TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FMRI-Y4R3- 20	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Determination of Position and Operations Analysis of Emergency Freight Parking in Florida State		5. Report Date: December 2023 6. Performing Organization Code:
7. Author(s) Evangelos Kaisar, Elif Akcali		8. Performing Organization Report No.
9. Performing Organization Name and Address Florida Atlantic University University of Florida Freight Mobility Research Institute		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 69A3551747120
12. Sponsoring Agency Name and Address Freight Mobility Research Institute Florida Atlantic University 777 Glades Rd., Bldg. 36, Boca Raton, FL 33431		13. Type of Report and Period: Final 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The transportation system is particularly vulnerable to disruptive events, while at the same time it is the primary sector for preparedness management and mitigation. The objective of this research is to create a safer network for drivers of the freight vehicles with minimum intervention to the pre-existing infrastructure of Florida state. The research will identify alternative locations with spatial tools for truck parking during an emergency situation in a dynamic way based on the needs of each driver individually. For that purpose, a suitability analysis model was developed, using ArcGIS platform. The model's output is all the possible parking locations during an emergency based on collected and modified input data. The results of the model revealed that in the worst-case scenario, while applying the strictest criteria for the excluded areas, the proposed parking locations could be utilized by more than 35,000 trucks. Furthermore, it was found that the proposed locations are also close to many facilities ensuring that drivers would be able to meet their needs even without using their vehicles. It was calculated that more than 2,000 parking locations are close to amenities (within a 0.25 miles distance) although those infrastructures were not built for this specific reason. The hundred proposed locations could be life-saving and at the same time could reduce the traffic jam, the risk of accidents and the cost.

17. Key Words Emergency Truck Parking, Disruption, Suitability Analysis, Emergency, Freight Vehicles		18. Distribution Statement No restrictions. This document is available to the public through Fmri.fau.edu	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

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Project ID: FMRI-Y4R3-20

Determination of Position and Operations Analysis of Emergency Freight Parking in Florida State

Final Report

by

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May 2024

ACKNOWLEDGEMENTS

This project was funded by the Freight Mobility Research Institute (FMRI), one of the twenty TIER University Transportation Centers that were selected in this nationwide competition, by the Office of the Assistant Secretary for Research and Technology (OST-R), U.S. Department of Transportation (US DOT).

DISCLAIMER

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EXCUTIVE SUMMARY

Florida is extremely vulnerable to many natural disasters such as flooding and hurricanes. Due to its several miles of coastline, significant drainage systems, and relatively low elevations, the entire state is especially susceptible to flooding at any time of the year. Extreme disruptions to the transportation networks and communications is one of the impacts of flooding and any kind of natural disaster or emergency situation. Hence, the importance of an integrated, comprehensive approach to disaster loss reduction is not neglectable. The transportation system in Florida needs to overcome many disruptions during the hurricane season caused by the heavy rains, strong storms, and many other local events. In these critical situations, the safe, fast, and reliable shipment of cargo is vital to ensure the continuation of the demands for society. Above that, the safety of truck drivers at all conditions remains the first priority. Therefore, this research focuses to support the identification and operation of the emergency truck parking network (ETPN) for freight operations in the State of Florida. The research team will focus on the opportunities and challenges associated with the identification and operation of the ETPN in Florida, and also, will focus on developing decision-making support for and managerial insight into the identification and operation of such networks. Specifically, the two specific objectives of this project are:

1. Conduct a statewide study to (i) assess the supply and demand for emergency truck parking, (ii) develop metrics to assess the safety and economic impact of emergency truck parking network, and (iii) build a prototype web-based tool or mobile app to guide truck drivers to emergency parking locations in Florida.

2. Develop simulation models to (i) analyze the performance of alternative emergency parking networks and (ii) generate insight into the impact of truck driver behavior on the expected performance of alternative emergency parking networks.

Consequently, this research can reduce travel time and improve safety which the cost saving can be spent on building new infrastructure. Furthermore, by directing trucks out of the network in a shorter time and preventing the illegal parking the mobility of other vehicles will be improved and the risk of accidents will be reduced. The results of this project will be served for protecting, managing, and organizing the freight movement in various critical/emergency situation.

1.0 INTRODUCTION

Freight transportation system in Florida is one of the most valuable contributors to the state's economy and growth while at the same time is responsible for the safe, fast, and reliable shipment of cargo to ensure the continuation of vital operations. Although, all the above are very critical for the operation of Florida state, the safety of truck drivers, under all circumstances, remains the first priority. This means that the truck parking availability needs to be ensured even in periods of high demand in truck parking facilities. The combination schedules of emergency situations and the tighter delivery of freight operations is one of the primary reasons for the increased demand of truck parking in the state of Florida. The "Statewide Truck GPS Data Analysis" study identified 300 truck parking facilities in Florida state with 10,093 truck parking spaces in total, 30 percent of which are provided by the public sector and 70 percent by the private [1]. Although, there are resting and sleeping facilities along major highways, many truck drivers cannot take advantage of them because of their unavailability in parking spaces, especially during emergency situations. This has a serious impact on drivers' safety since the truck driver is going to either keep driving or park at undesigned areas, such as the shoulders along the on/off – ramps of rest areas and other interchange ramps, increasing the risk of accidents. However, it is possible to develop protection methods to minimize the impacts caused by natural disasters, such as the identification and operation of emergency truck parking for freight operations in Florida.

Transportation system in Florida needs to overcome many disruptions during the hurricane season caused by heavy rains, strong storms, floods, and many other local events. At the same time, the ongoing pandemic was significantly affecting the movement of freight transportation and disruption on supply chain. The above mentioned have led to the conclusion that, dealing with emergency situations and weather disruptions are very common phenomenon for the competent authorities in the state of Florida. Furthermore, the freight transportation system is responsible for the safe, fast, and reliable shipment of cargo to ensure the continuation of vital operations, while at the same time the truck drivers safety remains the first priority. An emergency situation could be divided into two categories, long-term duration, or short term-duration, however, in both categories it is very important to ensure the safe movement of vehicles within the network without putting human's life in danger. Evacuation caused by heavy rains, storms, flooding, hurricanes are some of the reasons that could lead to parking closures on the affected area or to over- utilization of them outside of it. Furthermore, from literature research that is presented below, it was observed that truck drivers tent to park on shoulder lanes or other undesignated parking areas. Even though we had a considerable number of emergency events over the past decade, increasing the number of parking in the whole state and building new parking facilities for the non-recurrent events does not constitute a sustainable solution from a cost and space availability perspective. Based on this, creating smaller facilities, or use pre-existing ones will reduce the cost, space, travel time and at the same time they will ensure drivers' safety and better-performing transportation networks.

The goal of this research is to create a safer network for drivers of the freight vehicles with minimum intervention to the pre-existing infrastructure. The freight society will benefit in multiple aspects by identifying new parking locations. For instance, the travel and the parking searching time will be reduced and there will be cost savings from traveling and construction of new infrastructure. Furthermore, the safety will be improved, and the risk of traveling under emergency situations will be reduced. Additionally, removing a considerable number of freights from the transportation network in a short time will help improve movement and mitigate congestion conditions. Therefore, many illegal parking actions made by drivers in freeway shoulders or other unauthorized locations will be prevented and improve the safety of the system even in case of drivers' health or mechanical issues. The proposed research will be a useful tool for protecting, managing, and organizing the freight movement under any critical condition, and at the same time a sustainable solution that can be incorporated with the existing infrastructure of the study area.

The research will identify alternative locations with spatial tools for truck parking during an emergency situation in a dynamic way based on the needs of each driver individually. A dynamic app with ArcGIS background will address driver's needs and provide all possible locations based on suitability analysis. This research will contribute to safety improvements, travel time savings, cost-savings, improvement of the level of service, and risk reduction.

Moreover, emergency parking could also be adapted from the states that are not frequently impacted by natural emergencies, for example, for overcoming stops due to driver or vehicle issues. Stopping the truck in a road lane or in unauthorized locations could contribute to congestion problems that could last for hours causing critical disruptions in the network. Also, due to the long distances between authorized parking facilities a driving discomfort could lead to illegal parking or in the worst case to an accident. Although this research was focused on addressing emerging issues in the state of Florida, an adaptive model was created which could easily regulate mobility issues in other states as mentioned above.

The report is organized as follows:

- **Section 2: Literature Review**
  This section provides a summary of the relevant literature, focusing on research topics such as fixed-time control, actuated control, and adaptive control.

- **Section 3: Research Methodology**
  This section details the algorithm, including its design, methodology, and key features.

- **Section 4: Simulation-Based Performance Evaluation on Artirial and Grid Networks under Varied Traffic Conditions**
  This section evaluates the algorithm's performance through simulations on arterial and grid networks under various traffic conditions.

- **Section 5: Conclusions**
  This section summarizes the results and conclusions, discusses the limitations of the study, and outlines directions for future improvements and potential research opportunities.

2.0 LITERATURE REVIEW

Managing vehicles in an emergent situation, constructing, and identifying new truck parking locations is a topic that was always in the center of attention. For the state of Florida, there is a considerable number of publications and projects that had been conducted for examining and addressing truck parking issues and data collection about freight movement, however, the number of studies related to parking during emergency events can be considered very limited.

Specifically, Washburn et al. (2016) collaborated with the Florida Department of Transportation (FDOT) and analyzed the results from the implementation of detectors in pre-existing rest areas in Columbia County. They identified the advantages and disadvantages of using different sensors and provided a detailed procedure for the data collection [2]. These data can be used to identify the demand on different rest areas and the fluctuations in truck volumes between recurrent and non-recurrent events. Another research completed by Zanjani et al. (2015) was mainly concentrated on data collection and freight movement in the state of Florida. It was found that the number of freight records in 4 months was 145 million [3]. Furthermore, the idea of using alternative facilities for trucks was investigated by Bayraktar et al. (2012) where they determined truck parking trends at public rest areas and developed a suitable smart parking management system for commercial motor vehicles. They used grounded sensors in the Leon County rest areas on I-10 that detect the presence of vehicles as it comes to a stop above them [4].

