Development of Freight Parking Management Plan

Authors

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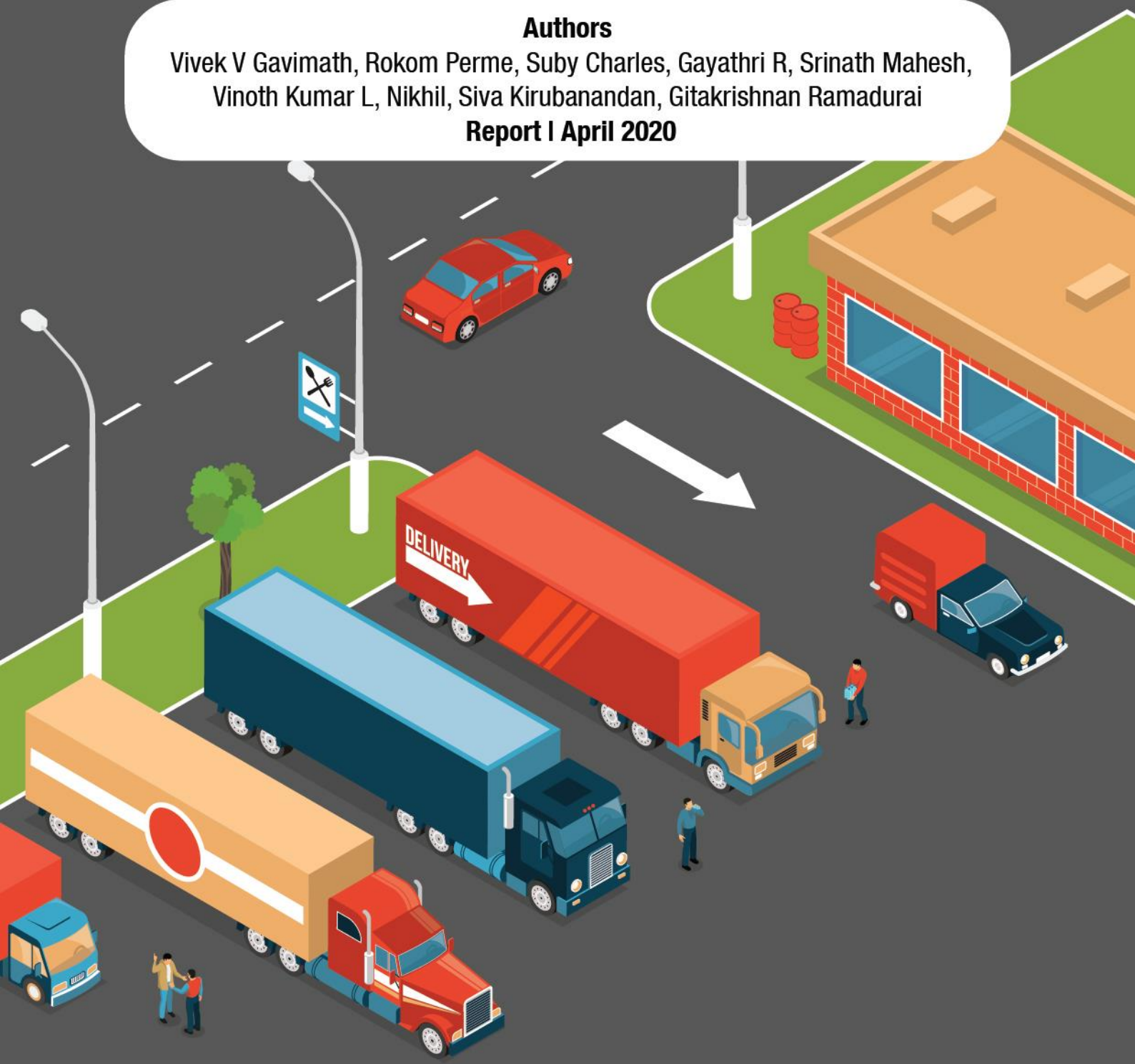
Report I April 2020



Centre of Excellence in Urban Transport

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Abstract

Parking is an unavoidable and integral operation of every vehicle trip. Parking characteristics (space dimensions, time requirements) of passenger vehicles and freight vehicles are different. The objective of the current study is to understand the freight vehicle parking demand and its characteristics in a dense commercial area in Chennai and develop a parking management plan for the same.

We chose Sir Theagaraya Road (STR) in T-Nagar area of Chennai for this study. Data collection included traffic volume count, parking inventory, road inventory, and establishment inventory.

We carefully analyse survey data to estimate the parking volume of freight vehicles on STR and their parking duration. Data from road inventory provided the dimensions of carriage-way, footpath, and parking bays. Traffic volume count helped to ascertain the hourly variation and peak hours of freight vehicle traffic.

We propose dedicated parking bays (~10% available bays) for delivery (freight) vehicles for the exclusive use of delivery vehicles. The current practice and proposed scenario were evaluated by performing simulations in PTV VISSIM software. Results indicated that the proposed plan improves travel time by ~20% on the stretch and reduced emissions by ~15%.

Introduction

Urban spaces are highly valued, as the demand is disproportionate to the limited supply. In recent decades urban areas have witnessed a surge in vehicle ownership, which has led to congestion on streets, increased emissions and fall in transit ridership. Parking is an operation intrinsic to every vehicle trip and increasing vehicle ownership translates into higher demand for the limited parking spaces available in urban areas. Thus, parking management is essential for the easy and smooth day-to-day occurrence of outdoor urban activities, especially in CBDs and commercial areas.

The last-mile delivery of goods is often the most challenging part of a logistic distribution chain. It is generally characterized by the disintegration of bulk into packages of goods, utilization of smaller capacity vehicle and delivery in congested urban streets. Desirable urban goods delivery is characterized by driving efficiency, delivery reliability, energy efficiency, and service efficiency. Travel time and average speeds are the indicators of driving efficiency. Delivery reliability is indicated by the variations in the travel times and arrival times to the delivery points.

