New England University Transportation Center
77 Massachusetts Avenue, E40-279
Cambridge, MA 02139
utc.mit.edu

Year 25 Final Report

Grant Number: DTRT13-G-UTC31

Project Title:

High-Resolution Urban Freight Modeling in Cambridge, MA

Project Number:	Project End Date:	Submission Date:
MITR25-2	5/31/16	4/18/17

Principal Investigator:	Chris Caplice	**Co-Principal Investigator:**	Eva Ponce
Title:	Executive Director, MIT CTL	**Title:**	Executive Director, MITx MicroMasters in SCM
University:	MIT	**University:**	MIT
Email:	caplice@mit.edu	**Email:**	eponce@mit.edu
Phone:	617-258-7975	**Phone:**	617-715-4169

The New England University Transportation Center is a consortium of 5 universities funded by the U.S. Department of Transportation, University Transportation Centers Program. Members of the consortium are MIT, the University of Connecticut, the University of Maine, the University of Massachusetts, and Harvard University. MIT is the lead university.

Table of Contents

1. Introduction

As cities grow, more goods need to be delivered into urban centers to satisfy growing and varying consumption demands. Although a critical enabler of sustainable growth and quality of life, the urban freight system that delivers these goods is often seen as a nuisance from the public perspective, in large because commercial vehicles contribute to traffic congestion and make use of public spaces such as loading zones. In this sense, the appropriate usage of public infrastructure by freight vehicles is critical to reduce the impact on society. Local authorities are responsible of providing the adequate quantity at proper locations of public loading zones to satisfy the delivery intensity of a particular city area and regulating the use of them. However, there is a lack of delivery data and suitable models that support local authorities for effective decision and policy making.

In this project, we propose a high-resolution methodology that balances theoretical and data-driven analysis to design loading zones in order to help local authorities to better deploy loading zones in critical logistics areas so that stakeholders make an efficient use of public infrastructure. Initially we conducted a field study to collect primary data in Cambridge, MA. This data collection process involved gathering information about business establishments, parking infrastructure and freight deliveries in the area studied. Then we quantify the number of delivery zones required based on the delivery intensity and use location-allocation modeling to locate delivery zones on potential parking locations. Finally, we assess the results using discrete event simulation. As a result, the new deployment of loading zones resulted in a 10% reduction of the time that freight vehicles spend parked in the area which means more public spaces for other purposes.

2. Problem Description

The problem under analysis consists on designing loading zones. There are two dimensions that need to be taken into consideration to design loading zones: the spatial and temporal dimensions. The spatial dimension reflects the nature of the problem. This problem requires to situate loading zones in convenient locations to satisfy the parking demand of commercial vehicles that deliver products to business establishments nearby. The temporal dimension describes the seasonal behavior of freight activity during the day. This delivery pattern concentrates most of freight deliveries at particular hours of the day or peak hours putting extra burden over loading zones during these hours. On the other hand, off-peak hours experience a lowered occurrence of freight deliveries reducing the occupancy of loading zones significantly.

A critical issue when tackling the design of loading zones is data collection. Traditionally, researchers have used surveys as the main method of data collection. Nevertheless, there might be discrepancies in what is reported in a survey and the reality (Muñuzuri, Cuberos, Abaurrea, & Escudero, 2017). Retailers tend to underestimate the duration of deliveries while answering a survey for example. That is why there is an increasing interest to collect data using direct observation as found in (Muñuzuri, Cuberos, Abaurrea, & Escudero, 2017), (Alho, De Abreu e Silva, & Pinho de Sousa, 2014) and (Dezi, Dondi, & Sangiorgi, 2010). In this project, we rely on direct observation as a means to collect data.

3. Methodology

In this section, we present a data-driven methodology that aims to help local authorities to better deploy loading zones in critical logistics areas so that stakeholders can make a better use of public infrastructure. The methodology developed (see Figure 1) is divided in three phases: Data collection, Quantitative modeling and Analysis of results.

The data collection intents to gather relevant information about business establishments, parking conditions and freight deliveries in the area. Direct observation and surveys to businesses managers are used during this stage depending on the data to be collected. The data collection effort allows us to capture high-resolution data to describe the commercial activity and estimate the freight delivery intensity by hour of the day in the area. Using the data collected as an input, a mathematical model is built to identify the optimal loading bays' locations to minimize the total deliveries duration and consequently the commercial vehicle parking time. The model also decides the best allocation of loading zones to business establishments to minimize the objective function. Finally, we analyze the results obtained and test the sensitivity of the model changing the values of key parameters.