A further research investigation had been done by the ATRI, using surveys, and was focused to five different states placed in Mid America. The survey revealed that one-third of truck drivers park in unauthorized locations when necessary. It was also observed that the searching time for parking ranged from 15 minutes to 1 hour, and three-quarters of drivers reported that parking facilities were at least 75% full, if not overcapacity. Finally, it was found that drivers solve truck damage and uncommon issues by parking on shoulder/ramps or in unsafe locations and no parking for oversized vehicle configuration [5]. Another interesting survey conducted by Giron-Valderrama et al. (2018) and confirmed that a high percentage of drives used illegal parking as a solution when they were unable to find space in a parking spot and highlighted the need for new facilities. The survey also resulted that 43% of all drives had parked on a highway ramp and/or shoulder while 9% of them said that they parked at their company's nearby location when their travel plaza was full [6].

Various studies have been conducted by Metropolitan Planning Organizations (MPOs) and State Departments of Transportation (DOTs) to evaluate the parking issues at rest areas from different perspectives during the past decades. In 2020, the FDOT conducted a Statewide Truck Parking Study working on existing truck parking studies by using new data and approaches to identify, prioritize, and recommend solutions to resolve the truck parking needs in different areas in the state of Florida [7]. A significant source for this study was a previous FDOT's research, called "Statewide Truck GPS Data Analysis", in which all the public and private truck parking locations were identified, and their utilization was analyzed [1], [8]. This research identified 300 truck parking locations in the state of Florida with a total of 10,093 truck parking spaces [1]. Another statewide study conducted by the Texas Department of Transportation (TxDOT) evaluated the supply and demand of truck parking facilities. It proposed potential strategies for addressing truck parking needs such as adding new amenities [8]. According to the Trucker Survey conducted by the Memphis MPO, truck parking was identified as the biggest challenge for the truck drivers in the Greater Memphis region. This survey disclosed that 81.9% of respondents selected truck parking as the biggest challenge [9].

Similarly, the Jason's Law Truck Parking Survey revealed that more than 75% of truck drivers and almost 66% of logistics personnel were experiencing problems with finding safe parking locations when rest was needed, while 90% of the drivers responded that they were dealing with difficulties to find safe and available parking during the night hours [9], [10]. Over the past decade, different studies were carried out by the States revealing serious problems regarding the unavailability in truck parking spaces. For example, Miami – Dade County possessed 293 truck parking spaces back in 2010, whereas there was a demand of 12,000 spaces, requiring 1,177 acres of property [11]. In 2015, the Virginia Department of Transportation (VDOT) published a study to address truck parking issues in the state of Virginia. The study was focused on three regions. Northern Virginia, Hampton Roads and Southwest Virginia where, based on stakeholder surveys, these regions appeared to have the most significant shortages of truck parking spaces. According to the estimated demand, the study showed that in Northern Virginia, there was a shortage of 1,069 truck parking spaces, in the Hampton Roads region a shortage of 671 spaces and in Southwest Virginia a shortage of 1,034 truck parking spaces [12]. In 2020, Maryland Department of Transportation (MDOT) conducted a study to evaluate the already existing truck parking facilities, identify the undesignated truck parking locations and provide recommendations to address truck parking needs in the state of Maryland. For example, the I-95/I-495 Weigh Station in Adelphi had 18 truck parking spaces on-site that could be used by truck drivers, whereas around 1,500 trucks parked in undesignated locations around this station area. Also, almost 1,300 trucks parked around the Maryland House Truck Plaza, while there were 55 available truck parking spaces [13].

Although there is an absence of research for emergency parking in Florida, there are other states that have examined the necessity of emergency truck parking, like Texas. TxDOT, in the memo completed for truck parking research, highlighted the importance of the existence of emergency parking locations. Briefly states that incidents or uncommon events can create an intermittent or emergency demand for truck parking. Road closures, floodings, large scale events like hurricanes, tropical depressions, sandstorms, etc. can all be considered emergency events. These types of events can generate a high demand for truck parking spaces in a short period of time [14]. Maryland constitutes an example that the importance of emergency truck parking has been taken into consideration and emergency truck parking is already in operation. MDOT considered necessary the existence of these locations during 6+ inch snowstorms for reducing the number of illegal parking on ramps and roadsides [15]. Moreover, an up-to-date event that emphasizes more the necessity for having environments for an unexpected event is the decision of Missouri to allow truck parking at weight stations during COVID-19 emergency [16]. Truck parking was allowed at all weight stations in order to reduce searching time, as long as it did not disturb the operations of the facility and without stopping the operation of the stations.

Prior studies have inspected the effects of interrupted freight transportation, however none of them include any solution related to the parking locations and the need for stop and rest in an emergency. For instance, Chang (2000) investigated the impact of natural disaster to freight transportation in the Port of Kobe [17]. Another worth mentioned study from Satoshi Tsuchiya (2007) presented the impact of transportation network disruptions and the transport-related losses based on two different scenarios [18]. Research by Grenzeback and Lukmann (2008) examined the economic impacts on the transportation sector during Hurricanes Katrina and Rita and focused on freight transportation [19]. Brown (2009) concluded that evacuation routes and emergency preparedness were necessary when examining the transportation sector in the event of a natural disaster but found that little or no attention had been paid to freight transportation at either the state or county level [20].

2.1 FIXED-TIME CONTROL WITH COORDINATION

Under fixed-time control, each controller has a predetermined timing plan. Fixed-time control is based on past traffic surveys and does not timely respond to real-time traffic conditions. Two strategies are generally employed to develop timing plans for an arterial street: progression-based methods (bandwidth maximization) and flow profile methods (delay and stops minimization). Green bandwidth maximization is essentially a geometry problem, which manipulates cycles in time-space diagrams to enable network intersecting coordination [22-23]. Morgan and Little et al. first formulate the bandwidth maximization optimization as a mixed-integer linear programming problem [24]. Little, 1966 & Little et al., 1981 develop MAXBAND to an arterial and network by adding cycle constraints [25-26]. Decades later, many extensions were introduced based on the original method and insights. Gartner considers the specific features of each link and develops MULTIBAND, which optimizes all the signal control variables and bandwidth progressions on each roadway segment [27-28]. PASSER V, developed by Texas Transportation Institute (TTI), explicitly optimizes over the set of possible phase sequences to maximize progression or minimize total delay. PASSER V works smoothly under both undersaturated and oversaturated traffic conditions [29].

Bandwidth optimization techniques use a portion of traffic data (e.g., traffic flow, signal spacing, and travel speed) to determine the widest progressive band. Still, it lacks consideration of the presence of queues and may result in a relatively long cycle length due to the single objective. The flow profile method generally attempts to minimize the total delay or the total number of stops in the roadway network by delay-offset relationship and then compute the offset required for progression. P.D. Whiting first uses the delay-offset relationship and applies network topology theory to derive the network offsets [30] The method is further improved by incorporating disaggregate and dynamic programming technique [31-32].

Example of flow profile method includes TRANSYT-7F and Synchro. TRANSYT-7F uses a hill-climbing algorithm to determine the offsets that minimize the network performance index (PI), which includes delay, progression, stops, fuel consumption, queuing, and throughput. Still, its performance relies significantly on the initial fed, such as initial choice of splits, pre-specified phase, and minimum green time [33].

Synchro combines the queue length and delay estimates from the Highway Capacity Manual (HCM) with a traffic flow model without modeling platoon dispersion effects to recommend whether signals should be coordinated and to adjust the offset [34].

2.2 ACTUATED CONTROL

The controller senses traffic conditions and collects real-time information through detectors. For vehicle-actuated and traffic-actuated control programs, the most used detector is the inductive loop detector [35].

If the vehicles' gap is more significant than a pre-determined maximum gap, the control program can decide to terminate the green phase and switch to the next phase. Based on the detector's location, vehicle actuated control can be divided into semi-actuated and fully actuated. The former has loop detectors implemented on the minor approach only and gives the green time when arrivals on the minor approach meet the pre-determined threshold. The latter implements loop detectors on all approaches and serves switch and green extension [36].

In networked control, the coordination between actuated controllers follows the same logic as the fixed time controllers. To ensure that traffic-actuated controllers return to the coordination phase in time, either floating or fixed forced off is used to force the termination of the uncoordinated phases. The forced-off point for each non-coordinated phase refers to the point in one cycle where each phase must terminate to ensure coordination at an appropriate time. The main difference between the two depends on whether another uncoordinated phase can use the excess time from the uncoordinated phase. This approach applies to the arterials or networks where there are significant gaps in traffic volumes on major and minor roads and where traffic volumes are below capacity [37].

2.3 ADAPTIVE CONTROL

In the traffic control field, no universal solution fits all situations. Traffic patterns depend on various external factors such as time, weather, and unpredictable situations such as accidents. These factors used to be indirectly considered in the adaptive traffic control system. However, the emerging artificial intelligence environment in transportation, such as the internet of things (IoT), vehicle-infrastructure communication, and deep learning, make this idea a better implementation in this era. With progressive censoring and data collection techniques, the system can capture real-time situations and adjust the signal timing accordingly. Although there are many ways to do this, achieving optimization control aims to maximize traffic flow through the network, minimize total delay, and maintain the appropriate saturation rate.

Numerous adaptive systems have arisen over the past decades, which have seen varying deployment and coverage levels in the literature. Split Cycle Offset Optimization Technique (SCOOT) is a centralized system based on data collected from far upstream detectors. It uses the TRANSYT (TRAffic Network StudY Tool) optimization method and prediction algorithm to produce cycles, offsets, and splits e to maintain the saturation rate of the intersection around the "ideal" value (typically 90 %). The changes are gradual and thus less likely to overreact a situation, but it suffers extensive calibration work [38-39].

