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EVALUATING DYNAMIC CURB MANAGEMENT STRATEGIES IN URBAN ENVIRONMENTS

Final Report

By
Evangelos I. Kaisar, Ph.D., Professor, & Director
ekaisar@fau.edu
Freight Mobility Research Institute (FMRI)
Department of Civil, Environmental and Geomatics Engineering
Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431

Anastasios Charisis[1], Miguel Figliozzi[2], Dan Liu[3],
[1,3] Freight Mobility Research Institute (FMRI), Department of Civil, Environmental and Geomatics Engineering, Florida Atlantic University
[2] Portland State University

for

Freight Mobility Research Institute (FMRI)
777 Glades Rd.
Florida Atlantic University
College Park, MD 20742

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DISCLAIMER

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXCUTIVE SUMMARY

City curbs and sidewalks are becoming ever more crowded as ride-hail companies and delivery businesses compete for pick-up and drop-off locations, and bike-share programs and dockless scooters are present in abundance in the communities across the nation. The demand for curb has grown so rapidly that local land-use planners and regulators are struggling to create policies to keep the pace of new mobility and increased delivery needs. Advancing technology innovation, growing frustration with congestion, and increasing environmental regulation have congregated to create a demand for a wider range of services with new approaches to meet urban mobility needs. As a response to this problem, some cities have chosen to dedicate more curb spaces for pick-up and drop-off locations, but the static allocation of space is inefficient when demand types and rates fluctuate hourly and daily. This work will study the effectiveness of a robust dynamic curb management environment in urban areas to reduce urban congestion and increase mobility and accessibility. Another key objective of this study is to develop a traffic simulation module that incorporates a parking choice model to select suitable parking facilities for all the modes and further finds the optimal allocation of the curb space for various uses that the overall transportation system performance can be enhanced.

As long as there have been cities, the street has always been a place where different uses and users come together and there have been conflicts regarding the allocation of public space amongst different uses and different users. Whilst the physical nature of the curb has remained largely unchanged, the use of it has not. The advent of the private car and the growth in goods vehicle movements through the 20th century led to a very different set of demands on the curb. Before 1980 curb access demand was limited to only taxi stands, parking, loading zones, and no-parking zones, and bus stops. After 1980, the growth of package delivery services such as UPS and FedEx increased the demand for curb access. In the past five years, the demand for curb space has expanded as many new services require access to it; this includes app-based ride-sharing/hailing services such as Uber and Lyft; shared economy delivery services like UberEats, DoorDash, and GrubHub; and the expansion of Amazon into delivery services. It is not just demand for the roadway side of the curb, even the sidewalk side of the curb has seen a growth in demand from scooters, bikes, and from restaurants and cafes expanding their areas by placing tables on the sidewalk. This demand for access is overburdening the curb. While the curb of today is a contested space, it is the changing nature of the demands on the curb which make now a particularly vital time to reconsider how the curb is used. When demand is higher than supply, there is an increase in double parking, inappropriate use of loading zones, safety problems as well as poor local environments in terms of pollution and a lack of effective public space.

While the curb has been managed for decades, in the past 10 years, it has become more crowded as new users mentioned above require access to it. Curbside management is the collection of operating concepts and techniques that allow cities to effectively allocate the use of their curbs and other high demand areas. To make changes as much as possible, leading cities are adopting different policies and techniques to prioritize the safe pedestrian movement, bicycling infrastructure and reliable transit followed by important curb uses, like deliveries, passenger pick-up and small public places. Having a reliable, consistent and real-time access to the curb has a major impact on the ability of people to move around the city efficiently and that association can help ease the transportation challenges, making life better for drivers, cyclists and pedestrians; and therefore, improving the safety and mobility of the people.

1. INTRODUCTION

The curb is a complex, shared environment, often defined by its mix of competing uses, roles in access and mobility, and provision of space for social gathering, commerce, and pickup/drop-off activities. The term "curb management" is a catch-all term that references the intentional act of defining the use, designation, and organization of curb space (1, 2). The curb may also be a space for landscaping and street furniture, as well as a social gathering and commercial endeavors such as parklets, food trucks, and street vendors. It's also vital for cities to consider ADA and accessibility requirements in combination with providing curb access to these various modes (4, 9 7). Figure 1 provides a graphical illustration of the various user groups seeking space at the curb.

Figure 1. Access to the curb user by the group (8)

While curb space has primarily served parking, it is increasingly important for communities to understand their curbs' utilization with the increase in user groups and changing needs. They can then determine if parking is the best use based on actual activity and demand or if parking/vehicle storage needs can be shifted to off-street locations. The curb also has the potential to provide greater access to more people if options beyond parking are considered. In general, supporting travel behavior other than driving alone may drastically increase the number of people who can be served on a street. Implementing curb management strategies can assist in supporting multiple travel options and thereby increase person throughput (shown in Figure 2). While a parking space may be able to serve those who drive, providing space at the curb for walking, biking, and transit modes, increases the person throughput and therefore access on that street segment.