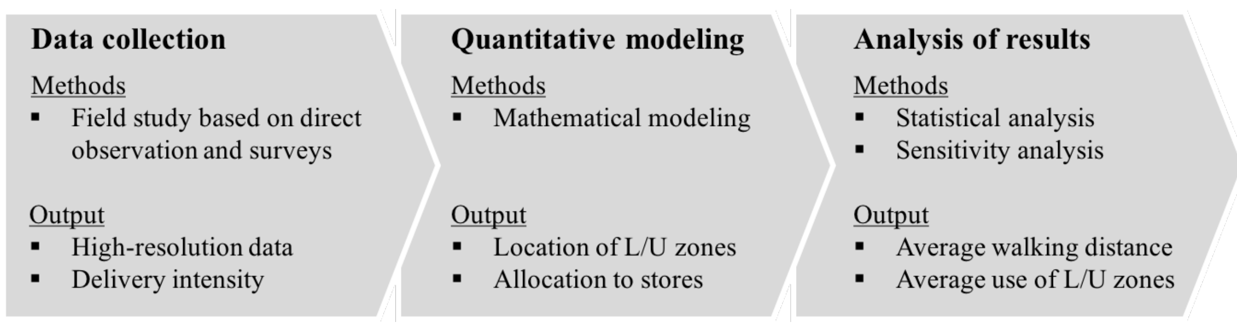

Figure 1. Methodology

4. Data Collection

During the data collection phase, a field study is conducted to collect primary data. The field study involves gathering information about business establishments, parking conditions and freight deliveries based on observation. Additionally, a survey might be conducted to complement the information that could not be observed (e.g. number of employees, night deliveries, etc.). Direct observation captures more adequately the reality of deliveries than surveys (Muñuzuri, Cuberos, Abaurrea, & Escudero, 2017). To the best of our knowledge, this project is the first one to capture freight deliveries data based on observations and to use it to inform decision models.

4.1. Establishment Inventory

The objective of the establishment inventory is to identify and record information about all business establishments in the area analyzed. Most of the information to be collected do not require interaction with business owners or managers thus can be gathered simply observing the information deployed in the storefront and the activities taking place inside the store. If some information requires assistance from business managers, a short survey might complement the observation. The information to be collected might be recorded using mobile applications (e.g. Flocktracker app) or paper-based forms. Mobile-based collecting data methods save time needed to translate paper written results into electronic format but also provide a means to collect geographical information of the establishment making use of the device's GPS.

The data collection effort depends on the number of business establishment to be inventoried and the information to be collected. We concentrated on collecting key information for the study and that required about 5 minutes per establishment of fieldwork. The information gathered can be summarized as follows:

- *Establishment name*: Commercial name of business establishment.
- *Type of business*: Type of business establishment based on the North American Industry Classification System (NAICS)[1] or equivalent system.
- *Address*: Address where the establishment is currently operating.
- *Geographical coordinates*: Latitude and longitude of the establishment's main entrance.
- *Private loading area*: Availability or lack of exclusive-use loading zone.
- *Private loading area length and width*: Dimensions of the private loading zone if available.
- *Number of employees*: Number of people currently employed at the establishment.

Many cities, via statistics and economics institutes, already provide this type of information. However, it is very important to validate and update this information through a fieldwork at least once a year since the openings and closings rates of retailer stores are very high.

4.2. Parking Infrastructure Inventory

The parking infrastructure inventory aims to collect information about parking conditions in the area. This study involves inventorying every single parking spot in the area of analysis. Similarly, to the previous study, this field study might be based only on direct observation and make use of mobile apps to record the data and coordinates of parking spots. Again, the data collection effort depends on the number of parking spots to be inventoried and the information to be gathered. We concentrated on collecting crucial information for the study which required about 3 minutes per parking spot of fieldwork. This information could be described as follows:

- *Type of parking spot*: The parking spots are classified according to their use (loading zone, parking area, reserved parking, bus stop, taxi stop).
- *Geographical coordinates*: Latitude and longitude of the parking spot.
- *Dimensions*: Length and width of the parking spot.
- *Regulation*: When the parking spot is open for public use (day of week and hours of the day) and maximum parking duration allowed.
- *Payment method*: How public can access to the parking spot (e.g. permit, meter, free).

---

[1] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy.

4.3. Freight Delivery Tracking

This study aims to collect information about freight deliveries taking place in the area of study. It involves recording fundamental information about the delivery and tracking the movements of the delivery man as soon as the truck stops on a parking spot until it leaves.