Sydney Coordinated Adaptive Traffic System (SCATS) utilizes a distributed, hierarchical system with central, regional, and local control strata to perform a large-scale network control. It uses detector data to calculate "degrees of saturation" and "link flows" under high volume scenarios and low volume scenarios, respectively, to adjust timing plans in three separate heuristic processes to reduce total delay [40-41].

Optimization Policies for Adaptive Control (OPAC) differs from previous control strategies in eliminating loops, offsets, and split constraints. Instead, OPAC has developed its phase-switching logic for local intersection control. OPAC generally maximizes the number of vehicles passing through an intersection by considering the saturation rate and the space available for storing vehicles on each link. Coordination is achieved by using "virtual cycle lengths." OPAC minimizes performance by continually optimizing the system rather than periodically updating local controller settings [42-43].

Real-time Hierarchical Optimized Distributed Effective System (RHODES) is a hierarchical traffic control system to optimizes timing plans on a chosen performance measure, such as average delays, stops, and throughput. RHODES uses data collected from upstream and stop-line detectors for each approach to calculate loads on links and predict future platoon sizes and route choices [44-45].

Then the controller at the intersection uses all the data and constraints to decide whether to change phases [46]. Varaiya et al. (2013) introduced the max pressure (MP) algorithm to reduce the risk of over-saturation and maximize the network's throughput by minimizing the pressure for a signalized network with multiple intersections. The 'pressure' of a phase is defined as the difference between the total queue length on incoming and outgoing approaches, which indicates the degree of imbalance of inflow and outflow of the corresponding approach through the intersection. The larger pressure is, the more unbalanced the distribution of vehicles is. Green time is given to phases with the most pressure to release [47]. Although the algorithm requires only queue information at the intersection and has been tested in simulation under various cases, it still relies on assumptions to simplify the traffic condition. It does not guarantee optimal results in the real world [48-49].

Dynamic optimal real-time algorithm for signals, queue-based heuristic (DORAS-Q) is a real-time, traffic responsive control applied to isolated intersections. When making a switch decision, the controller chooses the phase with the highest efficiency, which is calculated based on the existing queues, short-term predictions for the current approach arrivals rates, and average historical arrival rates for other phases. DORAS-Q is much less data demanding but does require knowledge of the existing queues and near-term traffic arrivals [50].

2.4 SUMMARY OF OPTIMIZATION OBJECTIVES

The purpose of this research is to conduct a statewide truck parking study that will specify a set of pre-identified alternative locations for emergency truck parking, identify the needs across the state, promote partnerships, with local government and private sector, enhance safety, reduce congestion, and improve efficiency on the Florida Freight Network. An emergency situation could be considered as a long-term duration or a short-term duration, however, in both categories, it is of great importance to manage the movement of vehicles in the network. Heavy rains, storms, flooding, hurricanes, and evacuation are some of the reasons that make the state of Florida prone to facing emergency situations more often. Increasing the number of parking in the whole state does not constitute a sustainable solution in terms of cost and space availability. Based on this, this project is proposing to create smaller facilities or to utilize the existing facilities more efficiently to reduce the cost, space, and travel time, in addition, to ensure the drivers' safety.

Moreover, the necessity of emergency parking is not only related to natural disasters conditions but also at the occurrence of any emergency situation such as vehicle mechanical failure. Stopping the truck on road, shoulders, or any inappropriate location will result in congestion that can last for hours causing a critical disruption in the network. The lack of nearby parking options can lead to illegal parking or even in an accident. American Transportation research institute (ATRI) has indicated that in five different states, 43% of truck drivers park on a highway ramp and/or shoulder. By increasing the number of possible parking locations and providing the information to drivers the amount of illegal parking, will be reduced (2018).

3.0 FRAMEWORK FOR IDENTIFYING EMERGENCY TRUCK PARKING LOCATIONS IN FLORIDA

The objective of this work is to identify all the possible truck parking locations that can be used under emergency situations in the state of Florida. For that purpose, a suitability analysis model will be developed, using ArcGIS platform. The model then will output all the possible parking locations based on collected and modified input data as described below.

For achieving this, methodology is separated in two phases, the phase one is the data collection and management and the second one the suitability analysis. With regards to phase one all the historical data about natural disasters and extreme weather conditions that happened in the state of Florida over the past decade were collected. Also, datasets with crashes related to freights, pre-existing truck parking locations (public and private) and gas stations were collected. The objective of this phase is the depiction of the current transportation network concerning the available facilities and infrastructure. Combining the data of the current transportation network with the events happened during previous extreme weather conditions is going to be the next step for building the suitability analysis model.

The final data from the first phase that were used as input for the suitability model are described below:

- Pre-existing truck parking locations (public and private)
- All the available parking locations in Florida (e.g., stadiums, supermarkets, warehouses etc.)
- Evacuation area by FDOT
- Gas stations
- Freight crashes during disruptions
- Amenities facilities:
  1. Telephone facilities
  2. Hospitals – Pharmacies
  3. Food supply areas (restaurants, fast foods, café, supermarkets, bakeries, kiosks)

4. Places of residence (hotels, motels, hostels)
5. Public restrooms
6. Drinking water facilities

The main sources for the collected data were the FDOT and the Open Street Map (OSM). Specifically, data as the pre-existing truck parking locations, locations of gas stations and locations of accidents related to freights were provided from the FDOT, whereas data like the available parking locations, evacuation area and locations of amenities facilities were extracted from the OSM data source. These data were modified and organized accordingly in Python 3.7 or ArcMap and CPU 1.60GHz, 1.80GHz.

The second phase of the methodology part includes the development of the suitability analysis model applying the modified data that were mentioned above. Due to the high volume of data, the suitability analysis was conducted in ArcGIS Pro software. Suitability analysis is a geoprocessing tool in ArcGIS Pro for allocating optimum locations for a facility based on input data and weighted criteria. The scope of this research was the construction of an adaptive model in which the above-mentioned datasets could be used accordingly based on the drivers' needs. For that reason, different scenarios were run and analyzed based on their input data. More specifically, five scenarios were created applying different parking selection criteria to each one of them. The implementation of different scenarios was achieved in order to ensure that the drivers would have enough available parking options according to their current location and needs. Since this study refers to the development of an adaptive model, different criteria were applied using the same model format. An illustration of this research's adaptive model, using different criteria, is demonstrated in **Figure 1**.

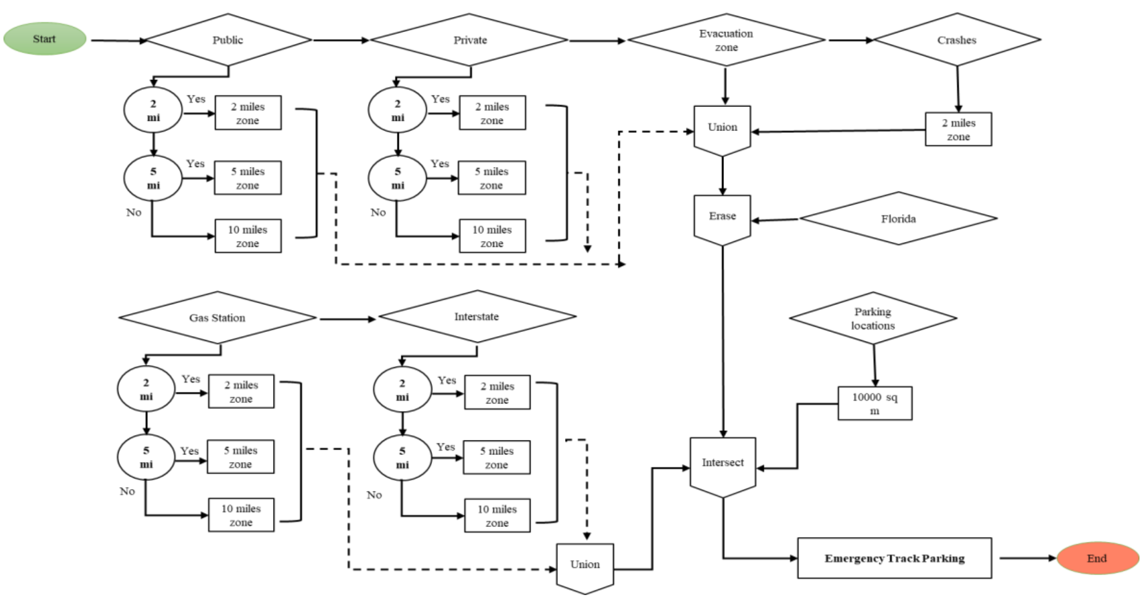


Figure 1. Adaptive Model Illustration

In the above figure the first step for constructing the suitability analysis model is the creation of zone areas around the public and private parking, the crashes, the gas stations, and the interstates' locations. As regards to crashes dataset, all the crashes events related to hurricanes that happened in the state of Florida over the past decade were extracted and applied to the suitability analysis model. Since this is an adaptive model, different zone areas could be created and simulated. For this study, the model was chosen to be simulated by creating 2, 5 and 10 miles zone areas around the input layers (datasets). Particularly, the model begins with creating zones around the private and public parking locations (2, 5 or 10 miles zone) and the crashes locations (2 miles zone). The following step is the combination of those layers' created zone areas with Florida's evacuation area (Union) and their removal from the Florida state layer (Erase). This approach was chosen because the dangerous areas had to be excluded as the main point is to direct drivers to safe zones. Moreover, two additional significant datasets, the gas stations, and the interstates, were used for the model's construction and furthermore for the parking identification. In those layers, zone areas (2,5 or 10 miles) were also created and combined (Union).