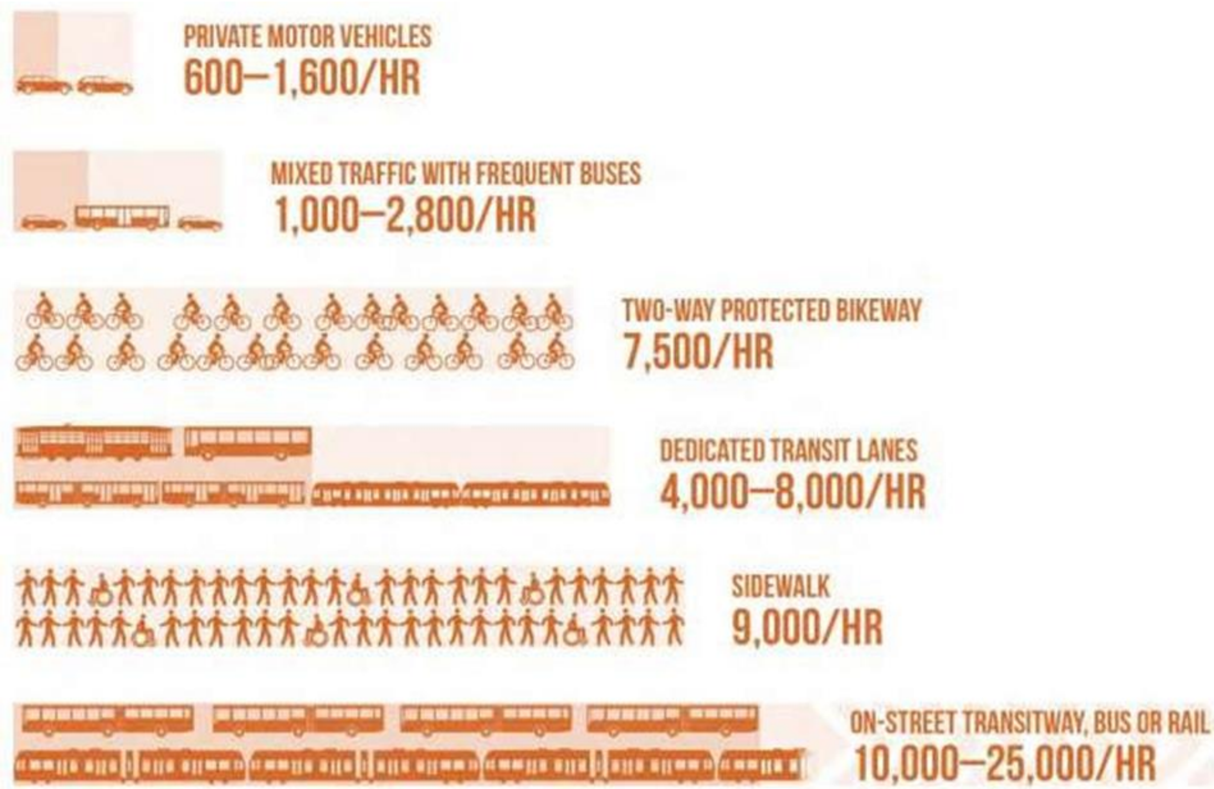


Figure 2. The capacity of a single 10-foot lane (or equivalent width) by mode at peak conditions with normal operations (8)

Cities can enhance transit by managing the curb. Around North America, cities have effectively improved transit operations by utilizing the following strategies to manage the curb:

- Shifting from parking lane to flexible zone
- Clearing the way for transit
- Moving loading and access nearby, and
- Looking beyond the corridor

While historically, single occupancy vehicles (SOV) were the primary mode of transportation to dominate on the street and at the curb, in many places, the curb has become a hub for a variety of modes and services. Importantly, providing access beyond single occupancy driving significantly increases person throughput on the street. Although cities are clearing the way for transit by taking control of their curbs, without room for loading, delivery workers and hiring vehicles are inconvenienced and cause delays to others. People who are bicycling and walking are put in danger by blocked bike lanes and bad visibility; drivers cruise for long distances to find parking.

This research would study the effectiveness of a comprehensive dynamic curb management system in urban areas to accommodate delivery vehicles, reduce congestion in urban areas and improve mobility and accessibility. Another main objective of this study is to develop a traffic simulation module that integrates a parking choice model to select appropriate parking facilities for delivery vehicles and further determines the optimum allocation of the curb space for various uses to improve the overall efficiency of the transport network.

2. LITERATURE REVIEW

The cities have implemented some trial and error-based approaches. Changes in parking supply are often contentious for both residents and commerce. In the latter case, shop owners often overestimate the number of clients that come by car in central city settings (9). On the contrary, some cities may seek to implement a broad-scale strategy such as New York City's tactical urbanism approach to use temporary materials in multiple pilot demonstrations of bicycle infrastructure, bus lanes, pedestrian plazas, and other adaptive re-uses of urban space (5, 15, 16). In either case, cities have a menu of options available to them. Balancing uses and priorities should flow from functional street typologies that cities such as London and Seattle have developed and should be strategic. The U.S. National Association of City Transport Officials (NACTO) has developed useful guidance on how cities in North America (and elsewhere) can ensure that the allocation of the street and curb space best supports efficient shared mobility services – including high-capacity public transport, micro-transit, ride- and bike-sharing while minimizing the impacts on private parking (9).

There is precedent in seeking to variabilise the use of scarce street (and road) space to have the capacity for different uses at different times of the day. These include systems that dynamically open or close lanes for traffic on motorways or at toll stations. Cities like Barcelona have put in place active lane management systems that allocate street space to exclusive bus use, normal traffic, bicycle travel, and night-time parking according to the time of the day and day of the week (12). Copenhagen has put in place several zones that allow bicycle parking during the day and night-time car parking or, alternatively, allow freight deliveries at sometimes of the day on otherwise dedicated bicycle parking bays (18). Flexible curb space allocation specifically targeting new mobility services is much less common, though, as current live trials and the modeling exercise results suggest, this is likely to change. Technology will play a role in bringing flexible use of space to the curb and will be helpful in managing this use – but over the longer term, curbs and streets will have to be designed for dynamic and flexible use. The concept of the self-adjusting curb is one that is increasingly becoming possible within a fast-changing technological environment. The conjunction of "flat use" physical curb design and technologically enabled curb space allocation renders new combinations of possible uses. "Flex-zones" as described by NACTO (9) or Shared-Use Mobility Zones (SUM zones) as defined by the Eno Transportation Foundation (6, 19) leverage adapted rules, light technologies, and a coordinated vision to help guide cities to cater for multiple potential curbs uses. Local authorities can use these concepts to guide priority settings for different temporary and permanent uses. Using, for example, the guidelines developed by Seattle, NACTO describes how a city planner might approach this exercise: A project manager using this method first assigns critical uses like transit stops, transit lanes, and quality bikeways—the uses that frequently find themselves competing for space on streets otherwise designed for motor vehicle traffic. Next, transit-and-business-supportive uses like bike share stations, commercial loading, and available passenger loading are designated to the extent needed to prevent bus blockages by these uses. The remainder of the curb can be devoted to valued public space uses such as parklets and stormwater infrastructure, pickup and drop-off areas for for-hire and private vehicles, and depending on local land uses, a cascading array of very quick-term, one-hour, multi-hour, and longer-term car storage (9).