In a similar way to previous studies, freight delivery tracking does not require assistance from delivery crew or business managers. All the information could be collected based on direct observation. Paper-based forms are preferred over mobile-based forms to collect this type of information due to the dynamic nature of deliveries. Simultaneous deliveries are quite frequent which are better captured with paper forms. The data collection effort is more intense in this type of study. At least one week of data collection is required to capture seasonal patterns along the hour of the day and day of the week. One person is able to cover a street segment (one block's face) and collect data from two sides of the street at the same time. The information to be gather is the following:

- *Arrival time*: Delivery vehicle arrival time at parking spot.
- *Parking place*: Type of parking spot where the delivery vehicle parked (private loading zone, loading area on street, parking area on street, reserved parking, bus stop, taxi stop, double parking).
- *Vehicle type*: Type of delivery vehicle (rigid truck, articulated truck, van, pick-up truck, motorbike, car, other).
- *Equipment*: Equipment used to deliver the goods (delivery dolly, pallet jack, none, other).
- *Establishment*: Business establishments visited during the stop.
- *Departure time*: Commercial vehicle departure time from parking spot.

As stated previously, the delivery man's movements are tracked in detail in this study. Basically, the different activities the delivery man performs are registered and measured how long they take. This provides high-resolution data by decomposing the commercial vehicle parking duration into three main activities as shown in Figure 2: Unloading/Loading, Service duration and Walking.

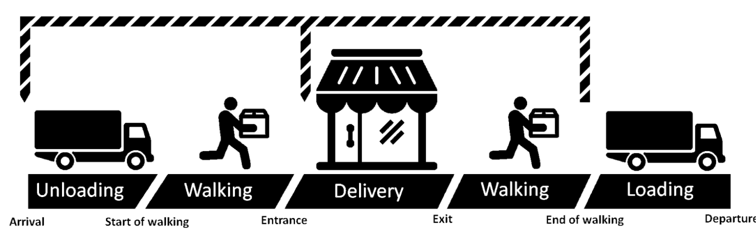

Figure 2. Composition of delivery vehicle parking duration

Unloading and loading involves all the activities needed to unload the goods and equipment from the truck before the delivery and to load returned products and equipment to the vehicle after the delivery. Walking implies carrying the merchandise by hand or with the help of an equipment (e.g. dolly) towards and from the store. Finally, the delivery itself, which takes places inside the store, comprises the physical transfer of goods and payment collection. The duration of these activities (unloading/loading time, walking time and service duration) constitutes the freight delivery duration that is equivalent to the time that the commercial vehicle remained parked also known as parking duration.

5. Quantitative Modeling

In this section, the mathematical model is presented. The model locates the loading zones and allocates business establishments to them in such a way that commercial vehicles' total parking duration is minimized. Reducing the parking duration will free loading zone's time that could be used for other deliveries or purposes.

Each business establishment identified during the establishment inventory should be served from the loading zones to be located. Similarly, every parking spot inventoried in the parking infrastructure study is considered as a potential loading zone. Our time frame is one day (from 6:00 a.m. to 6:00 p.m.) which is divided in one-hour periods.

To quantify the parking duration (Eq. 1), five parameters are defined based on the conceptual model shown in Figure 2. The number of trips[2], unloading/loading time and service time that an establishment requires at a particular time of the day are directly extracted from the freight delivery tracking study. The distance between an establishment and a parking spot is easily estimated given the geographical coordinates captured during the business establishment and parking infrastructure inventories respectively. Lastly, the delivery man walking speed relies upon the distance computed and the walking duration obtained also from the delivery tracking study.

The number of loading zones to locate varies according to the time of the day to fit the freight deliveries daily seasonality observed. Usually all loading zones are fully occupied during peak hours while most of them remain idle during off-peak hours.

The model is described as follows:

Indexes:
i = business establishment, $I = \{1, 2,.., n_i\}$
j = potential loading zone, $J = \{1, 2,.., n_j\}$
t = time of the day, $T = \{6{:}00, 7{:}00,..., 17{:}00\}$

Parameters:
b_{it} = number of trips to establishment i at time t
l_{it} = un/loading time to serve establishment i at time t (min)
h_{it} = service time spent in establishment i at time t (min)
d_{ij} = distance from loading zone j to establishment i (m)
s = walking speed (m/min)

Inputs:
P_{min} = minimum number of loading zones to locate
P_{max} = maximum number of loading zones to locate

---

[2] A (round) trip is defined as the delivery man's truck-store-truck tour.