Parking requirements of delivery (freight) vehicles differ from those of passenger vehicles like cars and two-wheelers, in terms of parking duration, volume and space dimensions. Also, freight vehicle parking spaces are to be located in the vicinity of the establishments they serve and accompanied by loading/unloading mechanisms such as trolleys, forklifts etc. Insufficient supply of parking spaces leads to double parking of freight vehicles, additional fuel consumption as vehicles detour searching for parking spaces, increased pollution and delay in deliveries.

Double parking is a common issue associated with commercial areas/ CBDs. Double parked vehicles block the vehicles parked in the bays by parking in the adjacent (access) lane, thereby hindering their entry/exit manoeuvres as well. Figure 1 shows the double-parking of cars in an on-street parallel parking setting. Double parking by freight vehicles results in partial/complete blockage of the carriageway, leading to congestion and reduced mobility. Additionally, double parking of freight vehicles has serious implications on the safety of both vehicular and pedestrian traffic.

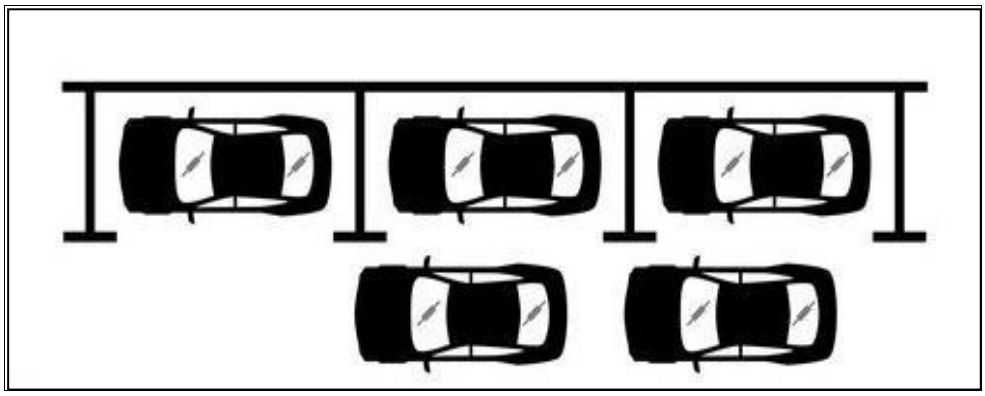

Figure 1: Double Parking (source: Shutterstock)

Objective/Purpose: In recent years, parking of freight vehicles has become a major issue while performing urban deliveries. The current study aims to quantify the impact of irregular parking of freight vehicles by using a simulation tool, supplemented by data from field studies. A holistic proposal for freight vehicle parking is presented after evaluating the potential benefits.

Freight vehicle parking management plan improves overall mobility in the city by alleviating carriageway blockage caused by freight vehicles, helps to decrease fuel consumption and tailpipe emissions as detours in search of parking spaces are minimized, and improves road safety. Relevant stakeholders for the present study include establishment (shop) owners, truck drivers, municipal corporation, traffic police, and the general public representing shoppers, vehicle and pedestrian traffic.

Literature Review

The last-mile delivery by freight vehicles in urban streets demands separate parking policies and supplies to make them efficient. Ignoring truck traffic in an urban area can often lead to overestimation of cruising speed by 223% and underestimation of travel times by 22.8%[1]. Freight vehicles have different characteristics from commuter (private) vehicles. Larger dimensions of freight vehicles mean that a larger space is needed for manoeuvring in and out of the parking slots and also for carrying out loading and unloading activities.

When parking spots near the destination are occupied by other vehicles, private vehicles 'cruise for parking' for finding a vacant parking spot nearest to the destination. However, freight vehicles do not cruise for parking. They resort to double parking when the parking space in front of the destination establishment is occupied by other vehicles. This encroachment to the carriageway of general traffic leads to a point of constriction at the urban streets with a narrower passage and longer travel time at the point of constriction for through vehicles[2].

In narrow streets that do not have enough space for double parking, freight vehicle drivers usually make a detour to return later. This added distance leads to more consumption of fuel, increasing the cost of transportation and emissions, which have an adverse impact on the environment. In the case of private vehicles, the cost of parking is borne by the user, which makes them sensitive to the cost of parking. While in the case of freight vehicles, goods demand is driven by the end-users of the goods. Hence freight deliveries do not change with the delivery cost. In simple words, private vehicles may change their choice of destination in a commercial area if the parking policies are not favourable, but truck drivers will not be able to do the same as the destination is driven by customer demand[3].

The problems from urban freight delivery stem from gaps in supply and demand. These gaps have spatial and temporal attributes associated with it. The demand for freight parking

[1] Amer A., Chow J.Y.J.(2017). A downtown on-street parking model with urban truck delivery behavior. Transportation Research *Part A: Policy and Practice*, 102 , pp. 51-67.

[2] Amer A., Chow J.Y.J.(2017). A downtown on-street parking model with urban truck delivery behavior. Transportation Research *Part A: Policy and Practice*, 102 , pp. 51-67.

[3] Shiftan, Yoram & Burd-Eden, Rachel. (2001). Modeling Response to Parking Policy. Transportation Research Record. 1765. 27-34. 10.3141/1765-05

at a given time may be very high for a location while other places may not have significant demand at that time.

The economic, social and environmental problems associated with the discussed characteristics of freight vehicles and their parking can be attributed to:

1. Provision of insufficient parking slots for the freight vehicles
2. Inadequate location and size of parking slots.
3. Lack of enforcement.