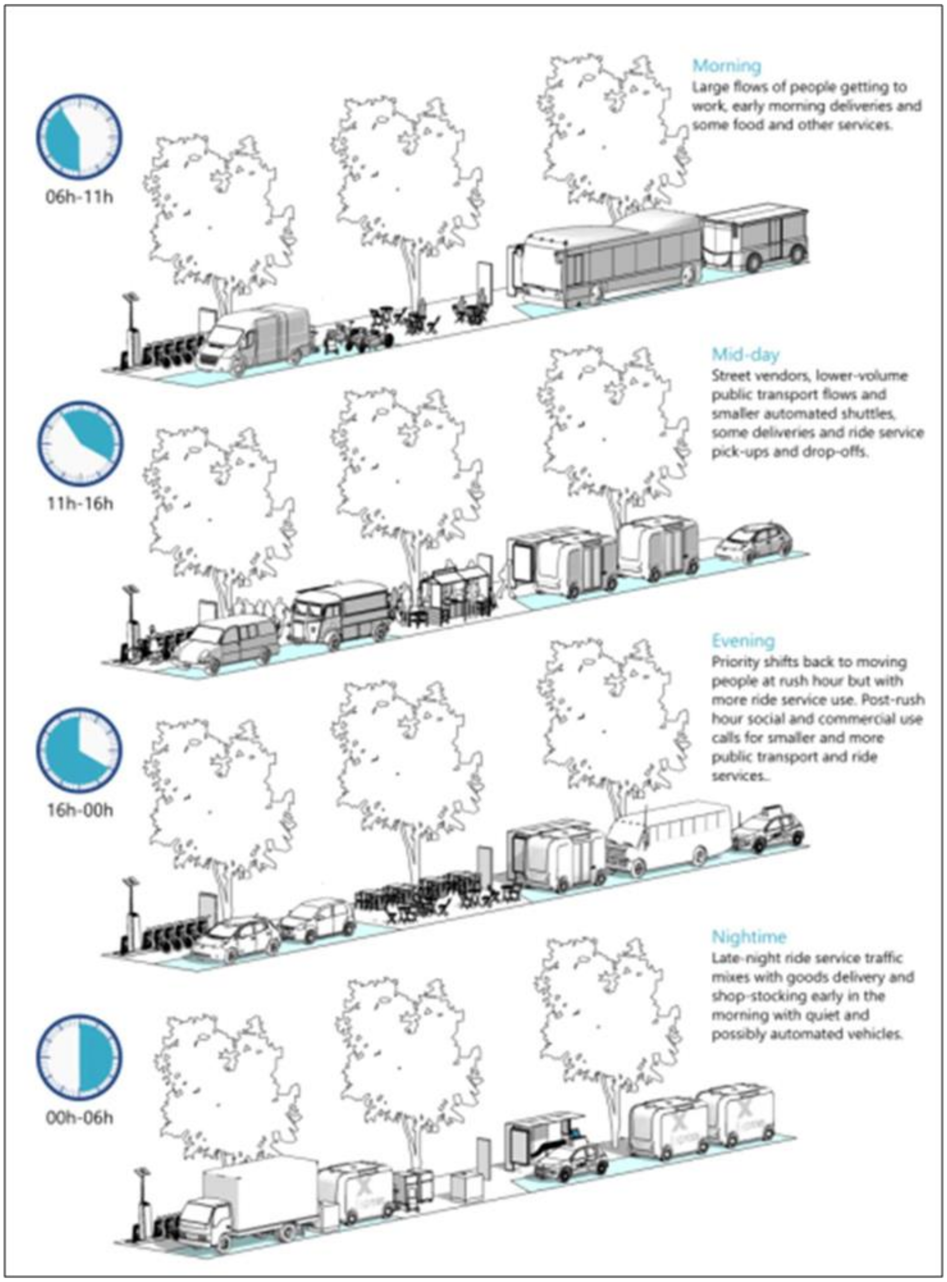


Figure 3. Dynamic use of curb space over the day (8).

Commercial vehicles are another source of congestion on city streets and at the curb. According to CityLab, commercial vehicles now account for 7 percent of urban traffic (11). The growing preference for online shopping has caused a dramatic uptick in freight delivery: in 2010, the U.S. Postal Service delivered 3.1 billion packages; by 2016, that number had climbed to 5.1 billion. Overall, there are more deliveries to residences, and they are increasingly more frequent and on-demand, with some companies trialing same-day or even one-hour deliveries.

Figure 4. Demand for loading spaces of delivery vehicles.

To address the increasing congestion from commercial vehicles making ever more deliveries, some city officials have become more active in their management of the space allocated to commercial vehicle loading. The first step in managing commercial vehicles' use of curb lanes is to understand existing infrastructure and usage. A study in Seattle found 40 percent of commercial vehicles were parked in bus lanes, passenger pickup, drop-off zones, tow-away zones, or other no-parking zones (10). The authors identified the cause of this as insufficient commercial vehicle loading space and noted the need to develop curb management strategies based on existing site conditions.

A study by the California Department of Transportation examined curbside parking and designated blocks in Los Angeles, Santa Monica, Irvine, Oakland, and Berkeley, in contexts ranging from downtown cores, commercial corridors, and suburban areas (10). Researchers found commercial vehicles were frequently parked in front of fire hydrants, inaccessible parking spaces, or in other "red zones" where standing, stopping, or parking is not permitted. Only 40 percent of commercial delivery vehicles used the appropriate loading zones. The study recommended continued collection of curb usage data and the design of parking management strategies for delivery vehicles.

3. METHODOLOGY

3.1. Dynamic Curbside Management

Cities traditionally managed the curb lane with a mixture of the time limit and vehicle use restrictions and pricing. These methods have taken the form of 2-hour parking limits, truck loading by permit or pay-to-load only zones, taxi zones, and metered parking. The exponential growth in demand for curb space has also stressed the existing alley and loading zone network, creating traffic safety and congestion issues such as double parking or blocking bike or bus lanes. Furthermore, the type of vehicles and the uses of the curb space have diversified. Whereas a traditional delivery would be made by a commercial vehicle or vehicle with a use permit in a loading zone or a taxi utilizing a taxi zone, the new delivery method combines the use of personal passenger vehicles, trucks, and non-commercial vehicles to deliver people and goods as quickly as possible. The introduction of independent contractors has exacerbated the management of the curb as the operator population has grown exponentially and become difficult for municipalities to manage. Lastly, whereas deliveries may have mirrored a typical parking session and vehicles sat unattended for 30 minutes to an hour, the new delivery demand profile utilizes the curb for five to seven minutes, proving difficult to maintain compliance through normal enforcement practices (*3, 17*).

Figure 5. Pilot zone demarcation (3, 17).

Within recent innovative collaborations with the private sector, Columbus and the District have conceptualized, planned, piloted, and evaluated the concept of dynamic curb access management. The technology and data-driven concept is premised on not only regulating price and time limits at a more minute-based scale but also curating the demand by user type and enabling more dynamic enforcement approaches to the curb. With the opportunity to test out new technological, analytical, and data-driven management approaches to dynamic curb management, Columbus and the District started to formulate pilot cases in late 2019. The District Department of Transportation (DDOT), owners of the District's curb space, began a 3-month research project to collect data on users of reservable commercial loading spaces. DDOT selected nine high-volume locations (dubbed research zones) for observation. Similarly, Columbus initiated its 6-month pilot program in November 2019 to demonstrate an app-based dynamic curb management system; selecting eight locations (dubbed loading management zones). The goals of the pilot cases were to increase safety and efficiency for all users of the public right of way, while supporting the operational needs of commercial establishments operating in the urban core of the city.