Decision variables:

$$x_{jt} = \begin{cases} 1 & \text{if parking spot } j \text{ is a loading zone at time } t \\ 0 & \text{otherwise} \end{cases}$$

$$y_{ijt} = \begin{cases} 1 & \text{if establishment } i \text{ is served by loading zone } j \text{ at } t \\ 0 & \text{otherwise} \end{cases}$$

Objective function:

$$\text{minimize } \forall t \quad \sum_j \sum_i \left(l_{it} + \frac{2d_{ij}}{s} \cdot b_{it} + h_{it}\right) \cdot y_{ijt} \quad (1)$$

Subject to:

$$\sum_j y_{ijt} = 1 \quad \forall i, t \quad (2)$$

$$\sum_i \left(l_{it} + \frac{2d_{ij}}{s} \cdot b_{it} + h_{it}\right) \cdot y_{ijt} \leq 60 \quad \forall j, t \quad (3)$$

$$P_{min} \leq \sum_j x_{jt} \leq P_{max} \quad \forall t \quad (4)$$

$$y_{ijt} - x_{jt} \leq 0 \quad \forall i, j, t \quad (5)$$

$$y_{ijt} = \{0, 1\} \quad \forall i, j, t \quad (6)$$

$$x_{jt} = \{0, 1\} \quad \forall j, t \quad (7)$$

The objective function, (1), minimizes the total parking duration (or delivery duration) reducing the walked distance between each business establishment and its nearest loading zone. The constraints insure that the various properties of the problem are enforced. Equation 2 requires that each establishment is assigned to exactly one loading zone. Eq. 3 guarantees that every loading zone is used less than 60 minutes per hour. Eq. 4 requires that the number of loading zones to be located remains within the bounds. Eq. 5 links the location variables and the allocation variables. Finally, 6 and 7 insure that the location variables (x) and allocation variables (y) are binary.

6. Analysis of Results

The goal of this section is to assess the suitability of the solution obtained by the mathematical model, that is to say, the location of loading zones and the allocation to business establishments.

To evaluate the rightness of the tentative deployment of loading zones, two metrics are considered: walked distance and occupation rate. Walked distance determines the proximity of a loading zone to assigned business establishments. Loading zones close to establishments they serve, allow to decrease walked time carrying the merchandise and, consequently, the commercial vehicle parking duration. Occupation rate indicates the percentage of the time that a loading zone is being utilized. Low occupation rates might indicate that a loading zone is not justified. Both measures can be computed per loading zone or at a system level.

On the other hand, the solution provided by the mathematical model is based on average and maximum values of the freight delivery intensity. It does not capture the stochastic nature of freight deliveries (e.g. random trucks arrival times, random duration of activities). Discrete event simulation offers a means to assess the impact of stochasticity on the solution proposed and act accordingly. In this sense, we propose a simulation model that resembles the variability observed in data collected and evaluates the proposed solution.

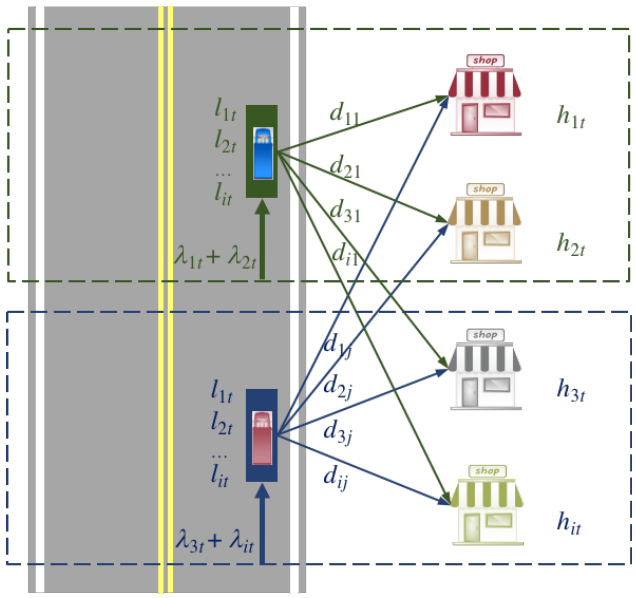

Figure 3. Simulation schematic view

In the simulation model (see simulation scheme in Figure 3) trucks arrive to loading zones following an empirical distribution that resembles the data collected. Each truck has a priority list of loading zones where to park based on the proximity to the business establishment that triggered the delivery. If the preferred loading zone is available, the delivery takes place. Otherwise, the vehicle searches the nearest loading zone to park and so on. The commercial vehicle parking duration that encompasses time for unloading and loading, walking and servicing the customer is randomly generated following an empirical distribution based on the observed data.

7. Case Study

The case study takes place in Massachusetts Avenue corridor, Cambridge, MA, specifically in Central Square's surroundings. Central Square constitutes itself an emerging dining destination, a transit hub for the region, a diverse residential neighborhood, an entertainment zone, a social service node and an emerging arts district (Red Ribbon Comission, 2011). Four street segments on Massachusetts Ave., between Pleasant St. and Sidney St., were analyzed as can be seen in Figure 4.