During an emergency situation the drivers' safety is always a priority. For that reason, the identified new truck parking locations should be close to the gas stations and to the interstates for immediate and safe evacuation. As a final layer of the model, all the existing truck parking locations in the state of Florida were used. Since this layer includes parking with various dimensions a decision was made for excluding those whose area is less than 10,000 m^2. Based on truck parking standards, a legal area for parking a truck should be grater than 100 m^2 specifically, the dimensions of each truck parking space should be 15' wide x 80' long according to FDOT's manual for design parking facilities [21]. In this model the truck parking areas were chosen to be above 10,000 m^2 for supporting a considerable number of trucks under emergency situations (more than 100 trucks). Finally, all the modified layers from the previous processes were combined for calculating their intersection (Intersect) and output the layer with the identified truck parking locations. In a more general point of view, the model creates suitable and non-suitable zones based on users' preferences, excludes areas that can be considered dangerous and inaccessible, and detects all the available parking locations at easily accessible areas.

3.1 DEVELOPMENT OF A FLUID DYNAMIC MODEL FOR WAITING TIME AT SIGNALIZED INTERSECTIONS

Fluid Dynamic model of the waiting time at general intersections signal control is developed. The recursive model minimizes the total passenger car equivalent vehicle waiting at the intersection. The model captures the effect of signal on vehicle waiting for all approaches and for all successive cycles. In this section, we start from the analytical model of DORAS (Wang et al., 2017).

Assume there is a finite set of signal phases for allocation of traffic right of way (ROW) to avoid vehicular traffic conflict at the intersection and improve intersection performance. Both upcoming vehicle arrivals and the present approach queueing are believed to be known continually. The green signal switches between phases. Each phase grants the ROW to a fixed set of approaches, and traffic from approaches in the same phase concurrently moves through the intersection. For example, a phase may grant green indications to both through and left-turning traffic from a direction. Furthermore, only one signal phase is ever given the right of way via green signals, while all other phases' signal indications are always red. An all-red period is typically required between any two phases for intersection traffic clearance and safety but is not necessarily so, such as in the lagging phase.

All the lost effective green time due to the signal switch is incorporated in the all-red interval. The discharge process is assumed to be known under the queueing and traffic arrival condition with a given signal indication. There are pre-defined rules, such as minimum and maximum green times for each phase or a predetermined order for the stages. In a special case, the set of rules is empty, which implies the maximum potential for intersection efficiency. This predefined set of guidelines considers actual application. A control policy decides on the sequence and durations of the phases. The control objective is to find a policy that minimizes the average vehicle waiting time at the intersection.

Instead of considering queue dynamics, we directly consider the waiting time dynamics in the study. The waiting time of an approach of an intersection can be describe in Equation (1). $\mathrm{w}^{\theta}(\boldsymbol{n}, t)$ the total intersection vehicle waiting time from time t to the end of control time horizon, given green phase π_k at time t and changes to π_{k+1} at $t^{\dagger}$, pivotal point of signal, where $t^{\dagger} \in [t, T]$.

$$\begin{aligned} \mathrm{w}^{\theta}(\boldsymbol{n}, t) = &\sum_{\forall i} \int_{T}^{t^{\dagger}} \left(n_i + \int_{t^{\dagger}}^{t} \lambda_i^{\theta}(\tau_1) d\,\tau_1 - \int_{t^{\dagger}}^{t} d_i^{\theta}(\tau_1) d\,\tau_1 + \int_{\tau}^{t^{\dagger}} \lambda_i^{\theta}(\tau_1) d\tau_1 - \int_{\tau}^{t^{\dagger}} d_i^{\theta}(\tau_1) d\,\tau_1 \right) d\tau \\ &+ \sum_{i} \int_{t^{\dagger}}^{t} \left(n_i + \int_{\tau}^{t} \lambda_i^{\theta}(\tau_1) d\tau_1 - \int_{\tau}^{t} d_i^{\theta}(\tau_1) d\tau_1 \right) d\tau_1 + w^{\theta}\left(\left(\boldsymbol{n_0} + \int_{T}^{t} \lambda^{\theta}(\tau_1) d\tau_1 - \int_{T}^{t} d^{\theta}(\tau_1) d\tau_1 \right), T \right) \end{aligned} \tag{1}$$

Where (n, t) is the intersection state variable, $\boldsymbol{n} = \{n_i\}$ is a set of vehicle queues for multiple approaches. n_i represents vehicle queue length for approach i. t represents the time before the end of the control horizon.

θ is the control policy that determines signal switch from one approach to another during the entire control horizon., in which $t^{\dagger}$ is a switch point for phase π_k to switch to phase π_{k+1}. The policy allows, but does not require, an all-red interval for a phase change. The logic is illustrated in Figure (1)

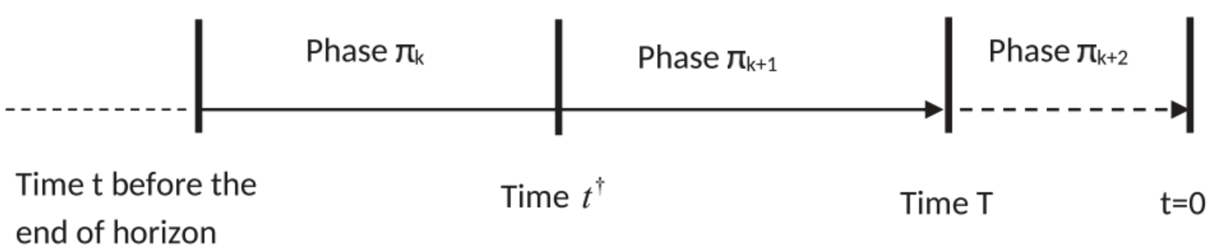


Figure 2 A policy over a control horizon

$\lambda_i^{\theta}(t)$ is the arrival rate from approach i under policy θ.

$d_i^\theta(t)$ the discharge rate from approach i under policy θ. The discharge rates are assumed to be continuously monitored and can be known through sensors at the intersection. For approach i, the discharge rate is

$$d_i^\theta(t) = \begin{cases} s_i & \text{the saturation flow rate when signal is green and when a queue exists} \\ 0 & \text{when the signal is red} \\ \lambda_i^\theta(t) & \text{when signal is green and when no vehicle queue is present} \end{cases} \quad (2)$$

$w^\theta(\boldsymbol{n_0}, t)$ the salvage waiting time at time T with a resultant state $(\boldsymbol{n_0}, t)$. For modeling, we assume t and T are both given.

In Equation (1), the first term is for waiting time after the pivotal point $t^\dagger$ till T when green phase switches from π_k to π_{k+1}. The big parenthesis within integral is for the total waiting vehicles at time $\tau \in (t^\dagger, T)$. The second integral is for waiting time before the pivotal point $t^\dagger$ till t. The third term is a salvage value term, which also has to do with the choice of pivotal point $t^\dagger$ because $t^\dagger$results in the queue $\boldsymbol{n_0}$ at time T.

3.2 PERFORMANCE ASSESSMENT USING ZONE-BASED SCENARIOS

To evaluate the model's effectiveness, different scenarios were run and are presented in the results part. The radius of the created zone areas was chosen to be 2, 5 or 10 miles as mentioned in the methodology part and after discussions with the stakeholders for each scenario. As indicated above, the goal of this research is the creation of an adaptive model where the input data and the applied criteria will vary based on the emergency. In order to evaluate the efficiency of the model, five different scenarios were applied with the first four referring to the radius of the zone areas and the last one being more realistic as it includes most common evacuation zones in the state of Florida based on FDOT. The results from the scenarios are presented in **Table 1.**

Table 1 Results of model for the different scenarios

Total existing parking		30404				
Total existing parking >10000 m^2		3123				
	New Parking Criteria	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Distance	Existing private parking	10 miles	5 miles	2 miles	10 miles	10 miles
	Existing public parking	10 miles	5 miles	2 miles	10 miles	10 miles
	Crashes	2 miles	2 miles	2 miles	2 miles	2 miles
	Gas stations	10 miles	5 miles	2 miles	2 miles	5 miles
	Interstates	10 miles	5 miles	2 miles	5 miles	5 miles
	Evacuation Zone	-	-	-	-	Yes
Total proposed parking		**317**	**1324**	**1938**	**258**	**176**

The data analysis and management phase led to the results that the total number of pre-existing parking areas in the state of Florida corresponds to 30,404. Although this is a considerable large number for parkings, only 3,123 of them are greater than 10,000 m^2, in which more than 100 truck parking spaces are available. It is obvious that the available infrastructure was not appropriately constructed for meeting freight vehicles requirements and for that reason large areas were chosen as models' inputs in order to reduce the possibility of drivers parking their vehicles in unsafe and illegal places. The initial number of the parking locations along with the created zone areas around the locations of the existing public and private parking, the crashes, the gas stations, and the interstates are the inputs for the scenarios 1, 2, 3 and 4. As presented in **Table 1** combining with **Figure 1**, in Scenario 1 an area with a radius of 10 miles around the private and public parking locations was excluded for the final identification of the truck parking areas. This means that the proposed truck parking locations will be located at least 10 miles away from the existing private and public parking.

Furthermore, an area with a radius of 2 miles around the locations of the crashes was also excluded since the proposed new truck parking areas should be placed at a fair distance from them. However, the proposed emergency truck parking locations should be located close to the gas stations and the interstates to ensure that the truck drivers will safely evacuate the interstates avoiding serious accidents and ship the cargo successfully after an emergency event. For that reason, the proposed truck parking should be in an area with a maximum radius of 10 miles around the gas stations and the interstates. Applying these criteria and running the model, ArcGIS Pro proposed 317 truck parking locations which can be used under emergency situations. This can be considered an adequate number of parking locations that can be used from trucks during an emergency event. For Scenario 2, the radius of the excluded areas (private and public locations) was deducted to 5 miles, whereas the radius of the area around the locations of the crashes remained immutable. The radius of the zone area around the gas stations and the interstates was also reduced to 5 miles. This Scenario resulted in 1,324 truck parking locations, which is a considerable higher number than the one in Scenario 1. This arose from the fact that the radius number of the excluded zone areas was significantly reduced (from 10 miles to 5 miles), thus the options for the possible truck parking were increased. The result of Scenario 3 follows the same logic with Scenario 2 and proposed 1,938 parking locations surpassing the number of the proposed locations of Scenario 2.