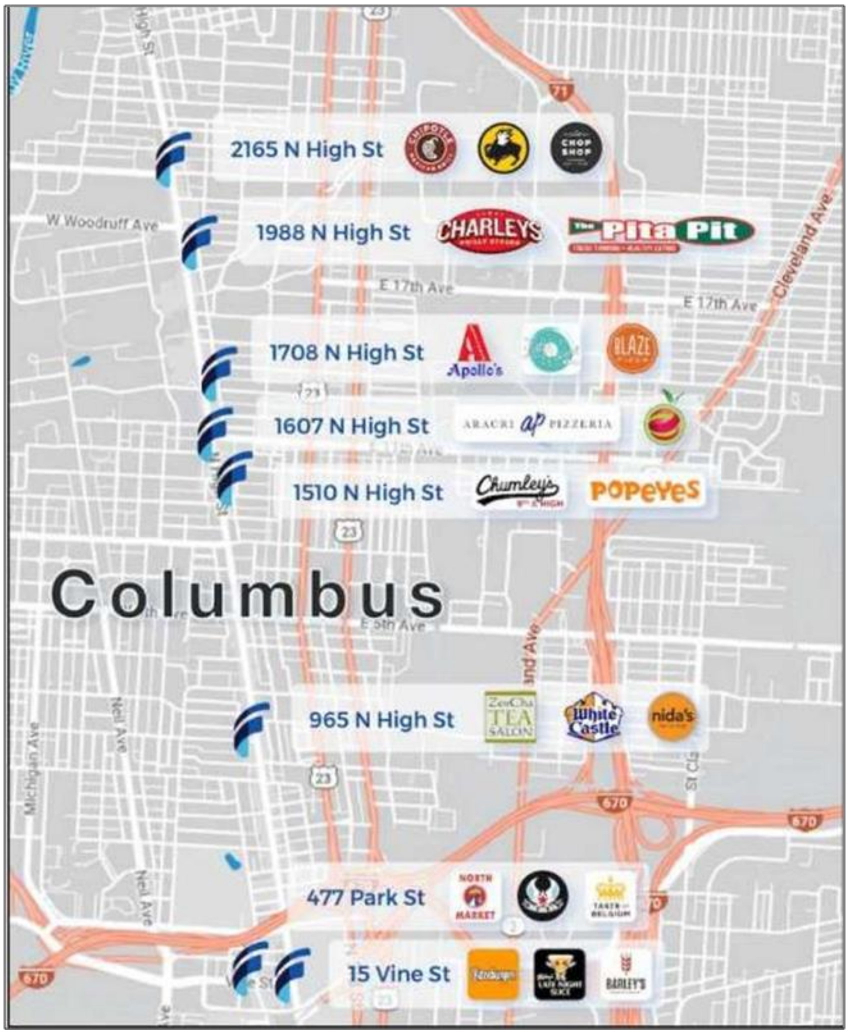


Figure 6. Study area-Columbus (3, 17).

Both cities installed temporary signage, pavement markings, and bollards at the beginning and end of the zone to clearly indicate that loading activity in the area was restricted to those who have reserved time in the app (see Figure 5). The District pilot team managed daily set-up/take-down of movable barricades and signs at the beginning and end of observation periods and collected all data on users. Registered users would reserve time to use the zone via the app or the pilot team.

Figure 7. Study area-district (3, 17).

3.2. Operational and Policy Levers

The pilot restricted zone access to users with active reservations made via app or, in the District, with the pilot team. Fees were not assessed during either pilot, but the real-world operational model would require payment. License plate data was fed to the enforcement app to verify compliance in Columbus. In the District, enforcement was performed by request from the pilot team for egregious violations; users who overstayed their reserved time were noted but not cited.

3.3. Parking Choice

Parking choice is the decision process of selecting a parking space from a given set of parking spaces located close to the agent's destination. It was observed that often four types of parking scenarios exist, which we model as distinct parking types.

- Public parking: Parking which is not reserved for anyone. All agents can compete for these parking spaces.
- Private parking: These parking spaces are assigned to specific activities and buildings. E.g., parking at home or a shop.
- Reserved parking: Parking reserved for a selected set of agents. E.g., parking reserved for disabled people.

- Preferred parking: Sometimes, it is necessary that a car must park at a location with a certain characteristic. E.g., a person driving an electric vehicle might require a parking space with a power outlet for charging.

The first three parking types depend on the static properties of parking. In contrast, the fourth parking type is more abstract and dynamic as it encompasses the individual situation and preferences of drivers combined with properties of the parking itself. Therefore, the same parking could qualify for one agent as a preferred parking type while not for another.

3.4. Simulation Platform

Commercially available simulation package Aimsun 20.0.2 will be used for the parking choice model development (*13*). Aimsun Next has grown from a microsimulator to a fully integrated application that now fuses microsimulation, mesoscopic simulation, macroscopic functionalities– all within a single software application. Aimsun is a leading international provider of software and services for traffic planning, simulation, and prediction. Acquired by Siemens in 2018, Aimsun now counts on their support to continue building on over 20 years of experience in algorithms, software, and operational know-how for mobility applications. Thousands of mobility professionals worldwide in government, research institutions, and private companies are successfully using Aimsun tools and services to model tomorrow's smart mobility networks today.

3.5. Parking Choice Modeling

The study area, i.e., a section of the Broward Blvd, is show in Figure 8. It is from the State Road (SR) 7 to the intersection of the NW 35th Ave and W Broward Blvd. The distance is around 1 mile. The entire corridor has 3 (three) signalized intersections. Those 3 (three) intersections are marked in Figure 9. The other 2 (two) intersections are 1 (SR 7 and W Broward Blvd) and 2 (SW 38th Avenue and W Browar Blvd).