Possible solutions:

The problems associated with parking can be mitigated by adopting strategies and policies which can be broadly classified broadly into;

1. Infrastructure development
2. Parking management techniques:
    a. Time restrictions
    b. Pricing strategies
    c. Space management
    d. Reinforcement

Infrastructure development is much costlier than parking management techniques. However, the provision of sufficient parking capacity for freight vehicles should be the priority. Failing this will render other policies ineffective and pointless. Acceptance rates by users also will be minimum, and there may be resistance by truck operators and establishments owners. On-street parking slots can be designated specifically for freight vehicles only. Since deliveries to all establishments do not happen at the same time, a designated parking slot can serve multiple establishments. The number of such parking slots and their locations should be optimized. This was proven to be more beneficial in a study done by Amer and Chow[4]. In their study assigning 20 of the 3712 parking spaces to delivery, trucks yielded a 6.1% reduction in travel time, a 53.3% reduction in truck double-parking. However, increasing the number of bays beyond the optimal will add very little

[4] Amer A., Chow J.Y.J.(2017). A downtown on-street parking model with urban truck delivery behavior. Transportation Research Part A: Policy and Practice, 102 , pp. 51-67.

benefit to the system at the cost of the public spaces[5]. Optimization of parking slots for the freight vehicles will result in drivers parking at some distance from their destination establishment and do the final delivery on foot. But because of the weight of the goods to be delivered, parking slots for freight vehicles need to be at a feasible distance from the destination establishment. In a study conducted by[6], the maximum distance covered on foot by the delivery agent was 75 m in the central district in the city of Bergamo. While in another study conducted in High Street, Winchester UK, the parking bays were provided such that the delivery guy has to cover approximately 80 meters on foot[7]. There should be time limits on the duration of parking when such bays are used for delivery. In Paris, a 30-minute time limit was imposed, where the average parking period was 14 minutes[8].

Time restriction of freight parking restricts the deliveries to specific time periods of the day, which is usually during off-peak hours. Off-Peak Hour Deliveries (OHDs) have been found to have social, economic, and environmental benefits in many studies and pilot implementations. OHDs can be implemented as Full-OHDs or Partial-OHDs. In Full-OHDs, delivery activities are permitted after the peak hour traffic has fully receded. While in Partial-OHDs, deliveries are permitted when the peak hour traffic starts waning. There are two modalities of OHDs which have been tested:

1. Staffed (assisted) OHD
2. Un-staffed (unassisted) OHD

In staffed OHD, staff from the receiving establishment is present to accept the goods. It prevents negative outcomes such as damage to goods, theft, etc. However, the staff present during OHD needs to be paid extra to be present in the establishment. Transporters benefit the most from full- or partial-OHD. There is little to no benefit for receiving establishments

[5] André Romano Alho,Joãode Abreu e Silva, Jorge Pinhode Sousa, Edgar Blanco (2018), Improving mobility by optimizing the number, location and usage of loading/unloading bays for urban freight vehicles, Transportation Research Part D: Transport and Environment, Volume 61, Part A, Pages 3-18

[6] Pinto, R., Golini, R., & Lagorio, A. (2016). Loading/unloading lay-by areas location and sizing: a mixed analytic-Monte Carlo simulation approach. IFAC-PapersOnLine, 49(12), 961–966. https://doi.org/10.1016/j.ifacol.2016.07.900

[7] Mcleod, Fraser & Cherrett, Tom. (2011). Loading bay booking and control for urban freight. International Journal of Logistics: Research and Applications. 14. 385-397. 10.1080/13675567.2011.641525

[8] Browne, M., Allen, J., & Attlassy, M. (2007). Comparing freight transport strategies and measures in London and Paris. International Journal of Logistics Research and Applications, 10(3), 205–219. https://doi.org/10.1080/13675560701467052

by shifting to OHDs. Hence, some incentive is required in the beginning to convince the establishments to adopt OHDs[9].

In un-staffed OHD, the transporter is given access to the storage facility of the establishment and no staff of the receiving establishments is present. It eliminates the need to pay to the staff, but there are chances of negative outcomes. There is a trade-off between cost and safety in the two modalities of the OHD. OHD has associated environmental benefits also. In a pilot study with Full OHD programs of New York City and São Paulo, the deliveries were made during the late night and early morning periods (7 PM to 6 AM), 45–67% reductions in emissions were observed. In Bogota, partial OHD was implemented, where OHD took place between 6 PM and 10 PM. The reductions in emissions were about 13%[10]. The same study also had estimated that a city in a developing country with 5-10 million population, such as Chennai, can reduce reactive organic gas (ROG), total organic gas (TOG), CO, CO_2, NO_X, PM_{10} and PM_{25} by 8418, 9584, 122753, 43.37, 17565, 2874, 2750 tons, respectively. Un-staffed OHD had been estimated to save $150–$200 million/year for the city of Manhattan at the same time eliminating the need to pay extra for the staff[11]. Apprehensions regarding the safety of goods can be eliminated by taking few steps such as installing cameras at the delivery godown.

Encroachment of parking bays reserved for freight vehicles by private vehicles does not have a significant impact on streets with low traffic densities. While the same has a significant impact on streets with narrow streets with high traffic densities[12]. When some of the on-street parking bays were reserved for freight vehicles in Paris, it was observed that 47% of the time, those bays were occupied by private vehicles[13]. Enforcement is required to find and penalize violators of parking policies. The fine cited from such violations can be used for further enhancement of the freight activities in the place.

[9] Holguín-Veras, J., Wang, X. (Cara), Sánchez-Díaz, I., Campbell, S., Hodge, S. D., Jaller, M., & Wojtowicz, J. (2017). Fostering unassisted off-hour deliveries: The role of incentives. Transportation Research Part A: Policy and Practice, 102, 172–187. https://doi.org/10.1016/j.tra.2017.04.005

[10] Holguín-Veras, José & Amaya, Johanna & Sánchez-Díaz, Iván & Browne, Michael & Wojtowicz, Jeffrey. (2018). State of the art and practice of urban freight management: Part I: Infrastructure, vehicle-related, and traffic operations. Transportation Research Part A Policy and Practice. 10.1016/j.tra.2018.10.037.