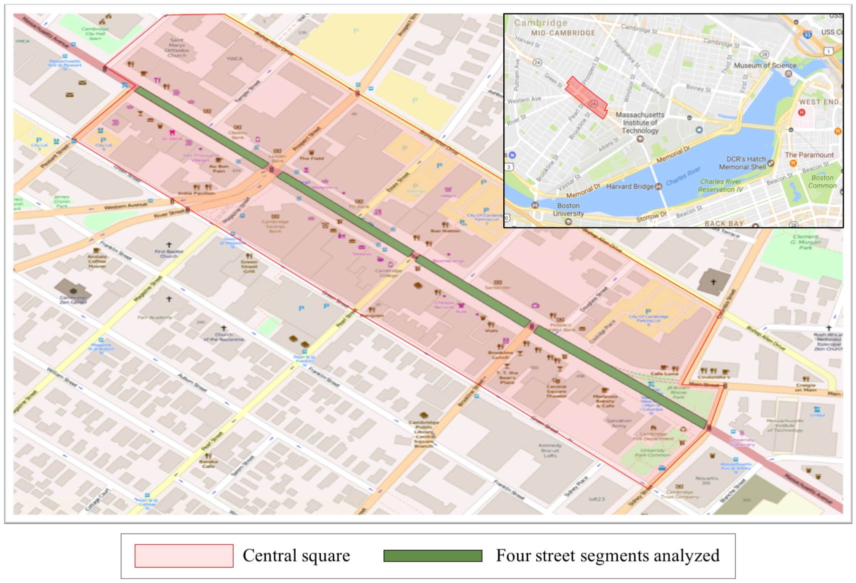

Figure 4. Area analyzed

7.1. Establishment Inventory

As described before, the data collection phase involves gathering information about business establishments, parking infrastructure and freight deliveries. This phase provides high resolution data that allows us to characterize the delivery activity in the surroundings of Central Square.

The business establishment inventory was based on direct observation using a mobile app called Flocktracker and a paper-based survey to establishment owners or managers. The data collection effort involved around 8 hours of fieldwork. There are 80 different business establishments in the area that belong to 27 distinct business types. This means that there is one business establishment every 15 meters in the area. Restaurants show the highest concentration of establishments accounting for one third of the establishments in the area. Banks and grocery stores also experience high density of establishments representing 11% and 6% of the establishments accordingly as shown in Figure 5.

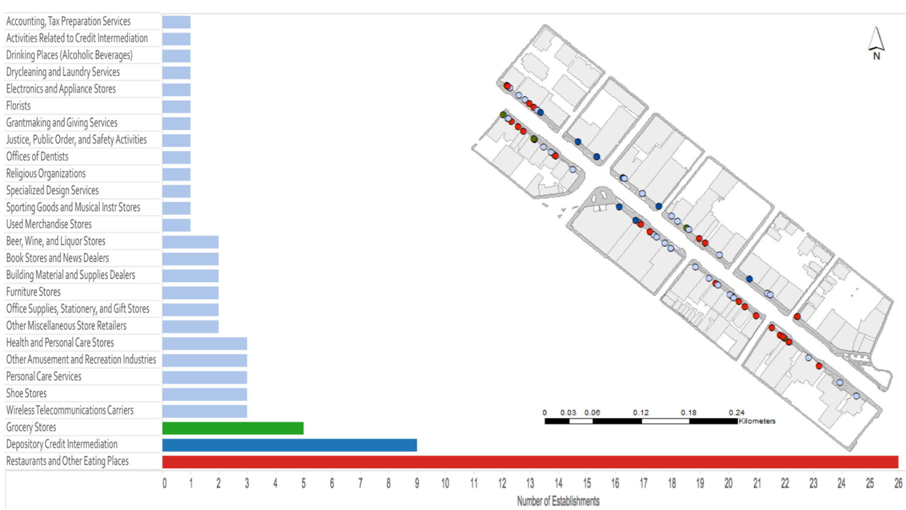

Figure 5. Business establishments

The parking infrastructure study was also based on direct observations using Flocktracker app and it required two hours of fieldwork. 58 parking spots (see Figure 6) are available for private and public vehicles in the area. These spaces are classified as follows:

- 42 metered parking spaces available for passenger vehicles.
- 7 loading zones used for freight activities.
- 5 reserved parking spaces accessible for disabled.
- 2 bus stops and 2 permanent taxi stops

There is one loading zone every 167 meters that serves to 11 business establishments. Most of the loading zones (4 out of 7) run from 8 a.m. to 6 p.m. which leads to 76 hours of freight parking availability per day (see Table 1).