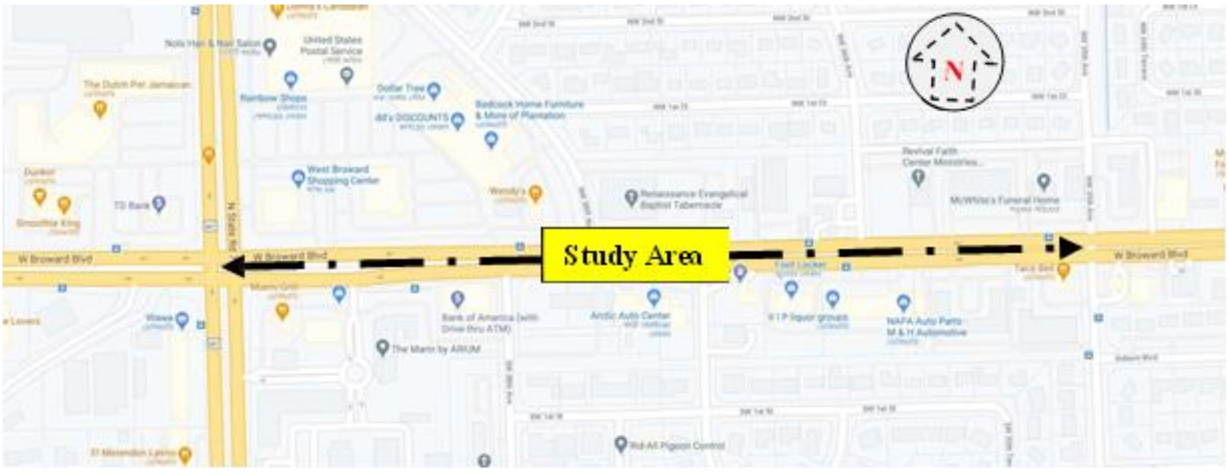


Figure 8. Study area-Boward Blvd

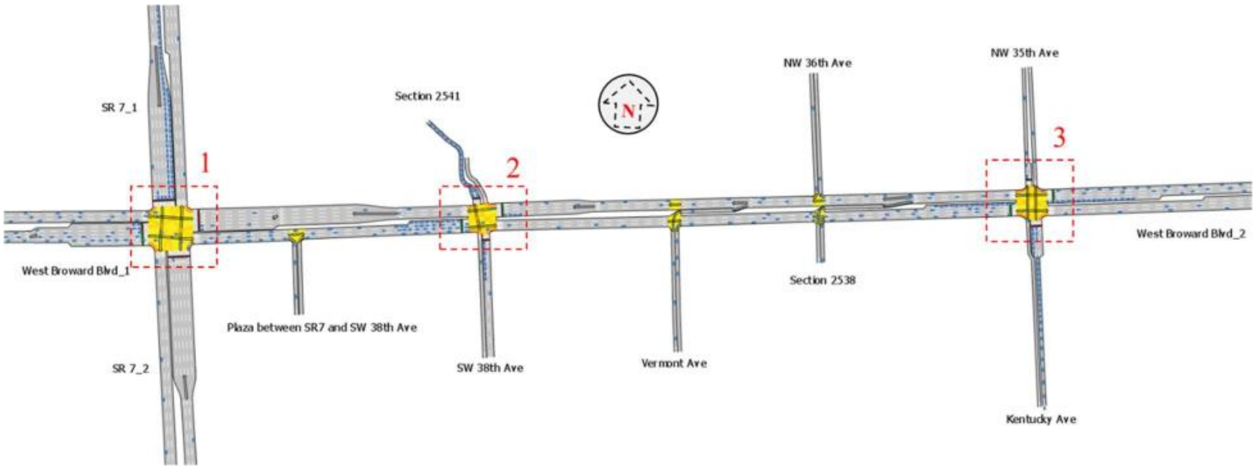
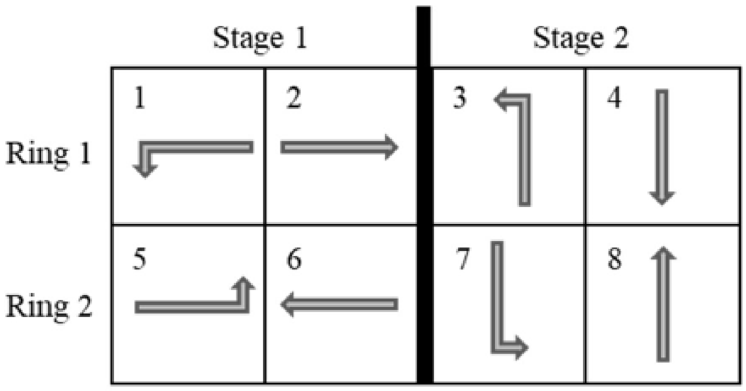


Figure 9. Geometry of the study area in Aimsun.

3.6. Signal Timing Plan

Figure 10 shows the signal timing plan for the 3 (three) intersection. The cycle length for all of them is considered 160 sec. According to federal highway administration (FHWA) rules, the proportion for the split is applied. Afterward, green time is calculated accordingly. The ring barrier controller diagram shows that east and westbound movements are made first, then the north and southbound movements. As the main street is the W Broward Blvd, a higher amount of split is applied to those parts.



	EB/WB Left	*EB/WB Through*	*NB/SB Left*	*NB/SB Through*
Proportion Split (%)	*15*	*43*	*7*	*35*
Min Green (s)	*0*	*0*	*0*	*0*
Max Green (s)	*19*	*66*	*6*	*53*
Yellow and All Red (s)	*4*	*4*	*4*	*4*

Figure 10. Signal timing plan (14).

3.7. Traffic State

Table 1 shows the traffic state for the entire network. In Figure 10, it is indicated that the maximum amount of split is in the W Broward Blvd; therefore, main street traffic is applied there. From Table 1, it is clearly noticed that a higher amount of traffic volume, e.g., 3500 veh/hr, and 2500 veh/hr in the West Broward Blvd_1, and West Broward Blvd_2, respectively.

Table 1. Traffic state

Street Name	Flow (veh/hr)
SW 38th Ave	600
Vermont Ave	421
Kentucky Ave	957
NW 35th Ave	219
NW 36th Ave	736
2538	500
2541	460
Broward Boulevard_2	2500
Broward Boulevard_1	3500
SR 7_2	200
SR 7_1	2000
Plaza between SR 7 and SW 38th	302

3.8. Dynamic Parking

Figure 11 shows the dynamic parking model. A dotted red circle marks those parking sections. The parameters considered for the incident are displayed in Table 2. It is seen that the incident length is 5 m, which starts at every 3 minutes, and lasts for 1 minute.