The increasing trend of the proposed truck parking locations, moving from Scenario 1 to 3, can be easily observed since the radius of the excluded zone areas is becoming smaller. At the same time reducing the radius of the zone areas around the interstates will help drivers to evacuate them safer and faster in their quest to find available parking. Scenario 4 or else referred as the mixed scenario was created in purpose of observing results by mixing criteria of the previous three scenarios and making the model more realistic. At the same time this scenario confirms the conclusions from the first three scenarios together, that excluding large areas around the existing private and public truck parking locations and considering that drivers will not drive more than 5 miles from the interstates for finding a parking location, result to the lowest number of parking. This scenario can be also considered as a test for the integrity of the model's results.

The last scenario or else the emergency scenario includes all the information from Scenario 4 along with Florida's evacuation zone area layer. Florida state authorities consider this zone more vulnerable to evacuation based on historical events so excluding locations that belong to these zones, will result 176 extra parking locations for the trucks. In a real-time model evacuation zone layers can be replaced or combined with hurricane track zone, flooding zones, fire zones etc. Regarding the amenity's facilities were mentioned in the methodology part, it was emerged that

2,161 out of 3,123 parking locations were within a walkable distance (0.25 miles) from them, and thus, they could be easily accessible to truck drivers for meeting their needs. Finally, taking into consideration that each parking location can accommodate at least 100 trucks, executing the model can ensure available parking to more than 2,000 vehicles. In **Figure 3** is presented the normal distribution of the available parking spaces based on Scenario's 5 results.

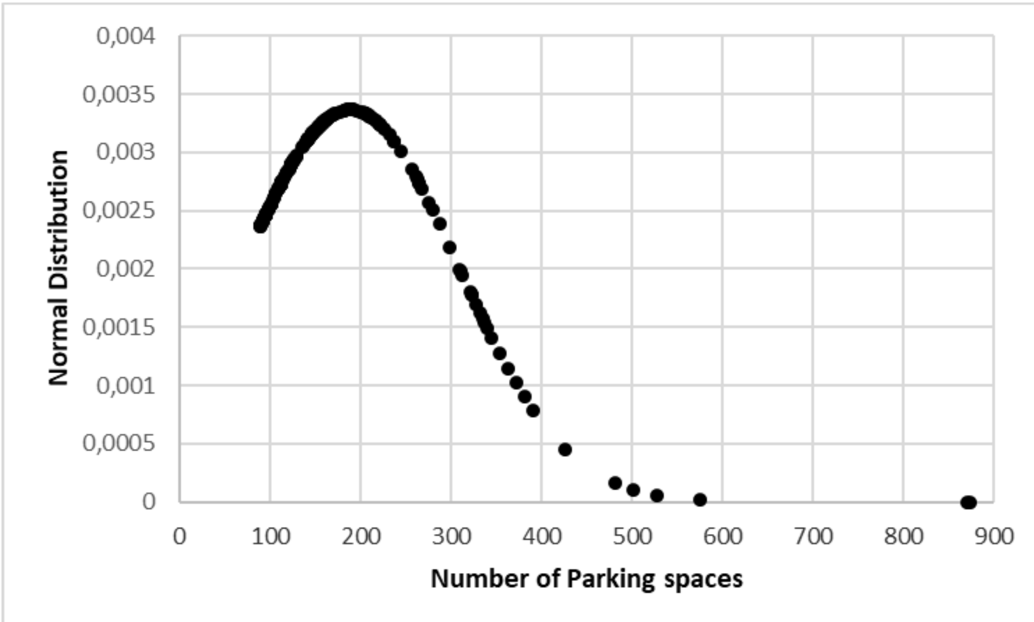


Figure 3 Normal distribution of emergency parking location on scenario 5

The above figure describes the average number of truck spaces for each identified emergency parking locations with respect to the density probability. Intuitively, it shows the chance of obtaining values near corresponding points on the X-axis. It can be observed that most of the identified parking possess around 200 spaces. The minimum number of available spaces of the proposed parking locations is close to 100 whereas the maximum is more than 850. Taking into consideration the mean value of the total spaces of the proposed parking locations for Scenario 5 it was emerged that these locations could be a shelter for around 35,000 truck vehicles during emergency events. This means that the transportation network will be able to remove, within a short time, a significant number of trucks while reducing traffic and mitigating the demand and overutilization of truck parking.

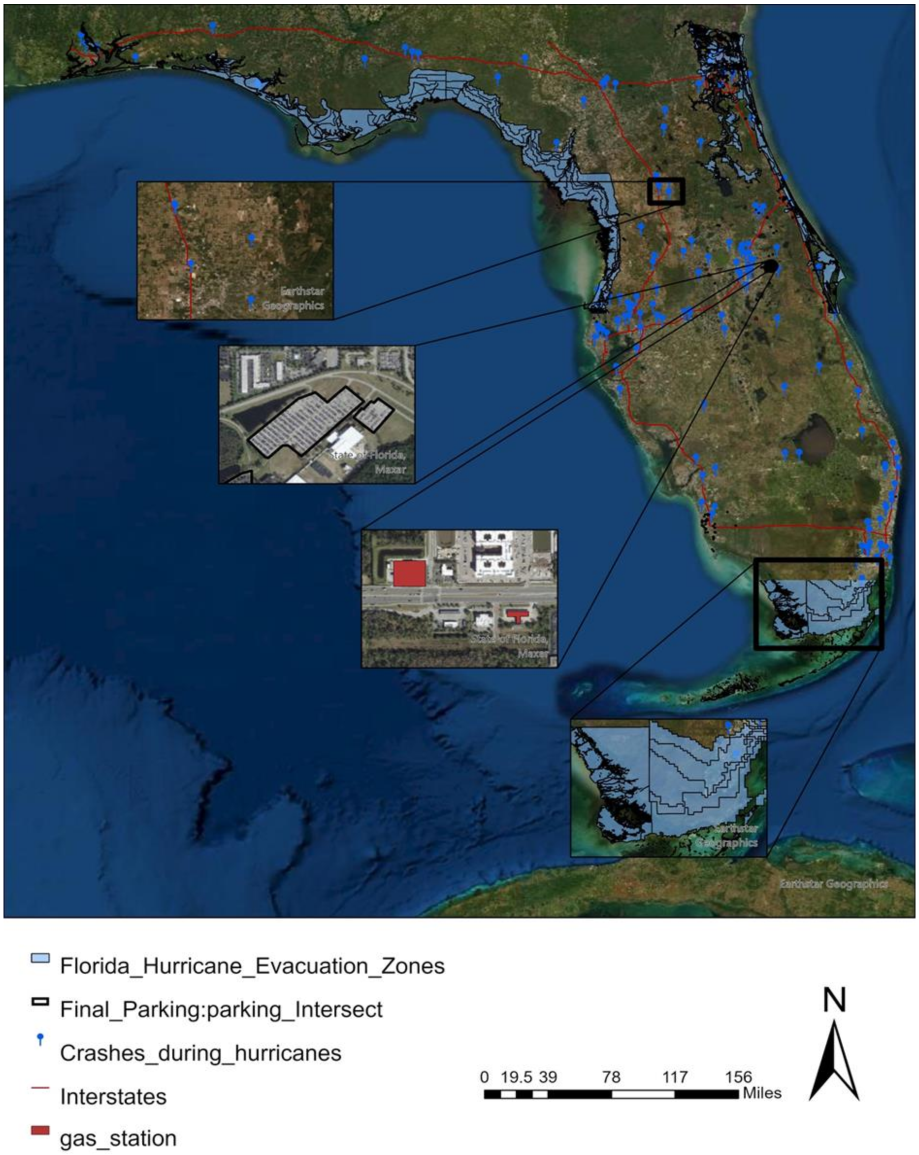


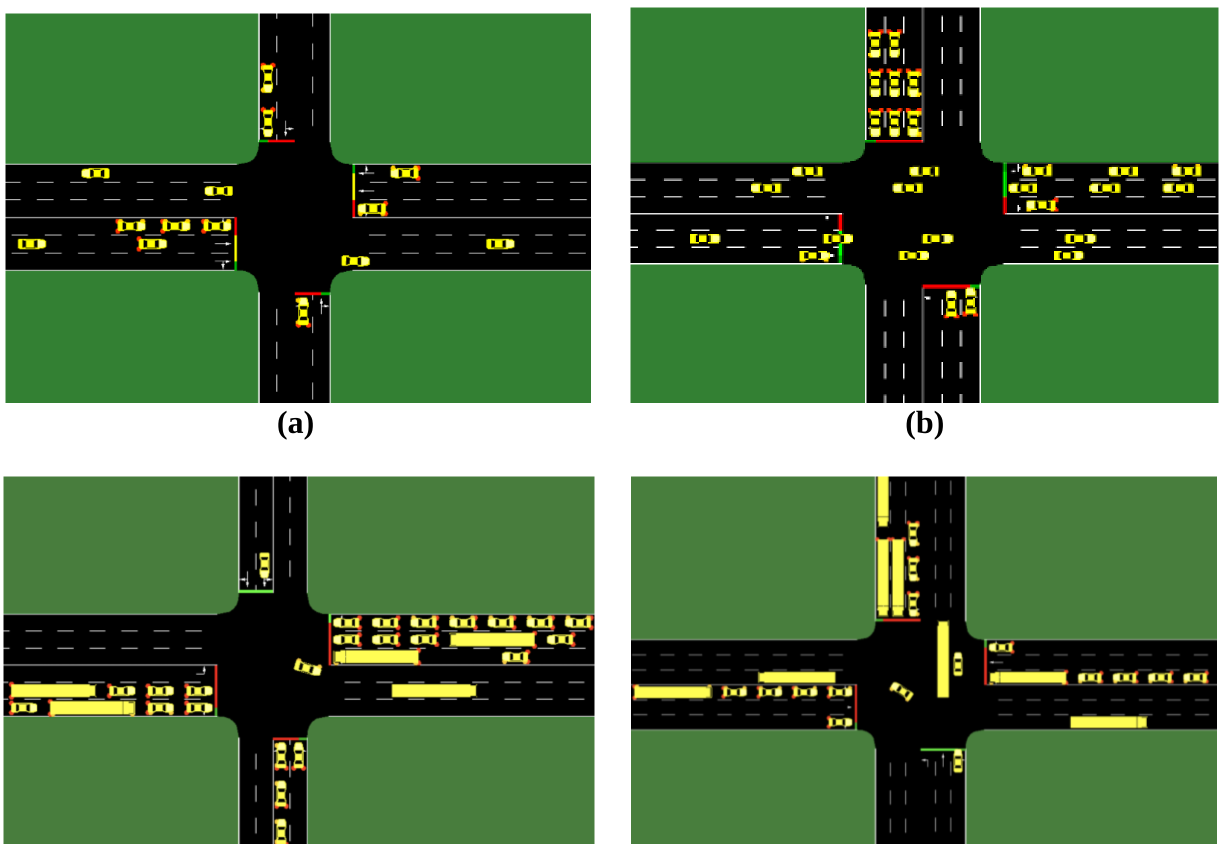
Figure 4 Map with the initial data and results of the model