Figure 6. Available parking spots

From \ To	6 p.m.	7 p.m.	8 p.m.
7 a.m.	1	1	
8 a.m.	4		1

Table 1. Loading zones availability

The freight delivery tracking study was based on direct observation using paper-based forms. The data was collected Monday to Friday from 6:00 a.m. to 6:00 p.m. during four weeks (1 week per street segment). We have observed 402 deliveries in total which means around 100 deliveries per street segment per week. The delivery intensity observed (number of deliveries and delivery duration) varies along the time of a day as can be seen in Figure 1. Figure 7 shows the average and maximum delivery intensity experienced by hour of the day. The delivery intensity daily seasonality refutes the common practice of deploying a fixed number of loading zones regardless the time of the day. Under this policy, loading zones might not have enough capacity during peak hours while remain underutilized the rest of the day. In the case of Central Sq., this might explain why 11% of the trucks double parked unable to find an available loading zone.

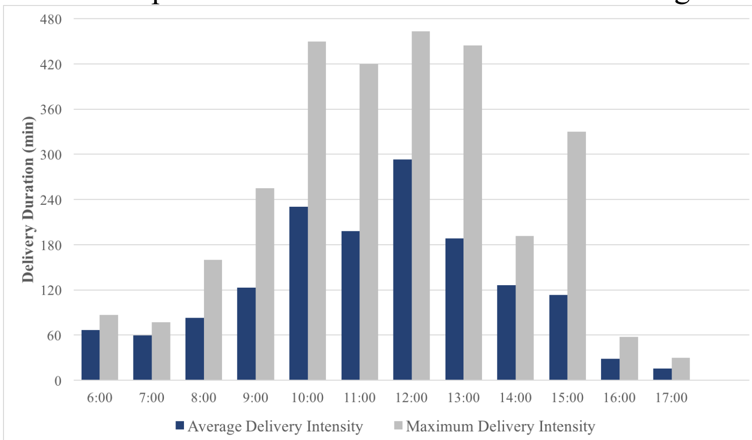

Figure 7. Delivery intensity

7.2. Quantitative Modeling

As described in section 5, each one of the 80 business establishments identified during the establishment inventory should be served from the loading zones to be located. Similarly, every parking spot out of the 58 parking spots is considered a potential loading zone.

To compute some of the parameters required by the mathematical model, establishments within the same NAICS category were grouped together. Table 2 shows the number of establishments, daily delivery frequency (deliveries per day), average number of trips per delivery, average service duration per day (min) and average service duration per hour of the day (min) per business type. Similarly, the unloading and loading time was aggregated by establishment type and spread over the day.

Establishment type	Establishments	Daily frequency	Number of trips	Service duration	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Activities Related to Credit Intermediation	1	1.5	1	1.80							1.33	0.14	0.33			
Beer, Wine, and Liquor Stores	2	1.5	2.91	10.62				5.69	1.13	0.63	3.17					
Book Stores and News Dealers	1	1	1	0.51					0.38	0.13						
Building Material and Supplies Dealers	1	1.5	1.11	3.40					0.25	0.63	1.83	0.56		0.13		
Depository Credit Intermediation	9	1.39	1.11	5.24			0.64	0.77	1.01	0.03	0.33	0.82	0.30	1.27	0.07	
Drinking Places (Alcoholic Beverages)	1	1	1	2.00					2.00							
Drycleaning and Laundry Services	1	1	1	0.08							0.08					
Electronics and Appliance Stores	1	1.5	1	4.50					0.25	0.25	0.33		3.67			
Florists	1	3	1.6	24.27	3.00			0.38	6.75	5.88	1.00	4.00	1.83	1.43		
Furniture Stores	2	1	1	0.98			0.17		0.50		0.17	0.14				
Grantmaking and Giving Services	1	1	1.25	2.20			1.00	0.57	0.25	0.38						
Grocery Stores (Nemp = 35 - 60)	2	1.17	1	1.29					0.88		0.33		0.08			
Grocery Stores (Nemp<=10)	3	1.17	2.1	6.44		1.33	1.00	1.12	1.17	0.92	0.78	0.04		0.08		
Health and Personal Care Stores	3	1.6	1.35	31.06	2.50	0.67	4.58	3.43	3.33	4.63	8.17	2.07	0.61			1.07
Office Supplies, Stationery, and Gift Stores	2	1	1.75	2.49						0.13			0.08	1.88		0.40
Other Amusement and Recreation Industries	2	1	1	1.06						0.06		1.00				
Other Miscellaneous Store Retailers	1	1	1	0.67							0.67					
Personal Care Services	2	1.33	1.125	2.43				1.04		0.42	0.11	0.86				
Religious Organizations	1	1	1	0.83					0.25	0.25			0.33			
Restaurants and Other Eating Places (Nemp 1-10)	5	1.36	1.53	4.38	1.25		0.14		0.50	0.38	0.14	0.21	0.11	1.65		
Restaurants and Other Eating Places (Nemp 11-15)	2	1	3.5	2.67				0.38			1.58	0.71				
Restaurants and Other Eating Places (Nemp 16-20)	8	1.94	1.27	4.77		0.30	0.26	0.32	0.30	0.32	0.48	1.57	0.29	0.64	0.29	
Restaurants and Other Eating Places (Nemp 21-25)	3	1.72	1.96	19.17				0.73	0.79	5.13	7.72	2.29	1.67	0.67		0.17
Restaurants and Other Eating Places (Nemp 30-40)	2	1.3	1.5	2.85		0.83		0.57	0.81	0.06		0.41	0.17			
Restaurants and Other Eating Places (Nemp 50+)	2	1.73	2.3	11.75	0.08				6.67	2.63		2.37				
Shoe Stores	2	1	1	0.90					0.04			0.86				
Sporting Goods, Hobby, and Musical Instrument Stores	1	1	1.67	1.81	1.50						0.17	0.14				
Used Merchandise Stores	1	1	1	0.33							0.33					
Wireless Telecommunications Carriers (except Satellite)	3	1	1	3.40					0.04		1.22	0.08	0.78	0.17	1.11	