[11] Holguín-Veras, J., Jaller, M., Destro, L., Ban, X. (Jeff), Lawson, C., & Levinson, H. S. (2011). Freight Generation, Freight Trip Generation, and Perils of Using Constant Trip Rates. Transportation Research Record, 2224(1), 68–81. https://doi.org/10.3141/2224-09.

[12] André Romano Alho,Joãode Abreu e Silva, Jorge Pinhode Sousa, Edgar Blanco (2018), Improving mobility by optimizing the number, location and usage of loading/unloading bays for urban freight vehicles, Transportation Research Part D: Transport and Environment, Volume 61, Part A, Pages 3-18

[13] Browne, M., Allen, J., & Attlassy, M. (2007). Comparing freight transport strategies and measures in London and Paris. International Journal of Logistics Research and Applications, 10(3), 205–219. https://doi.org/10.1080/13675560701467052

All these measures need to be considered and implemented together to reduce/optimize the cost of urban freight deliveries, improve efficiency and reduce all other externalities.

Methodology

This section provides a brief description of the methodology adopted for the current study.

A literature review was carried out to identify various issues associated with freight (delivery) vehicle parking in urban areas globally and understand policies and practices adopted to deal with. A reconnaissance survey was carried out to identify different locations with high freight vehicle parking demand in Chennai. In line with the aforesaid objective, subject to feasibility, time and resource constraints, and presence of densely placed commercial establishments, the study stretch was finalized.

Appropriate data collection methods were employed to yield information regarding freight vehicle traffic and their parking demand characteristics, parking supply, and inventory of establishments in the study stretch. All the data collection methods are presented in detail in section 4 of this report, along with analysis and description of data.

Based on the insights gained from data analysis about the existing freight parking practices, a commercial traffic simulation tool was used to model the vehicular traffic flow and their parking manoeuvres, including double parking of freight vehicles. A proposed dedicated freight parking scenario was also modelled, and comparison of travel time and emissions was made between the two scenarios.

Freight Parking Characteristics and Management Plan – Sir Theagaraya Road

For the current study, Sir Theagaraya road in T-Nagar, Chennai - 1.1 km stretch from Panagal Park to South Boag road was chosen after a reconnaissance survey. This stretch of Sir Theagaraya Road, T-Nagar is a popular shopping hub also called as Pondy Bazaar in Chennai metropolitan area located south of Chennai Central railway station. Anna Salai arterial road runs along the east of T-Nagar and Mambalam station on the Chennai sub-urban railway line is located on the western border. Panagal Park is an important landmark in T-Nagar area.

Sir Theagaraya road connects Panagal park to Anna Salai with an East-West orientation and measures about 1.4 km. Thanikachalam road, Dr Nair road and Boag road having North-South orientation intersect Sir Theagaraya road (Figure 2).

Figure 2: Study Stretch - Sir Theagaraya road, T-nagar (Source: Google Maps ™)

Sir Theagaraya road has mixed land use with predominantly commercial use. It houses several retail/wholesale outlets (of clothes, footwear), restaurants, and branches of leading banks. Along the study stretch, a 4-star hotel and a school are also located. Branches of popular departmental stores and jewellery dealers are present on the study stretch.

Figure 3: Delivery vehicle parked on Sir Theagaraya Road

Figure 4: Carriageway blockage by freight vehicle on Sir Theagaraya Road

Given the dense commercial nature of Sir Theagaraya road, it attracts shoppers. An estimated 2 million people visit the stretch and neighbourhood during festival seasons, and the numbers during a typical weekend are about 500000 whereas on a normal weekday it is 200000.

1.1 Data collection

Data regarding freight vehicle volume and their parking characteristics (volume and duration) were collected to understand the freight vehicle parking demand and supply. An inventory of establishments along the study stretch was carried out, and their classification

as per the National Industrial Classification (NIC) was done. Additionally, road inventory survey was carried out to collect the geometric features. Secondary data collections included maps, layouts, and traffic movements at the study stretch.

4.1.1 Establishment Inventory Survey

Sir Theagaraya Road is densely packed commercial/shopping hub of the city which houses numerous establishments (shops) dealing with products ranging from textiles, footwear, to restaurants, petrol pumps and banks/insurance firms. To deduce the exact number of establishments and the product traded at the respective establishments, an inventory of establishments along the study stretch - Sir Theagaraya Road was completed.

The survey involved IITM Project Staff traverse through Sir Theagaraya Road to note down the details (wholesale/retail, commodity traded) of individual establishments. Given the close and compact placement of establishments along the study stretch, a survey was conducted by 'walking'. Due care was taken not to omit any establishments and in case of multi-storey complexes walking through ensured correct count. The data from this survey was compiled, and classification of establishments along the study stretch as per National Industrial Classification (NIC) was completed. Table 1 and Figure 5 presents the classification of establishments along Sir Theagaraya Road.