For a better understanding of the input layers and the proposed truck parking locations, a map with the representation of those is presented in **Figure 4**. Specifically, **Figure 4** describes the map with some of the initial input layers used and the parking results of Scenario 5. Because of the small size of the emergency parking locations, the gas stations, and the crash locations, compared to the state's dimension, some random points were chosen to be presented in detail. On the map below the main interstates can be distinguished with a red line which are also the main transportation arteria for trucks. The blue points represent the exact location of accidents during the past decade caused by hurricanes and tropical storms. Furthermore, the gas stations are identified and described by red polygons. With black polygons are depicted the emergency parking locations that meet all the above mentioned criteria of Scenario 5. Finally, the evacuation zone area of the Florida state is represented on the map with a light blue color, and it is located around the perimeter of the state.

4.0 SIMULATION-BASED PERFORMANCE EVALUATION ON ARTIRIAL AND GRID NETWORKS UNDER VARIED TRAFFIC CONDITIONS

4.1 CONFIGURATION OF SIMULATION SCENARIOS

Numerical tests are conducted on two types of networks: a single corridor and a grid network. The reason for separately testing on a single corridor is that single corridors are often the major means of dealing with urban traffic. We have utilized the SUMO 1.8 micro-simulator in conjunction with TraCI (Traffic Control Interface) 1.8 for modeling both the cases. SUMO (Simulation of Urban MObility) is an open-source, microscopic and continuous traffic simulation package designed to handle large traffic networks simulation with a large set of tools for scenario creation (Ma et al., 2022). SUMO allows us to create a traffic simulation environment and track every vehicle. TraCI implements the real-time signal control possible. In this study, the algorithm is realized by Python 3.8.

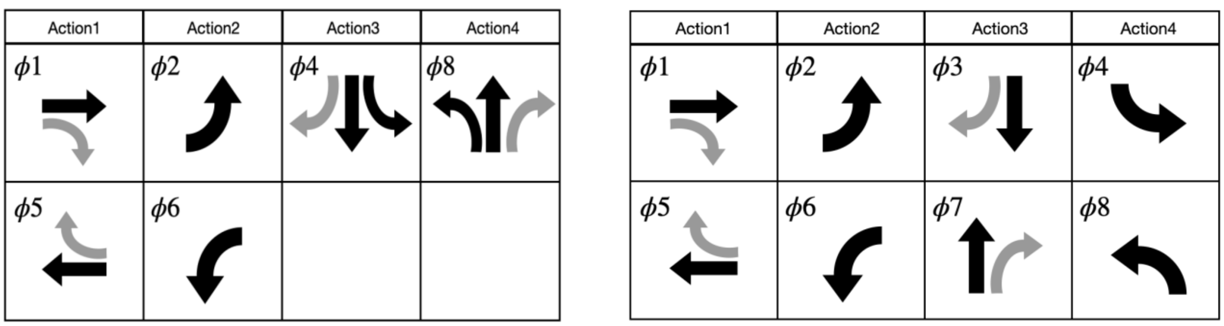


(a) **(b)** **(c)** **(d)**

Figure 5: Intersection simulation environment

Figure 5 (a) and **(c)** presents the layout of an individual intersection of major and minor arterial without and with truck volume, respectively, in the simulation network. **Figure 5 (b)** and **(d)** present the intersection of two major arterials, without and with truck volume, respectively. The link on minor arterial at each intersection consists of two through lanes. Each of the through lanes also servers the turning traffic. The link on major arterial at each intersection consists of one left-turn lane and two through lanes. One of the through lanes also servers the right-turning traffic. In reality, there are singular dominating corridors that can be easily identified.

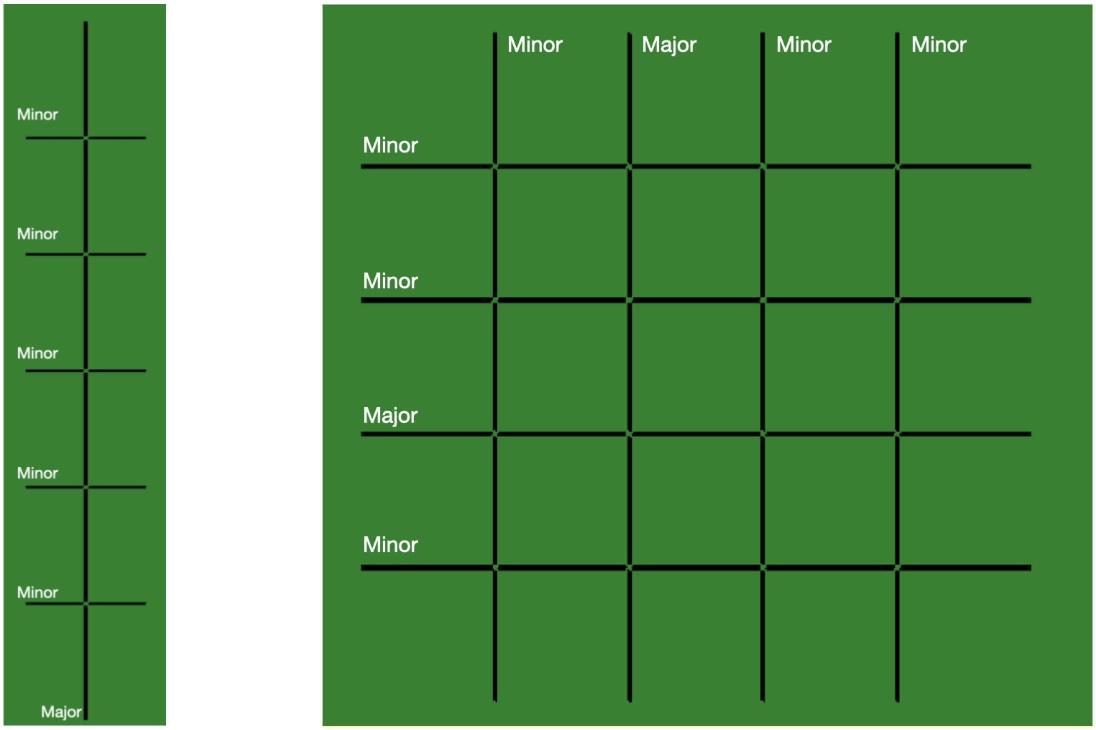
Figure 6 (a) presents the available phase timing plan for the intersection of major and minor arterial, and **(b)** shows the one for the intersection of two major arterials. The phase plan also contains the available action for selecting the phases. The amber interval is set as 5 seconds and represents the time between two consecutive phases to clear the intersection, consisting of 3 seconds yellow and 2 seconds all-red interval. The min green time is 5 seconds, and the max green time is 30 seconds. The ring-and-barrier diagram is for illustrative purposes and presents the phase plan for the simulation. Notice here the phase sequence is used for test purposes. Our algorithm does not require the fixed phase sequence when implementation.



(a) **(b)**

Figure 6: Available phases in traffic signal control of the simulation

Figure 7 illustrates the arterial **(a)** and grid network **(b)** used in the simulation. The test arterial consists of five intersections and the grid network contains $4 \times 4 = 16$ intersections. The arterial in the numerical test consists of one major arterial road with higher traffic volumes and five minor roads with lower volumes. The minor street crossings spaced 1640 ft (500 m) along the major arterial with free-flow speed v_f 50 mph. The grid network in the simulation makes of two major arterial roads with higher volumes and three minor roads with lower volumes in each direction. The distance between roads, free-flow speed, and the normal travel times are the same with the arterial. Three traffic scenarios, high, medium, and low, are used for the test, as indicated in **Table 2**.



(a) **(b)**

Figure 7: Arterial and grid network environment

Table 2 Traffic volume in the simulation

Traffic Scenario	Major Roads(veh/h)	Minor Roads(veh/h)
Low	500	200
Medium	900	300
High	1300	400

Also, in each scenario, the effect of different truck ratios (0%, 10%, 25%, and 40%) on each control algorithm was tested simultaneously for the same major and minor traffic volume scenarios. The research will convert truck to two passenger vehicle in the simulation (Federal Highway Administration, 2017). The vehicle type defaults are shown in **Table 3**.