Table 2. Delivery information aggregated by business type

The minimum and maximum number of loading zones to be considered in the mathematical model were defined based on the delivery intensity observed. Figure 8 shows the parking availability or capacity of existing loading zones and our proposal. The current capacity fails to provide enough parking space for deliveries occurring during peak hours. However, there is excess capacity during off-peak hours at which loading zones remain idle. On the contrary, our proposal better copes the delivery variability observed during the day by varying the number of loading zones deployed. The day begins with only 2 loading zones (6:00 to 8:00). At 8 a.m. two additional loading zones are included to the system (8:00 to 10:00). Four extra loading zones are added at 10 a.m. (10:00 to 14:00) to cope maximum delivery intensity. After peak hours, the number of loading zones is reduced at 2 p.m. and 4 p.m. to 4 and 2 respectively. Table 3 summarizes the number of loading zones proposed per hour of the day and Figure 9 shows their location.

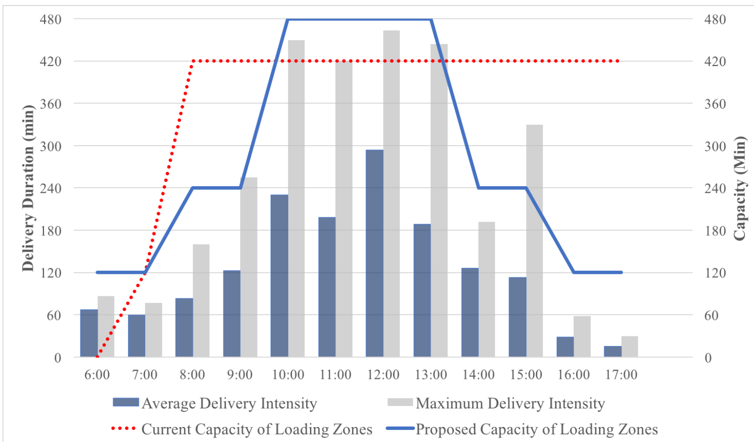

Figure 8. Current and proposed freight vehicles parking capacity (in minutes)

	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Current	0	2	7	7	7	7	7	7	7	7	7	7
Proposed	2	2	4	4	8	8	8	8	4	4	2	2

Table 3. Number of loading zones

Figure 9. Proposed loading zones

7.3. Analysis of Results

As described in section 6, the proposed deployment of loading zones is assessed and compared with the current scenario based on two metrics: walked distance and occupation rate. The proposed location of loading zones reduces the daily walked distance by 39% as can be seen in Table 4. This means that the proposed loading zones are closer to those business establishments where the deliveries are taking place reducing the total parking time per day by 14%. Even though the parking time is reduced, the average occupation rate is increased, that is to say, the loading zones are also better utilized. This is explained because the loading zones availability is reduced from 72 to 56 hours daily releasing infrastructure for other uses.

	Walked distance	Occupation rate	Parking time
Current location	22.10 Km	34.0%	1,469 min
Proposed	13.45 Km	37.4%	1,257 min
Improvement	39.1%	10.0%	14.4%

Table 4. Comparison of current and proposed deployment of loading zones based on mathematical model

As stated before, the mathematical model does not capture the stochasticity of freight deliveries. Delivery trucks arrive to Central Sq. randomly and the duration of the different activities (loading/unloading, walking and service) has also a random component. We simulated the arrivals of freight trucks to resemble the arrival rate observed in the data. Similarly, the unloading/loading time, walking speed and service duration are also simulated based on the data collected.