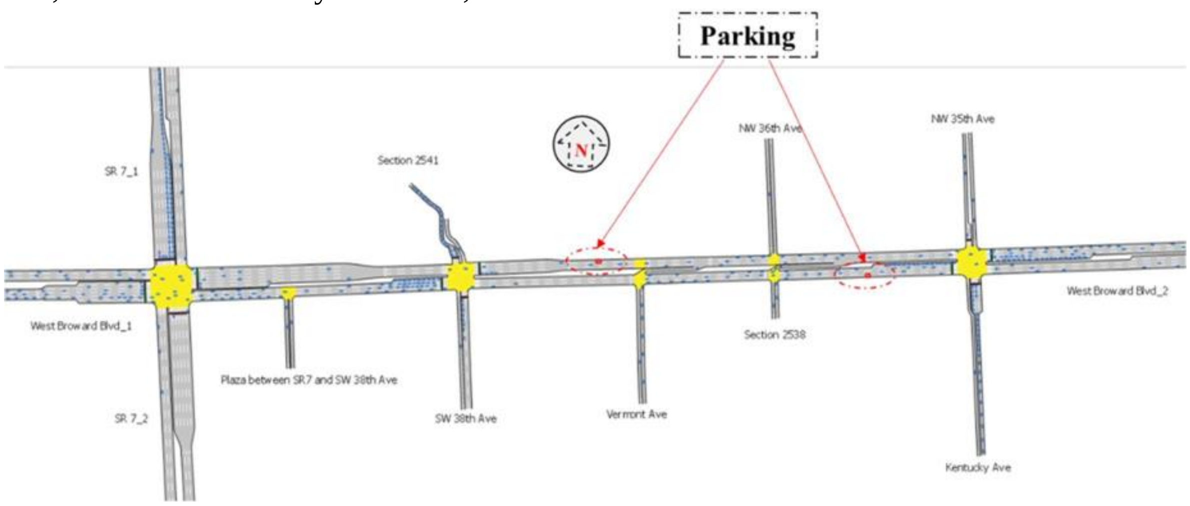


Figure 11. Dynamic parking

Simulation experiments have been conducted for 1:00:00 hour. For each scenario, 10 (ten) replications were performed. Then the average results were calculated for consideration.

Table 2. Periodic section incident parameters (13)

Incident Length:	5.00	Deviation:	0.00
Lanes to Cover:	1		
Starts Every:	00:03:00	Deviation:	00:00:20
Duration:	00:01:00	Deviation:	00:00:20

4. RESULTS

4.1. Dynamic Curbside Management

In the District, the most frequent users of these research zones were On-Demand Delivery Services (ODDS), accounting for 37 percent of all zones uses, consistent with expectations based on the zones selected. This is starkly contrasted in Columbus, where approximately 90 percent of users of the zones were ODDs. The other users of the District's zones included "other" vehicles (27 percent), ride-sourcing and taxis (18 percent), freight (11 percent), parcel delivery (5 percent), and municipal vehicles (3 percent). Overall, the zones were utilized most on Fridays, with Thursday close behind; they were least used on Sundays. ODDS had notable spikes on Thursdays and Fridays; rideshare and taxis spiked on Saturdays. Freight and parcel deliveries saw its lowest activity on Saturdays and Sundays.

In assessing dwell time, there were some notable findings from the pilot cases that can inform operations. In the District, it was found that for:

- ODDS: median dwell times of 7-11 minutes were observed; active curb use from 11 a.m.- 6 p.m. seven days a week.
- Freight deliveries: median dwell times of 7-11 minutes, active curb use 9 a.m.-3 p.m. weekdays; about half of weekday activity on Saturday, with little on Sunday.
- Parcel deliveries: median dwell times of 7-11 minutes, active curb use 11 a.m.-2 p.m. weekdays.
- Ridesourcing & Taxis: median dwell times of 1.5-2.5 minutes; curb use rising through the afternoon to peak at 6 p.m.; activity is steady throughout the week and weekend, with a slight peak on Sundays and slight dip midweek.

With most of the activity in the zones in Columbus being ODDS, the average dwell time was measured at 5 minutes, with freight and parcel deliveries taking approximately 7 minutes per use. Zone use peaked in the early afternoon and evening, with the highest use recorded in the 6 p.m. hour.

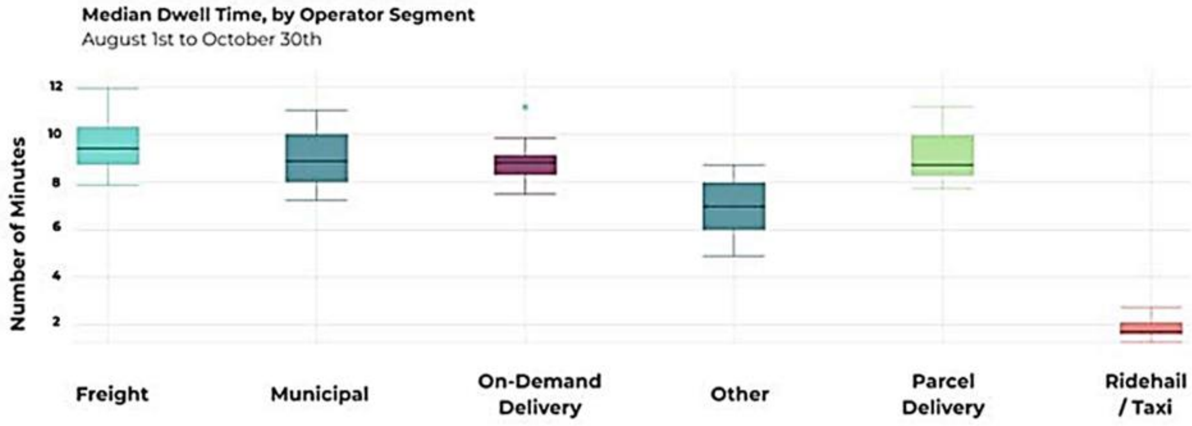


Figure 12. Median dwell time by user type in the District.