Table 1: Classification of establishments and count in the study area

Class	Economic Activity	Count
1811	Printing	04
4649	Wholesale of other household goods	04
4711	Retail sale in non-specialized stores with food products, beverages or tobacco predominating	14
4730	Retail sale of automotive fuel in specialized stores	02
4741	Retail sale of computers, peripheral units, software and telecommunications equipment in specialized stores	17
4759	Retail sale of electrical household appliances, furniture, lighting equipment and other household articles in specialized stores	11

Class	Economic Activity	Count
4761	Retail sale of books, newspapers and stationery in specialized stores	01
4763	Retail sale of sporting equipment in specialized stores	02
4771	Retail sale of clothing, footwear and leather articles in specialized stores	153
	Retail sale of pharmaceutical and medical goods, cosmetic and toilet articles in specialized stores	16
4773	Other retail sale of new goods in specialized stores	76
5610	Restaurants and mobile food service activities	19
5621	Event catering	01
6419	Other monetary intermediation (excluding RBI)	35
6511	Life insurance	02
6612	Security and commodity contracts brokerage	09
6810	Real estate activities with own or leased property	09
6910	Legal activities	01
7110	Architectural and engineering activities and related technical consultancy	05
7420	Photographic activities	01
7911	Travel agency and tour operator activities	12
8219	Photocopying, document preparation and other specialized office support activities	05
8530	Higher education	01
8549	Other education	06
8620	Medical and dental practice activities	03

Class	Economic Activity	Count
8690	Other human health activities	01
9101	Library and archives activities	01
9512	Repair of communication equipment	08
9601	Washing and dry cleaning of textile and fur products	01
9602	Hairdressing and other beauty treatment	15
9609	Other personal service activities	02
14105	Custom tailoring	19
Total		456

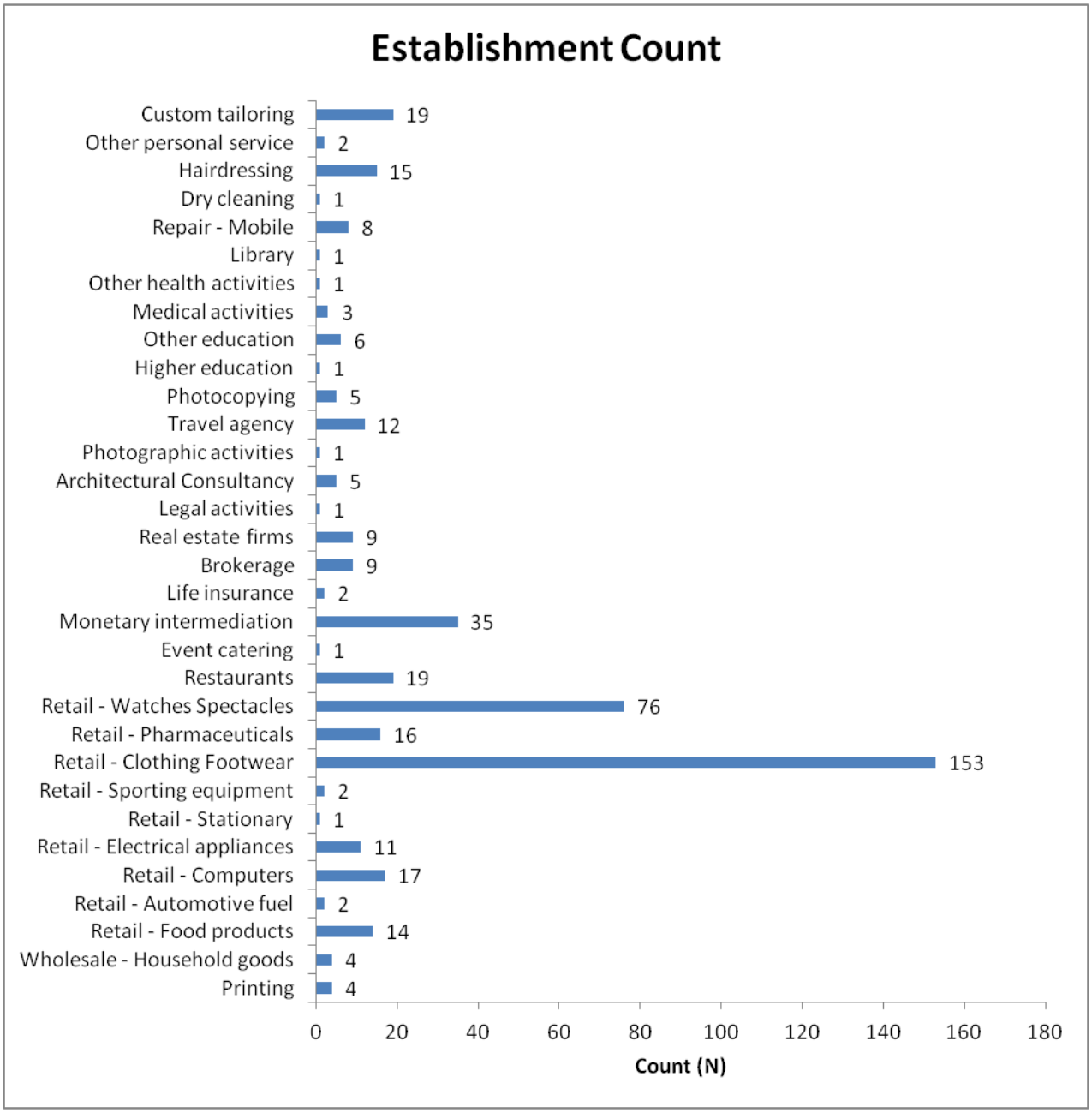

Figure 5: Classification of establishments

Figure 5 clearly shows retail shops dealing with clothes and footwear are dominant along Sir Theagaraya Road, followed by specialized stores of optical, watches, and jewellery (76). A considerable number (35) of banks and insurance firms can also be noticed. A total of 456 establishments are operational along the study stretch.

4.1.2 Road Inventory Survey

Geometric design elements of the road (right of way) are vital for assessing the current parking supply and also serve as input to future designs. A road inventory survey was

carried out by IITM Project Staff to collect dimensions of the carriageway, footpath, parking bays and locations of ramps provided for accessing off-street parking facilities.

As part of this survey, a team of IITM Project Staff walked along Sir Theagaraya Road holding a rodo meter (Figure 6) to measure the dimensions. Carriageway and footpath width at multiple mid-block locations, location of on-street parking bays and their dimensions, and locations of ramps were collected. Entry and exit gate locations of petrol pumps and shopping complexes were duly noted.

