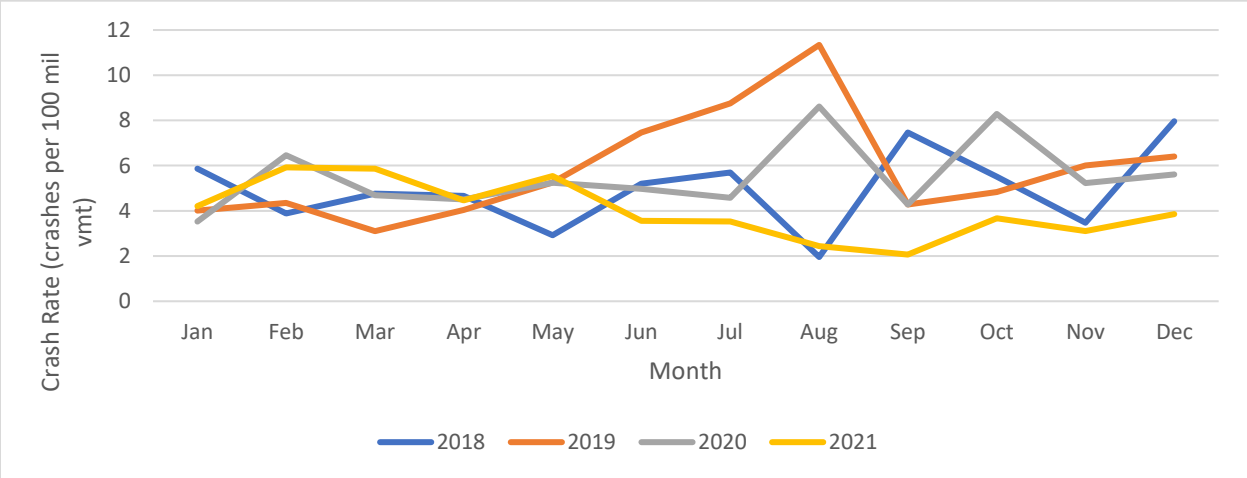


Figure 25: Crash rates on I-95

Statistical Analysis

Crash Frequency

Q-Q plots for the monthly crash frequency data were plotted for each interstate and they had correlation coefficients above 0.95. For this reason, the mean monthly crash data may be assumed to be normally distributed and thus fit to apply paired t-test for sample means to test whether crash frequencies were higher in 2020 compared to 2018, 2019, and 2021. Equation 1 presents the formulated hypothesis tests:

Null hypothesis (H_o): $\mu_1 - \mu_2 = 0$

Alternative hypothesis (H_a): $\mu_1 - \mu_2 > 0$

Where:

μ_1 = average monthly crash frequency in the year 2020

μ_2 = average monthly crash frequency in the year 2018 or year 2019 or year 2021

The results have been summarized in Table 7.

Table 7: Statistical analysis results for crash frequency in 2020 versus in 2018, 2019, and 2021

Road	Mean Monthly Crash Frequency - 2020			Mean Monthly Crash Frequency – Pre and Post Lockdown Years				Test Results		
	Mean	Variance	n	Year	Mean	Variance	n	t-critical	T	Significant?
I-10	160	1,174	10	2018	221	1,525	10	1.833	-2.923	YES
				2019	230	2,661	10	1.833	-5.126	YES
				2021	171	1,138	10	1.833	-0.585	NO
I-75	380	5,424	10	2018	459	2,705	10	1.833	-2.27	YES
				2019	438	3,520	10	1.833	-2.275	YES
				2021	462	851	10	1.833	-4.209	YES
I-95	1,863	137,277	10	2018	2,304	31,244	10	1.833	-2.853	YES
				2019	2,349	58,078	10	1.833	-4.23	YES
				2021	1,942	33,034	10	1.833	-0.482	NO

Speed

A paired t-test for sample means was employed to check whether the mean annual speeds for the AM peak, PM peak, and off-peak periods were greater in 2020 than in the other three years. Equation 2 presents the formulated hypothesis tests:

Null hypothesis (H_o): $\mu_1 - \mu_2 = 0$

Alternative hypothesis (H_a): $\mu_1 - \mu_2 > 0$

Where:

μ_1 = annual average vehicle speed in the year 2020

μ_2 = annual average vehicle speed in the year 2018 or year 2019 or year 2021

The results have been summarized in the table below.

Table 8: Statistical analysis results for 15-minute annual average traffic speed in 2020 versus in 2018, 2019, and 2021