We simulated 10,000 days and compared the performance of the current and proposed solutions based on the metrics defined previously. Our solution experiences a reduction of 24% in the total walked distance per day compared with the current situation. This means that a delivery man visiting the area would walk less due to the convenient location of the loading zones improving his productivity. Moreover, the reduction in the walked distances causes a decrement of 10% of the commercial vehicles total parking duration per day. On the other hand, the proposed deployment of loading zones makes a better use of infrastructure which is reflected in a higher occupation rate (increment of 15.5%).

	Walked distance	Occupation rate	Parking time
Current location	24.20 Km	43.0%	1,856 min
Proposed	18.30 Km	49.6%	1,667 min
Improvement	24.4%	15.5%	10.2%

Table 5. Comparison of current and proposed deployment of loading zones based on simulation

Additionally, a third metric is incorporated to handle the stochastic nature of the problem: failed delivery rate. A failed delivery occurs when a freight vehicle cannot find any available loading zone (all the loading zones are occupied at the same time). This percentage is tracked by hour of the day as can be seen in Figure 10.

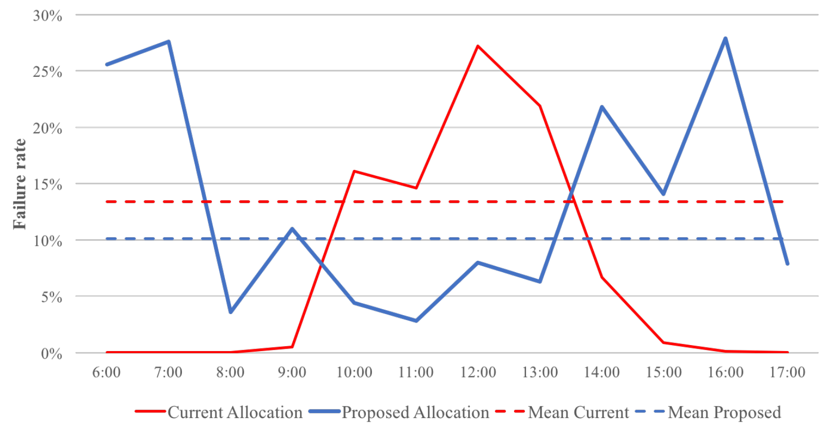

Figure 10. Failure rate per hour of the day

8. Conclusions

In this project, we developed a data driven methodology to design loading zones in order to help local authorities to better deploy loading zones into critical logistics areas so that stakeholders make an efficient use of public infrastructure. The methodology is structured in three phases that involve data collection, quantitative modeling and analysis of results. The methodology was applied to Central Square in Cambridge, MA.

The new deployment of loading zones resulted in a 10% reduction of the time that freight vehicles spend parked in the area which means more public spaces for other purposes. In addition, the proposed deployment of loading zones makes a better use of infrastructure which is reflected in a higher occupation rate (increment of 15.5%). Finally, the solution proposed experiences a reduction of 24% in the total walked distance per day compared with the current situation. Which at the end, has an impact in the service level provided to the establishments, providing a better service level.

The data-driven methodology developed in this project can be applied to different cities and other logistics congested areas, to help local authorities to better use of the public infrastructure to support freight activities.

As future developments, the methodology can be complemented using cameras to collect data in specific areas. Among the benefits of using cameras we can mention 24/7 hours of observation, the opportunity to observe night deliveries and analyze the benefit of implementing new policies that contribute to a more efficient freight delivery system in urban logistics congested areas.

References

Alho, A., De Abreu e Silva, J., & Pinho de Sousa, J. (2014). A state-of-the-art modeling framework to improve congestion by changing the configuration/enforcement of urban logistics loading/unloading bays. *EWGT2013 16th Meeting of the EURO Working Group on Transportation. 111*, pp. 360–369. Procedia - Social and Behavioral Sciences.

Dezi, G., Dondi, G., & Sangiorgi, C. (2010). Urban freight transport in Bologna: Planning commercial vehicle loading/unloading zones. *Procedia - Social and Behavioral Sciences, 2*(3), 5990– 6001.

Muñuzuri, J., Cuberos, M., Abaurrea, F., & Escudero, A. (2017). Improving the design of urban loading zone systems. *Journal of Transport Geography, 59*, 1-13.

Red Ribbon Comission. (2011). *The Mayor's Red Ribbon Commission on the Delights and Concerns of Central Report.* Cambridge: Red Ribbon Comission.