Figure 6: Rodo meter survey

The data from road inventory survey - width of the carriageway, the width of the footpath, and dimensions of on-street parking lots were used for editing the network in traffic simulation platform. Parking supply was computed taking into account the locations of

ramps, entry/exit gates of shopping complexes and petrol pumps. Length and width of parking lot adopted were 5m and 2m, respectively. These values are within limits specified in IRC 35, as per which on-street parking lot length can be 4.5 to 6m and width can be 1.7 to 2.5m. Subject to these constraints, the parking supply was computed to be 103 parking lots.

Secondary data collection: Apart from the primary data collection described previously, traffic volume data from 'Pedestrian Plaza' report by a private consultant for Pondy Bazar was collected for the present study. Future traffic circulation plan was gathered from municipal authorities and articles which appeared in dailies.

4.1.3 Freight Vehicle Volume Count Survey

In order to ascertain the volume of freight vehicles plying on different roads in the study area, volume count survey of freight vehicles was conducted. The survey duration was 14 hours, during 0700 and 2100 hrs on December 15, 2018. A total of eight locations for data collection were chosen strategically to capture the freight vehicle volume (Table 2). Three survey locations were on Sir Theagaraya Road, Two on Raja Bather Street and one each on Nana Street, Deena Dayalu Street and Lakshmikanthan Street respectively (Figure 7).

15 December 2018

14 hours; 7 am to 9 pm

License plate matching technique

08 locations

Table 2: Survey locations

Road Name	No. of Survey Locations	Survey Location Code

Sir Theagaraya Road	03	T1 T2 T3
Raja Bather Street	02	RBS1 RBS1
Nana Street	01	NS
Deena Dayalu Street	01	DDS
Lakshmikanthan Street	01	LS

Enumerators were assigned to the eight survey locations and instructed to note down the license plate numbers of freight vehicles crossing their respective locations along with time at the instant of crossing. Later the license plate numbers from all survey locations were matched to ascertain freight vehicles' traffic volume, parking volume and duration.

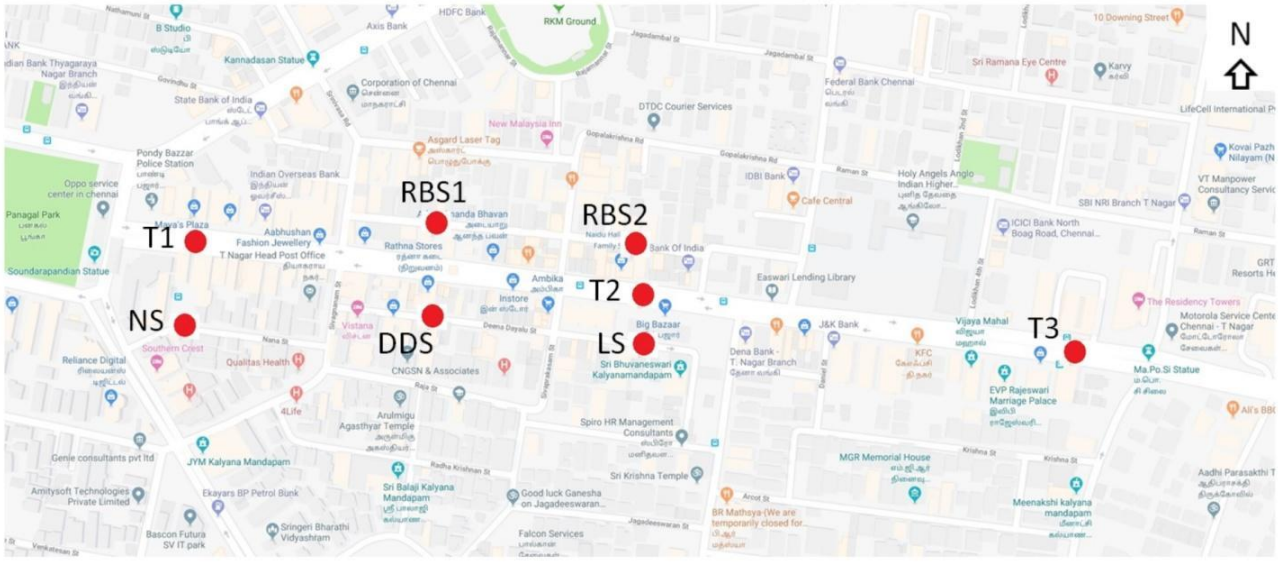

Figure 7: Survey locations (Source: Google Maps ™)

4.2 Data Analysis

This section presents the analysis of data collected from different surveys described in section 4.1.

4.2.1. Freight Vehicle Traffic Volume

The freight vehicle traffic volume from 0700 to 2100 hrs at eight survey locations is summarised in Table 3.

Table 3: Hourly volume (mid-block) of freight vehicles

Time Interval	Survey Location							
	T1	T2	T3	RBS1	RBS2	NS	DDS	LS
0700 to 0800 hrs	29	13	44	05	00	01	02	03
0800 to 0900 hrs	17	18	40	04	01	02	03	01
0900 to 1000 hrs	32	27	62	06	11	05	08	06
1000 to 1100 hrs	47	45	68	06	11	05	08	06
1100 to 1200 hrs	39	46	76	10	05	13	03	07
1200 to 1300 hrs	42	39	79	08	05	10	07	03
1300 to 1400 hrs	30	46	83	13	15	10	09	06
1400 to 1500 hrs	30	35	67	03	15	05	05	03
1500 to 1600 hrs	39	39	81	07	07	05	08	06
1600 to 1700 hrs	41	35	85	07	12	05	03	02
1700 to 1800 hrs	16	19	61	06	04	07	04	03
1800 to 1900 hrs	20	17	59	07	14	07	05	04
1900 to 2000 hrs	22	25	44	02	06	01	03	01
2000 to 2100 hrs	13	26	41	06	03	06	03	03
Total	417	430	890	90	100	81	68	52

The hourly variation in freight vehicle volume on Sir Theagaraya Road (T1, T2, and T3) is presented in figures 8, 9, and 10.