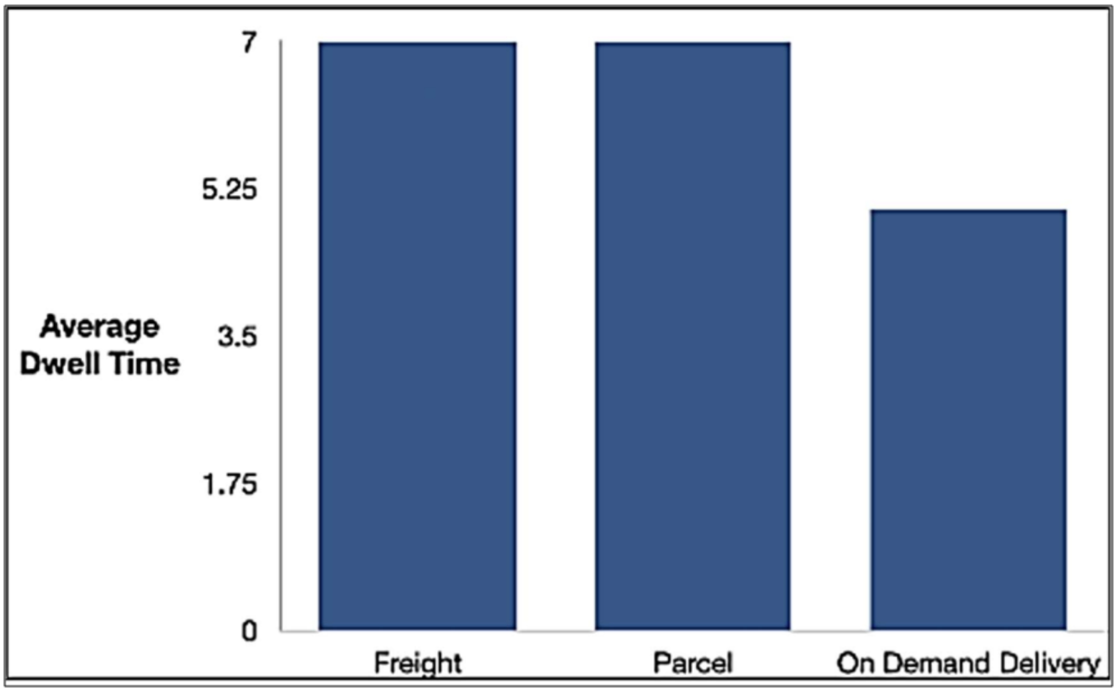


Figure 13. Median dwell time by user type in Columbus

4.2. Safety Implications

Providing consistent curb access and actively managing curb use gradually reduced unsafe driver behavior around research zones, based on data collected at the research zones before and after the dynamic curb management strategies implementation (see Table 3). Research staff logged incidents of U-turns and double parking at research zones on a weekly basis during the research; while initially, U-turns increased around the zones, the incidents decreased once drivers learned about and integrated the zones into their delivery patterns. By the end of the project, research staff logged a 64 percent decrease in double parking and illegal U-turns at these zones in the District. With Columbus piloting the zones remotely, they relied on survey responses on driver behavior to estimate safety benefits. The survey asked drivers, "What percent of the time when you used an LMZ would you have illegally or double-parked if it weren't there?" Based on the 63 responses to this question, the pilot team estimated that the installation of the zones prevented approximately 9,700 instances of double parking or other illegal parking.

The District pilot team recorded 25 crash incidents over the life of the project. At least six incidents appear to be misclassified based on notes recorded. Nine did not include notes that described the nature of the incident. Ten incidents resulted in collisions, at least one of which required a police response. The majority of those collisions involved zone signage, with five appearing to be minor two-vehicle crashes. Fourteen of the incidents occurred at two locations; three locations had no incidents. Columbus did not report any crash incidents at their zones over the course of their pilot.

Table 3. Safety statistics

	District		
Timeframe	Double Parking	Illegal U-Turn	Total
Pre-Launch Weekly Average	154	97	
Post-Launch Week 1 Average	123	147	
Post-Launch Week 14 Average	25	34	
Crash Incidents			25

4.3. Parking Choice Modeling

This part of the study discusses the transportation network performance metrics, e.g., delay time, number of lane changes, and capacity.

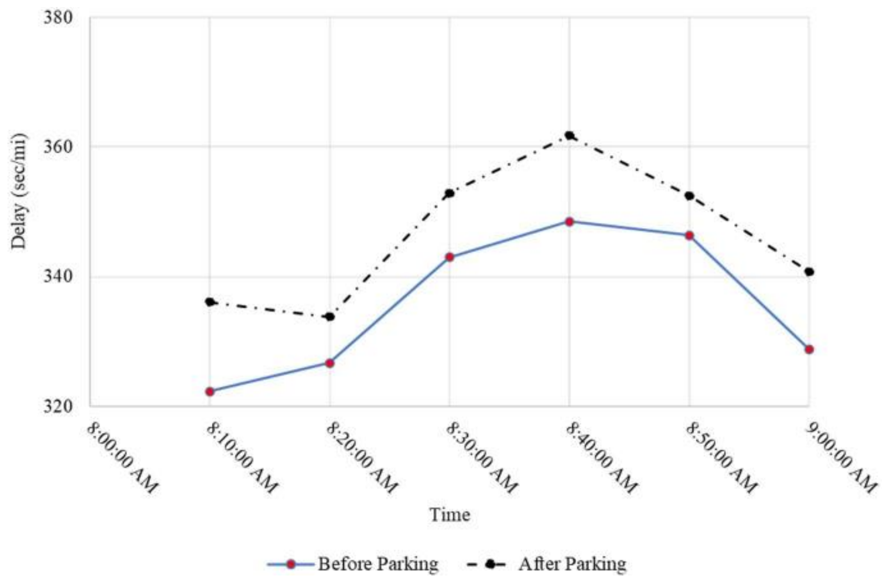


Figure 14. Delay (sec/mi).

Figure 14 shows the delay time for the network before and after the dynamic parking management facilities. The solid blue line represents the before-parking scenario, and the dotted black line represents the after-parking scenario. The graphical representation shows that comparing before parking and after parking scenarios, it is noticed that delay time increases in the after parking.