Table 3 Vehicle Type parameter defaults in the simulation

Vehicle Type	Length Width Height	MinGap	Acceleration	Deceleration	Emergency Deceleration
Passenger	5 m 1.8 m 1.5 m	2.5 m	2.6 m/s^2	4.5 m/s^2	9 m/s^2
Truck	16.5 m 2.55 m 4 m	2.5 m	1.1 m/s^2	4 m/s^2	7 m/s^2

4.2 ALGORITHMS USED FOR SIMULATION-BASED TESTING

We compare our model with the Fixed timing plan with coordination and DORAS-Q.

Fixed-time: Fixed-timing plan and offsets optimized with PASSER V. Fixed timing plan with green wave progression is the most classical approach achieving coordination on arterial in practice.

DORAS-Q: DORAS-Q is designed for isolated intersection control and may be applied to the network as a distributed control system in which each intersection only optimizes its control and the entire system adapts gradually, it requires the existing queue length, short-term (usually 5 seconds) and the average historical arrival rates for each phase to estimate the switch-to efficiency and phase efficiency. Then decide on changing or keeping the current phase based on the discharge efficiency.

MaxFlow: the algorithm is designed in Section 3.3. It also requires the existing queue length, short-term estimation of input flow rate and discharge rate to calculate the efficiency for each phase and then decide on changing or keeping the current phase based on the discharge efficiency.

4.3 AGENT PERFORMANCE ON SCENARIOS WITH UNIFORM PASSENGER VEHICLE FLOW

We compare our model with Fixed timing plan with coordination, DORAS-Q and Maxflow timing plan with green wave progression is the most classical approach to achieving coordination on the arterial in practice. Fixed-timing plans and offsets are optimized with PASSER V. DORAS-Q (Wang et al., 2017) is designed for isolated intersection control, and may be applied to the network as a distributed control system in which each intersection only optimizes its control and the entire system adapts gradually. MaxFlow defines the efficiency for each phase and select the phase with max efficiency. **Table 4** illustrates the results of the simulation.

Table 4 Average vehicle delay in arterial and grid network case with uniform passenger vehicle flow (in seconds)

	Low Volume		Medium Volume		High Volume	
	Arterial	Network	Arterial	Network	Arterial	Network
Fixed-time	30.93	93.73	38.06	139.87	89.82	191.16
DORAS-Q	23.25	72.77	36.64	84.82	76.64	148.92
MaxFlow	21.49	69.23	33.94	76.65	74.62	143.24

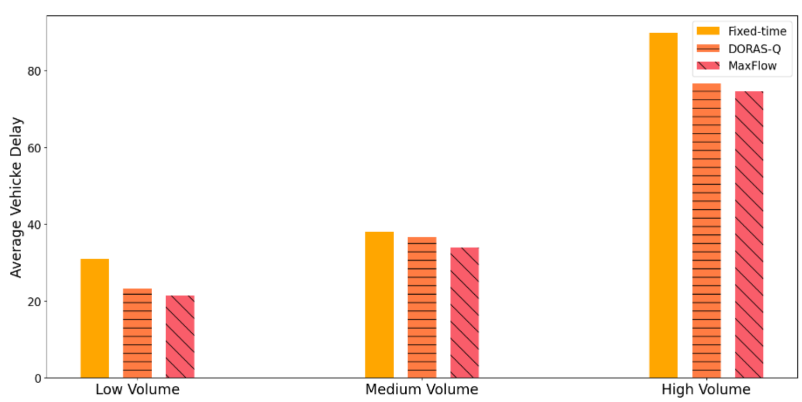


Figure 8: Average vehicle delay in arterial case (in seconds)

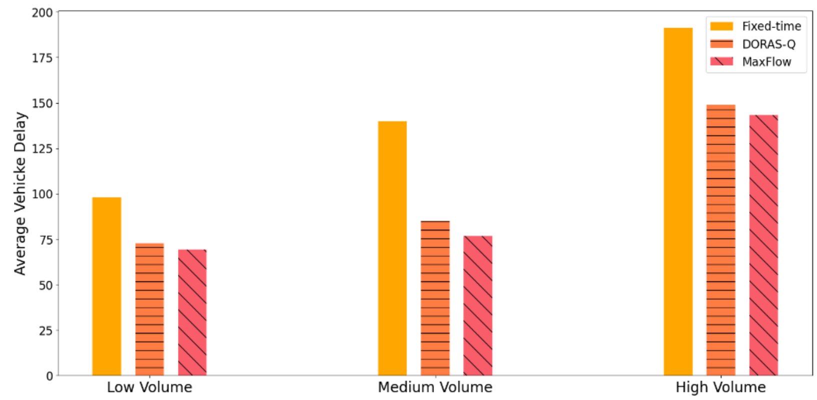


Figure 9: Average vehicle delay in grid network case (in seconds)

Figure 8 and **Figure 9** present MaxFlow outperforms the other two signal control algorithms in most of the scenarios in the arterial and grid network cases. Not surprisingly, fixed-time control performs at the bottom, but it does not stop using it as a benchmark. Under all scenarios, DORAS-Q outperform the fixed time control with coordination. Notice that, DORAS-Q and MaxFlow have similar performance in the high-volume scenario.

4.4 AGENT PERFORMANCE IN SCENARIOS WITH TRUCK FLOW

We also investigate the effect of different truck ratios (0%, 10%, 25%, and 40%) on each control algorithm. All settings are exactly the same as the uniform passenger vehicle flow case except for the different truck ratio. We also conduct the simulation in the low, medium, and high traffic flow scenarios. Specifically, the high traffic volume of 25% truck means that the traffic volume on the major/minor arterials remains at 1300/400 vehicles/hour, with 975/300 trucks/hour on the major/minor arterials and 325/100 vehicles/hour passenger vehicles on major/minor arterials, respectively. When calculating the queue, we assume a truck equal two and half passenger vehicles.

4.4.1 Agent Performance with 10% Truck Volume

Table 5 illustrates the results of the simulation under all scenarios with 10% of truck volume.

Table 5 Average vehicle delay in arterial and grid network case with 10% truck volume (in seconds)

	Low Volume		Medium Volume		High Volume	
	Arterial	Network	Arterial	Network	Arterial	Network
Fixed-time	36.96	99.26	52.72	153.79	132.38	226.39
DORAS-Q	28.87	74.82	49.76	96.09	130.47	184.25
MaxFlow	25.92	62.44	41.27	92.43	121.67	171.28

Figure 10 and **Figure 11** present MaxFlow outperforms other signal control algorithms in both arterial and grid network cases. Not surprisingly, fixed-time control performs at the bottom, but it does not stop using it as a benchmark. Under all scenarios, DORAS-Q performs better than the fixed time control with coordination in terms of waiting time per vehicle.

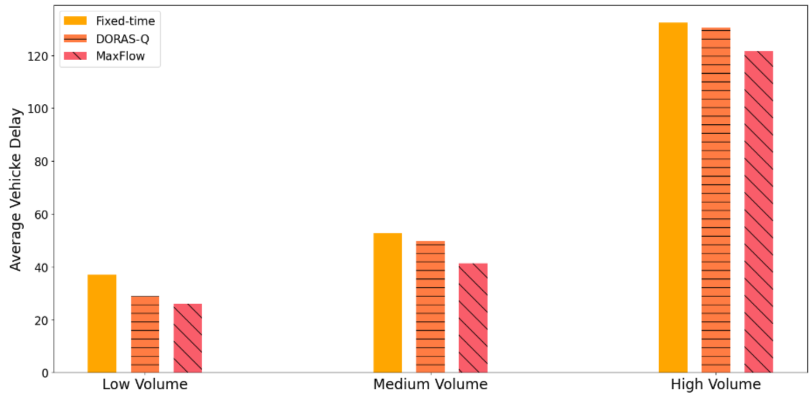


Figure 10 Average vehicle delay through the arterial with 10 % truck volume (in seconds)

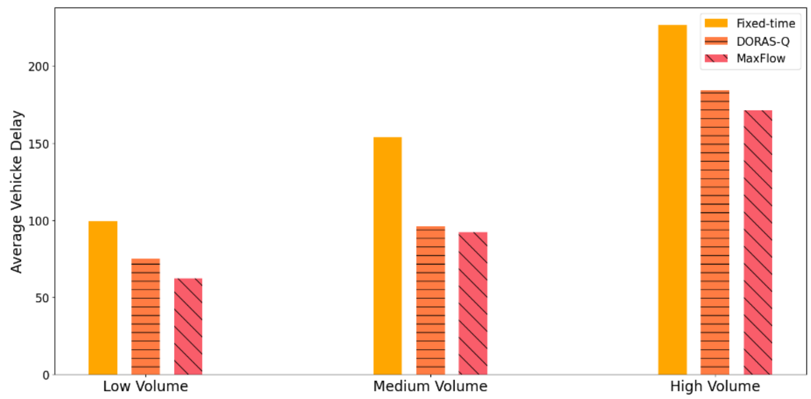


Figure 11 Average vehicle delay through the grid network with 10 % truck volume (in seconds)

4.4.2 Agent Performance with 25% Truck Volume

Table 6 illustrates the results of the simulation under all scenarios with 25% of truck volume.

Table 6 Average vehicle delay in arterial and grid network case with 25% truck volume (in seconds)

	Low Volume		Medium Volume		High Volume	
	Arterial	Network	Arterial	Network	Arterial	Network
Fixed-time	42.13	100.62	84.94	181.88	148.03	258.91
DORAS-Q	31.14	75.38	57.52	128.95	118.36	227.39
MaxFlow	30.54	69.89	50.78	119.71	116.27	227.85

Figure 12 and Figure 13 present MaxFlow performs the best in both arterial and grid network cases as well. Similar to the 10% truck volume case, DORAS-Q outperform the fixed time control with coordination.