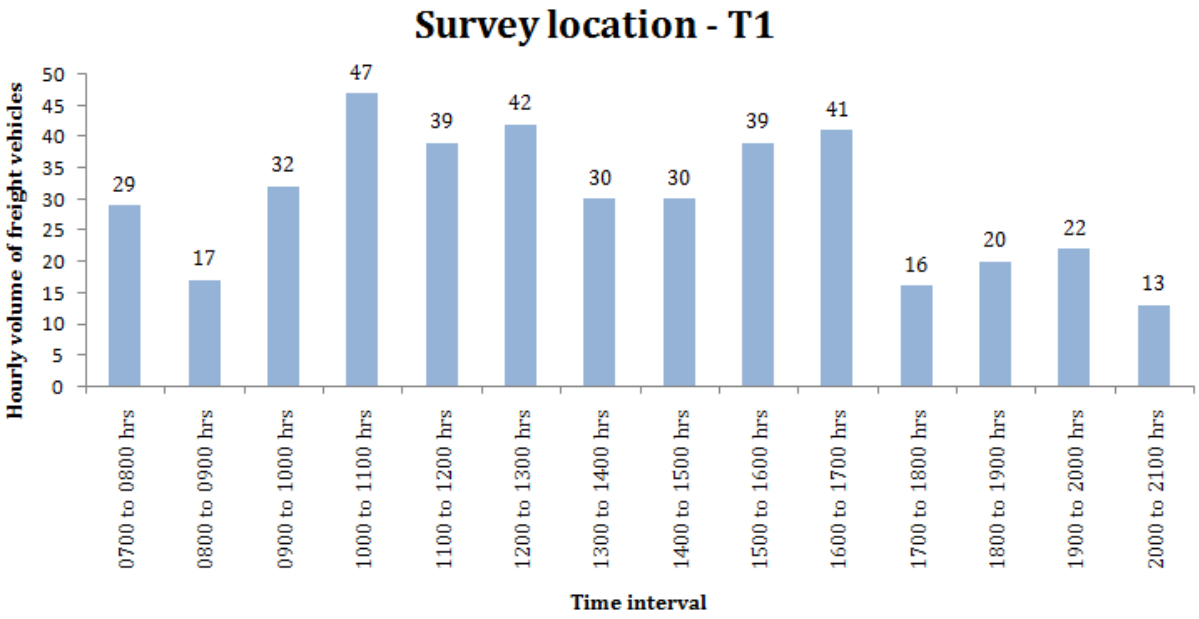

Figure 8: Hourly variation in freight vehicle traffic volume on Sir Theagaraya Road (T1)

From figure 8 we can observe that freight vehicle volume at survey location - T1 steadily increases from 0800 hrs, reaches a maximum between 1000 to 1100 hrs and remains nearly the same till 1300 hrs. Following a dip thereafter, the evening peak is between 1600 to 1700 hrs. Average volume at the location is 30 and peak-volume is 47.

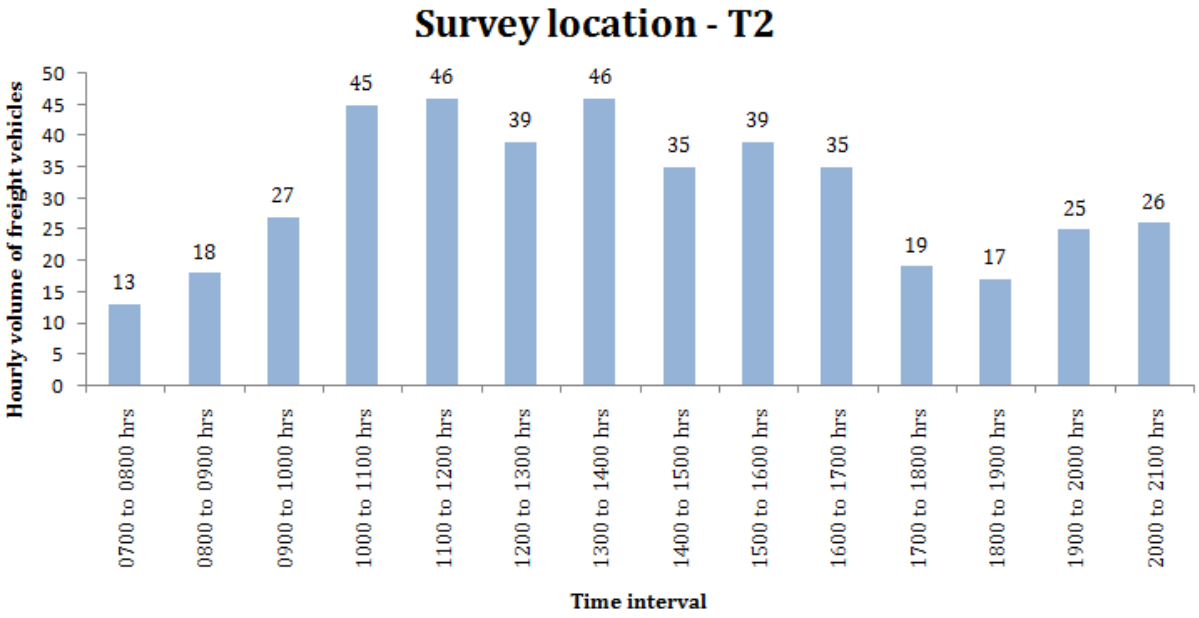

Figure 9: Hourly variation in freight vehicle traffic volume on Sir Theagaraya Road (T2)

At survey location - T2 increasing trend in volume can be observed from 0800 hrs and reaches peak volume between 1100 to 1200 hrs. Post 1700 hrs volume decreases till 1900

hrs, after which it slightly increases and remains almost constant till 2100 hrs. Peak hour can be observed twice during 1100-1200 hrs and 1300-1400 hrs. Peak, least, and average volumes are 46, 13, and 30, respectively.