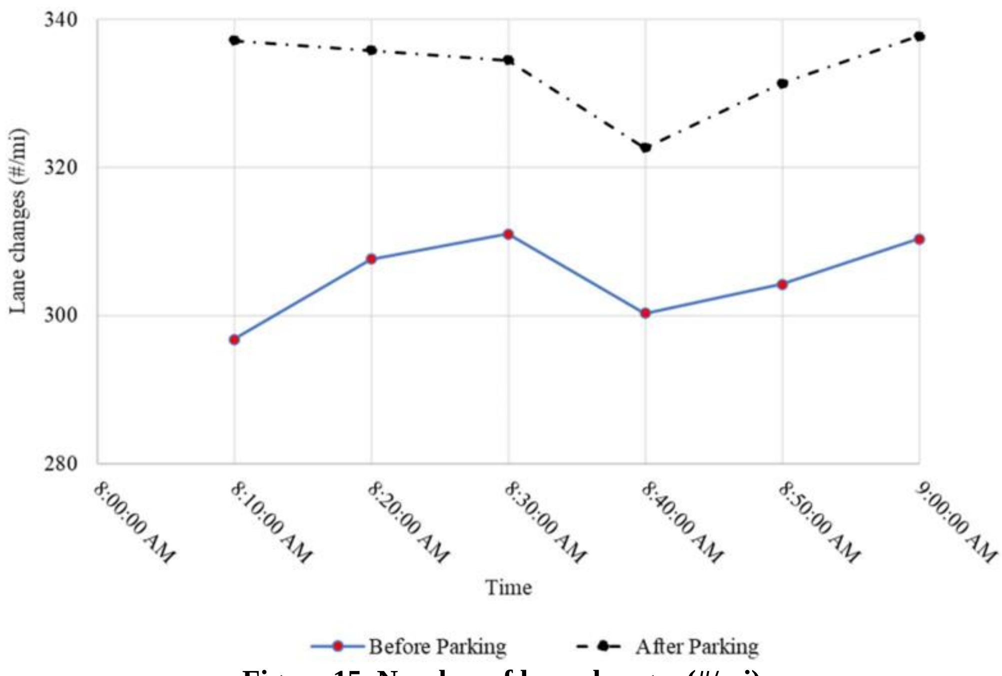


Figure 15. Number of lane changes (#/mi).

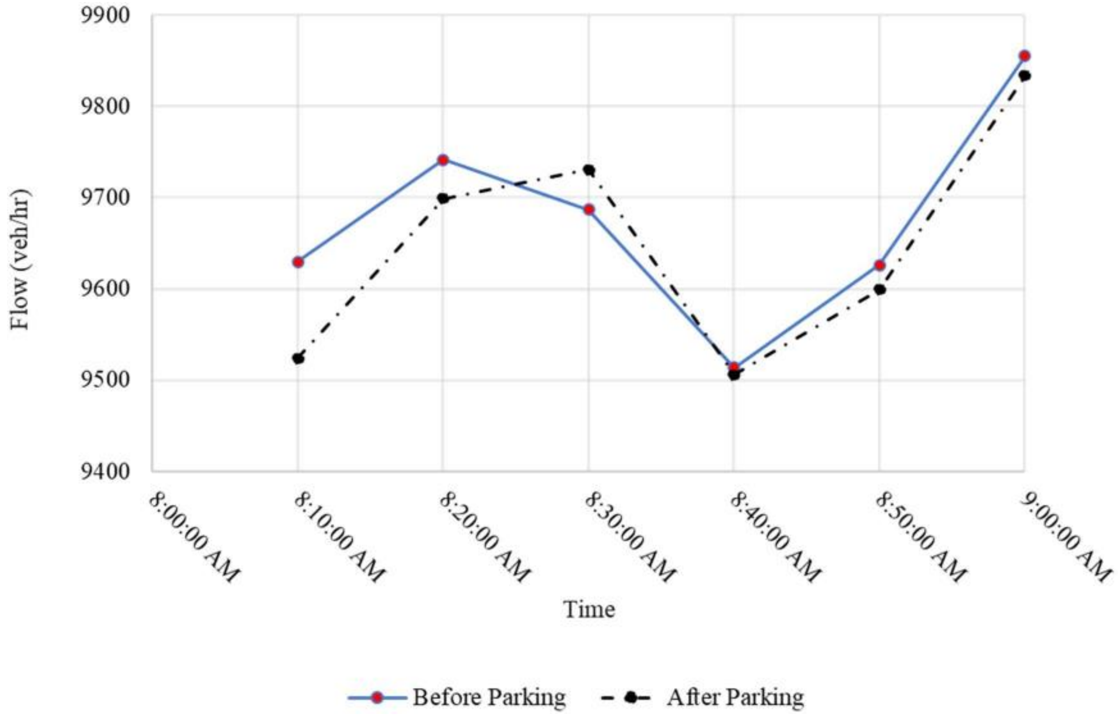


Figure 16. Flow (veh/hr).

Figure 15 shows the number of lane changes per mile basis, comparing the before-parking and after-parking scenarios. Likewise, the delay time in the previous illustration shows that the number of lane changes increased due to the parking implementation. It is mainly because some part of the corridor has been used for parking for some particular time period; therefore, drivers act aggressively. More lane changes happened.

Figure 16 shows the output of the system, comparing the two considered cases. In this part of the study, it is noticed that, although travel time increases, which is mainly triggered by delay time and another factor, i.e., lane changes increase because of the closure of the corridor for some time period, the flow of the system has not been affected much. Yes, flow decreases, but looking at the comparison shows that flow is a little less than the without the parking scenario.

This is mainly because, considering the network, it might afford a higher amount of flow than the considered. That's why, although some other parameters have been changed, but system's output remains almost the same.

5. CONCLUSIONS

Both the District and Columbus are taking lessons learned from the respective pilots to further advance the practice of dynamic curbside management. The district department of transportation (DDOT) is planning to collect additional data on the use of its pickup/drop-off zones (*19*) to better understand the distribution of users and real demand. Key differences will be the lack of a reservation system, strict limitations on activity (standing or active loading only), and no dedicated enforcement. Additionally, both cities are exploring the feasibility of charging users under existing commercial loading regulations and industry practices, considering strategies for de-conflicting the temporal demands for loading zones amongst user types and conceptualizing a new regulatory structure to better incorporate the dynamic curb management principles explored in the pilot program. Additionally, in June 2019, Columbus issued a Request for Information (RFI) to solicit initial feedback and input on a possible loading zone management system for the city. The city plans to use the information received in this request to ultimately expand the use of dynamic curb management throughout the city's loading zones in the public right of way.

Another part of the study to develop a traffic simulation module that integrates a parking choice model to select appropriate parking facilities for delivery vehicles has been studied with the W Broward Blvd network. From the analysis of the results, it is found that comparing the two scenarios, i.e., before parking and after parking, the output of the system has not been affected in a large scale. Other transportation metrics, e.g., delay (affects travel time), number of lane changes (directly connected with safety), have experienced some amount changes. After the parking implementation, all of these metrics have got increased. Correlating these, the capacity of the system has decreased a bit.

Taking a close look, it is seen that the considered whole Broward network has experienced a less amount of traffic volume than the ultimate capacity. Therefore, increment in delay and driver's aggression has not affected much in the system's output. This network can be further studied with the real-time data for the calibration and validation at first. Afterward, considering a large-scale network could be more beneficial to investigate the scenarios.

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