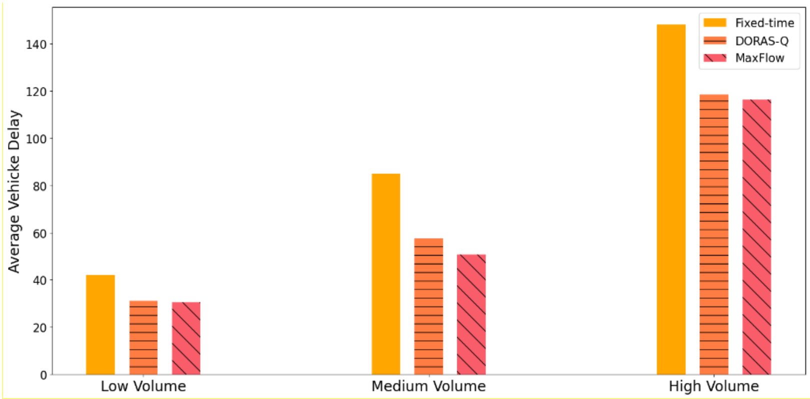


Figure 12 Average vehicle delay through the arterial with 25 % truck volume (in seconds)

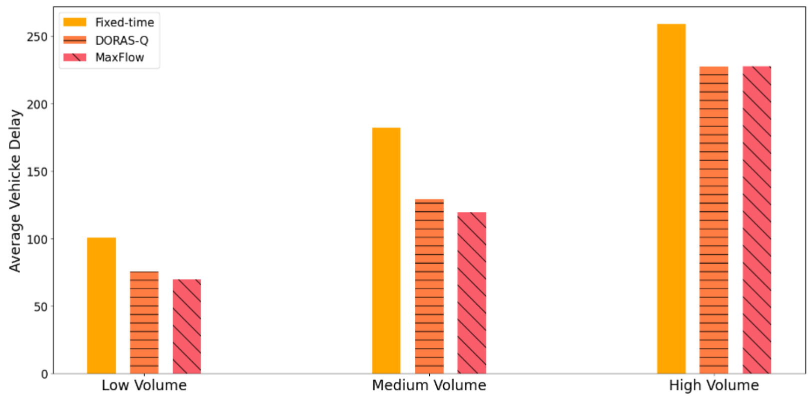


Figure 13 Average vehicle delay through the grid network with 25 % truck volume (in seconds)

4.4.3 Agent Performance with 40% Truck Volume

Table 7 illustrates the results of the simulation under all scenarios with 40% of truck volume.

Table 7 Average vehicle delay in arterial and grid network case with 40% truck volume (in seconds)

	Low Volume		Medium Volume		High Volume	
	Arterial	Network	Arterial	Network	Arterial	Network
Fixed-time	69.04	106.25	129.64	192.63	267.68	274.39
DORAS-Q	34.02	76.68	120.33	146.14	225.39	259.32
MaxFlow	31.29	59.80	117.61	128.93	217.78	254.63

Figure 14 and Figure 15 presents MaxFlow outperforms the other four signal control algorithms in both arterial and grid network cases. With higher percentage of truck volume, the algorithm also proves its efficiency.

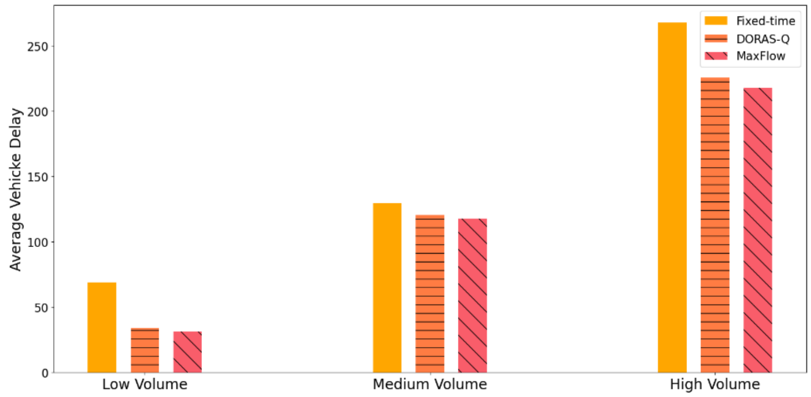


Figure 14 Average vehicle delay through the arterial with 40 % truck volume (in seconds)

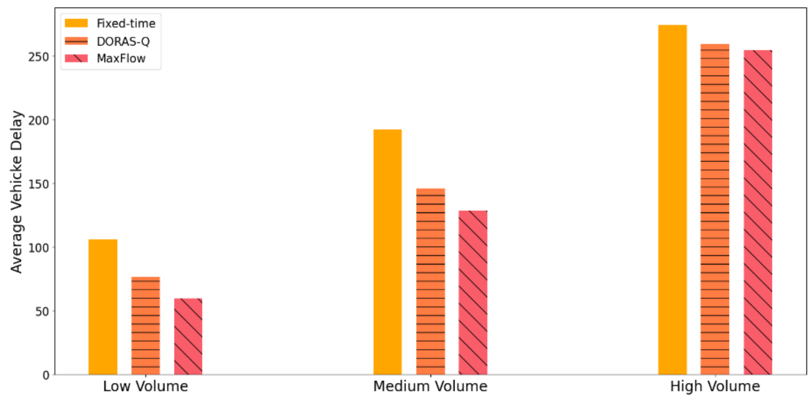


Figure 15 Average vehicle delay through the grid network with 40 % truck volume (in seconds)

4.5 KEY FINDINGS AND INTERPRETATIONS

We summarize the simulation results in sections 4.3 and 4.4. Considering the truck flow may increase, the simulation may increase the total delay at the intersection. The higher the truck volume percentage, the more delay driver may experience at the intersection with the area. MaxFlow has satisfactory performance in most of the scenarios in the arterial and network case.

The green wave undoubtedly facilitates the vehicle's movement on the arterial and gird network with signalized intersections. However, even though the green wave is added, the fixed timing design does not inherently consider the dynamic changes in traffic flow or responsiveness to the current situation at the intersection. Not surprisingly, fixed-time control performs at the bottom, but it continues using it as a benchmark.

DORAS-Q estimates the intersections' efficiency within a certain period and predicts future arrivals. However, it just focuses on two phases – the current phase and the next switch-to phase- and requires fixed sequences. The MaxFlow algorithm can be interpreted as a generalization of the DORAS algorithm. Also, the theoretical foundation for the MaxFlow algorithm is more solid, which avoid the suspicious process of taking derivative on both sides of the dynamic equation. In most scenarios, the DORAS-Q and MaxFlow outperform the coordinated fixed-time control because each intersection could utilize the arrival steam information from nearby intersections. We can see that the removal of fixed-time sequences significantly improves waiting time.

On the other hand, the truck volume may bring more impact or turbulence on the downstream traffic volume and then decrease the algorithm's performance compared with the uniform passenger vehicle flow case. Using the conversion factor to convert the truck to a passenger vehicle in the queue length estimation may need to be revised in the algorithm. Although the algorithm is based on the queue length estimation, more truck characteristics may need to consider and improve the algorithm's mechanism.

First, a truck is usually longer than a passenger vehicle. A conversion factor or truck coefficient is typically used to convert the truck to a passenger vehicle equivalent in transportation engineering. With the same traffic volume, truck traffic flow will be higher than the equivalent pure passenger vehicle flow. Second, trucks are slower to accelerate and decelerate than passenger vehicles. When trucks approach or leave the intersection, the inhomogeneous may heterogeneity the traffic flow. The conversion factor may be different when the controller decides the phase. Also, the truck volume brings more disturbance to the coverage of the RL baseline algorithms. The results variation is more considerable than the pure passenger vehicle flow case.

5.0 CONCLUSION

The high frequency of the emergency events along with the increased demand in preparation and mitigation phase of each emergency led to the fact that more parking locations should be available during non-recurrent events. However, building new infrastructure is not always the best solution for fulfilling the demand as it increases the cost and is not resilient enough to cover all the possible emergency scenarios. Creating a real-time model that can adapt its parameters base on each situation while using pre-existing infrastructure can increase resiliency and safety, fulfill the demand, and reduce the cost.

The analyzed research proposed a model to serve as director for the identification of emergency truck parking, by using parameters or criteria derived from drivers needs from previous emergency events. The results of the model revealed that in the worst-case scenario, while applying the strictest criteria for the excluded areas, the proposed parking locations could be utilized by more than 35,000 trucks. Furthermore, it was found that the proposed locations are also close to many facilities ensuring that drivers would be able to meet their needs even without using their vehicles. It was calculated that more than 2,000 parking locations are close to amenities (within a distance of 0.25 miles) although those infrastructures were not built for this specific reason. Another significant finding was that excluding areas around the public and private pre-existing truck parking infrastructure is a critical factor for changing dramatically the final number of the proposed emergency truck parking. This also led to the conclusion that most of the proposed locations are placed close to the existing truck parking system giving the opportunity to the drivers to reroute and drive in a close distance for finding available space in the appropriate locations when the first ones are occupied.

Concluding, non-recurrent events are usually very unique and need to be managed dynamically in real-time. Building emergency infrastructure is not only a high-cost solution, but also a non-adaptable one. Having such a solution (with a static position) is not always the best option for a continuously differentiated event. The hundred proposed locations by the above methodology could be life-saving and at the same time could reduce the traffic jam, the risk of accidents and the cost. Future possibilities of this research include the creation of an app using ArcGIS environment. This app will be provided to all truck drivers so that they can decide the criteria of the input layers. Based on the emergency event and the drivers' location, the app will propose the most suitable parking locations that can be utilized. In that way, each proposed parking will satisfy each driver’s personal needs and guide them through the shortest path from their current location to their parking preference.

ACKNOWLEDGMENTS

We would like to thank the Freight Mobility Research Institute a TIER 1 University Transportation Center that sponsored this research. Also, we would like to thank District 5 Modal Development Office, Florida Department of Transportation for their assistance in providing the data that were used in this research and for their advises during it.

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