Peak Period	Road	Annual Average Vehicle Speed in 2020			Annual Average Vehicle Speed in Pre and Post Lockdown Years				Test Results		
		Mean	Variance	n	Year	Mean	Variance	n	t-critical	T	Significant?
AM Peak	I-10	63.13	49.45	100,000	2018	56.76	197.02	100,000	1.645	128.246	YES
					2019	56.9	189.18	100,000	1.645	127.582	YES
					2021	58.73	113.58	100,000	1.645	108.994	YES
	I-75	66.14	58.27	100,000	2018	64.3	146.53	100,000	1.645	40.72	YES
					2019	63.53	130.69	100,000	1.645	60.026	YES
					2021	67.09	79.06	100,000	1.645	-25.472	NO
	I-95	57.16	138.04	100,000	2018	55.33	154.6	100,000	1.645	33.96	YES
					2019	55.21	155.53	100,000	1.645	36.066	YES
					2021	56.04	122.5	100,000	1.645	22.059	YES
PM Peak	I-10	63.44	43.24	100,000	2018	59.75	82.66	100,000	1.645	104.028	YES
					2019	60.26	74.01	100,000	1.645	92.799	YES
					2021	60.26	74.01	100,000	1.645	92.799	YES
	I-75	64.45	118.28	100,000	2018	62.2	209.19	100,000	1.645	39.281	YES
					2019	59.57	239.34	100,000	1.645	81.467	YES
					2021	61.34	225.07	100,000	1.645	53.086	NO
	I-95	55.47	166.7	100,000	2018	53.32	184.01	100,000	1.645	36.368	YES
					2019	53.18	192.22	100,000	1.645	38.34	YES
					2021	52.76	169.12	100,000	1.645	46.842	YES
Off Peak	I-10	64.65	18.36	400,000	2018	62.89	23.63	400,000	1.645	171.456	YES
					2019	63.64	17.81	400,000	1.645	106.121	YES
					2021	62.55	33.36	400,000	1.645	184.804	YES
	I-75	67.44	45.52	400,000	2018	68.09	63.76	400,000	1.645	-38.841	NO
					2019	67.64	46.1	400,000	1.645	-13.262	NO
					2021	69.73	53.51	400,000	1.645	-145.428	NO
	I-95	57.47	131.11	500,000	2018	56.97	131.32	500,000	1.645	21.478	YES
					2019	56.9	134.54	500,000	1.645	24.453	YES
					2021	57.21	115.51	500,000	1.645	11.459	YES

CHAPTER 6: CONCLUSIONS

This study investigated the changes in the pattern of traffic crashes during the outbreak of the COVID-19 pandemic. The comparative analysis was conducted to explore the variations in the pattern of the traffic crashes amid the COVID-19 outbreak in Florida. The study first investigated the trend of the crash frequency on daily basis since the first confirmed cases in Florida from March 1 to April 30, 2020. Moreover, the crash frequency, crash severity, and specific crash types by the manner of the collision were also analyzed and compared across the three years. The analysis was based on the three Florida interstate highways (I-10, I-75, and I-95) for two months across the three years i.e., March and April 2018-2020. The real-time traffic data and crash data for March and April 2020 were considered as the period during the outbreak of the novel COVID-19 pandemic while the same corresponding period in the previous years 2018 and 2019 was considered as the normal conditions. An extended analysis similar to this was also performed to include the whole period from January 2018 to December 2021 to also observe traffic conditions and traffic crash trends in the two months just before the emergence of the pandemic (January and February) and in the period after April (May to December). Crash frequency and crash rates were analyzed on monthly basis and the observations made in 2020 were compared to similar months in 2018, 2019, and 2021.

The analysis based on the crash frequency trends since March 1, 2020, after the first confirmed case in Florida, indicated that there was a decreasing trend following the restrictions imposed to limit the rapid spread of the virus. The decrease was more pronounced in April 2020 compared to March 2020 due to the mandatory stay-at-home order which came into effect on April 01, 2020. While there was a decreasing trend in the crash frequency in 2020, there was no such a decreasing trend in the corresponding period in the previous years 2018 and 2019. While there was a reduction

in crash frequency amid the coronavirus pandemic outbreak, there was an increase in the crash frequency per 100M DVMT. The increasing trends in the crash frequency per 100M DVMT were not observed in the previous years 2018 and 2019.

Results show a reduction of 45% in total crashes in the second half of March 2020 compared to a similar corresponding period in 2019. The second half of March 2020 was considered phase two of the closing phases whereas schools and businesses were closed. In April 2020, the total crash frequency was reduced by 30% compared to the same month in the years 2018 and 2019. The proportion of single-vehicle crashes increased by up to 44% in the second half of March 2020 and in April 2020 compared to similar periods in 2018 and 2019. The proportion of rear-end crashes decreased in all phases of the pandemic, most notably in April 2020, decreasing to up to 27%, nearly half the proportion of rear-end crashes in 2019 (51.5%). On the other hand, the proportion of run-off-road crashes increased from 10.9% in April 2019 to 32.4% in April 2020.

Overall, results also show a reduction of 20% in total crashes for the period from March to December 2020 compared to a similar period in 2019 (in contrast to the increase of 2% in total crashes from 2018 to 2019 for the same period. An increase of 4% in total crashes occurred in March to December 2021 compared to a similar period in 2020. The month of April 2020 experienced the most dramatic changes in crash proportions for most categories of crashes compared to April 2019: greatest increase in the proportion of single-vehicle crashes (hence greatest decrease in the proportion of multivehicle crashes), the greatest increase in the proportion of run-off crashes, and the greatest decrease in the proportion of rear-end crashes.

The increase in the proportion of single-vehicle crashes and run-off-road crashes observed amid the outbreak of the novel COVID-19 pandemic was attributed to the increase in traffic speeds observed in different sections of the interstate analyzed. Note that the average traffic speeds in

different sections analyzed were above the speed limit in most of the daytime since March 16, 2020. It is worth mentioning that traffic speed is the main cause of the run-off-road crashes which resulted in single-vehicle crashes. The results of this study may help agencies and authorities understand the impacts of the pandemic on transportation operation and safety that may be useful in operational and strategic planning for dealing with future pandemics.

There were several limitations in this study that could be addressed in future research. Several factors associated with road safety were neither observed nor controlled so as to isolate COVID-19 lockdown as the sole independent variable in the study. Factors such as demographic characteristics of drivers using freeways and manner of policing of traffic laws might have changed during the study period, significantly enough to affect the results of the analysis. In addition, crashes may be categorized into more classification criteria. For instance, crashes could be categorized by causes of crashes (such as driver distraction, unfamiliarity of roads by drivers, and poor condition of roadway facilities) or type of vehicle(s) involved (such as non-motorized traffic, passenger car, and trucks). An intensive analysis involving traffic volume data could also help in providing more insight on the changes in traffic crash rates.

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