Similar variation is observed at survey locations T3, wherein a steady increase in volume can be found from 0800 to 1400 hrs. Post 1400 hrs following a dip for a short period, the volume rises to reach peak volume of 85 from 1600 to 1700 hrs, thereafter it falls. Minimum volume at this location is 40.

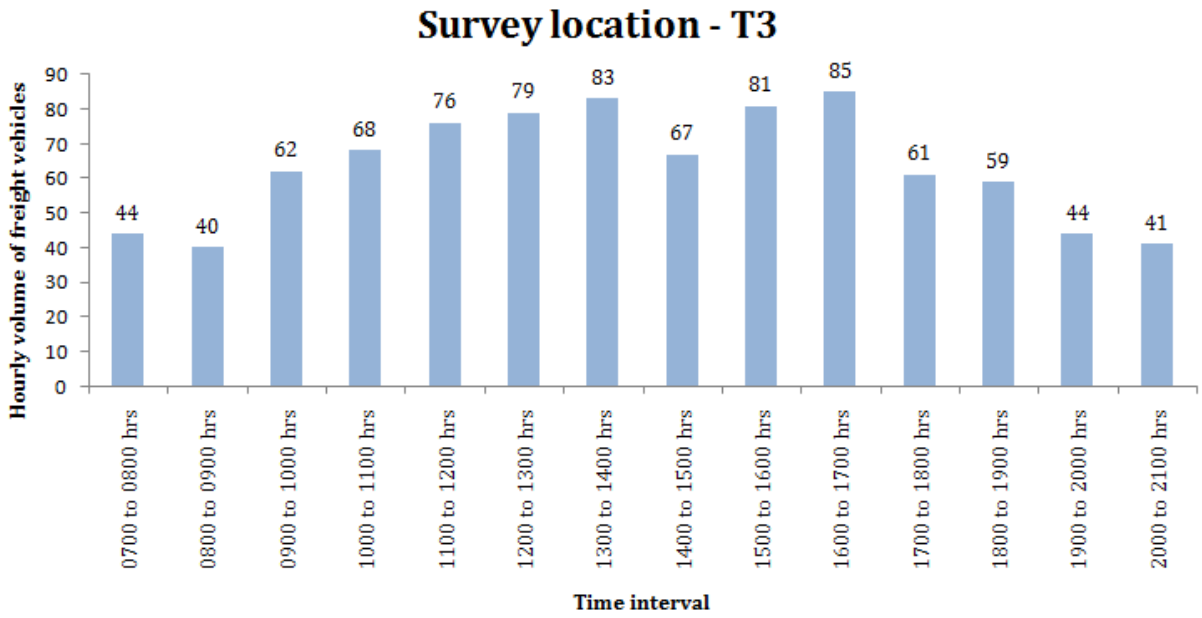

Figure 10: Hourly variation in freight vehicle traffic volume on Sir Theagaraya Road (T3)

Variation in the hourly volume of freight vehicles along Raja Bather Street (RBS1, RBS2) is depicted in figures 11 and 12.

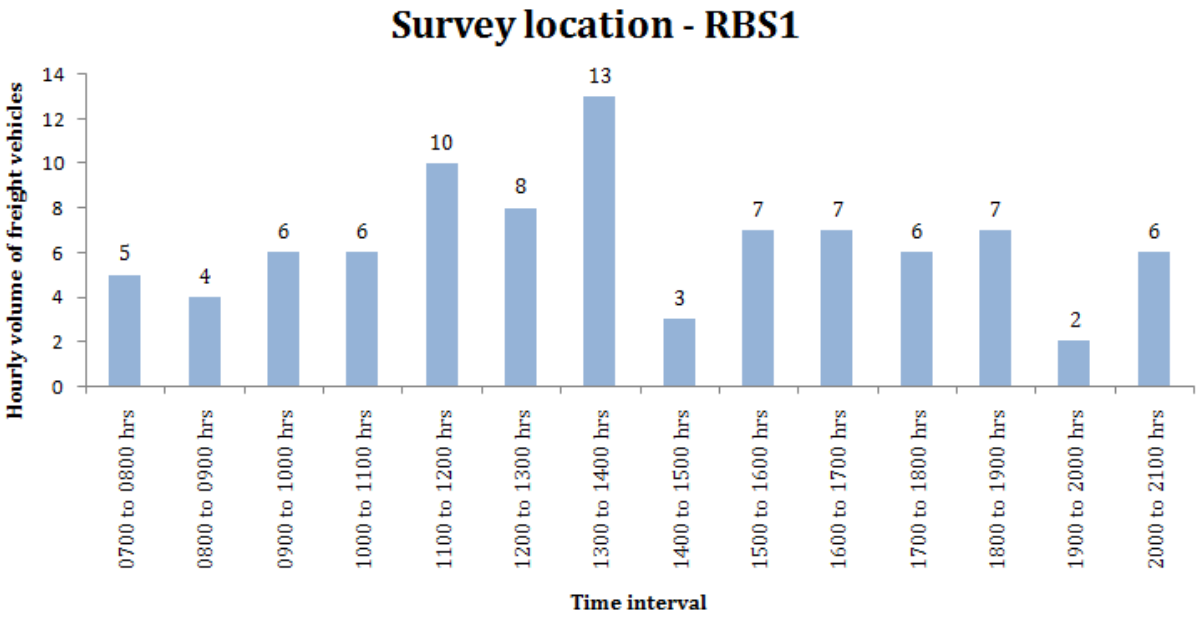

Figure 11: Hourly variation in freight vehicle traffic volume on Raja Bather Street (RBS1)

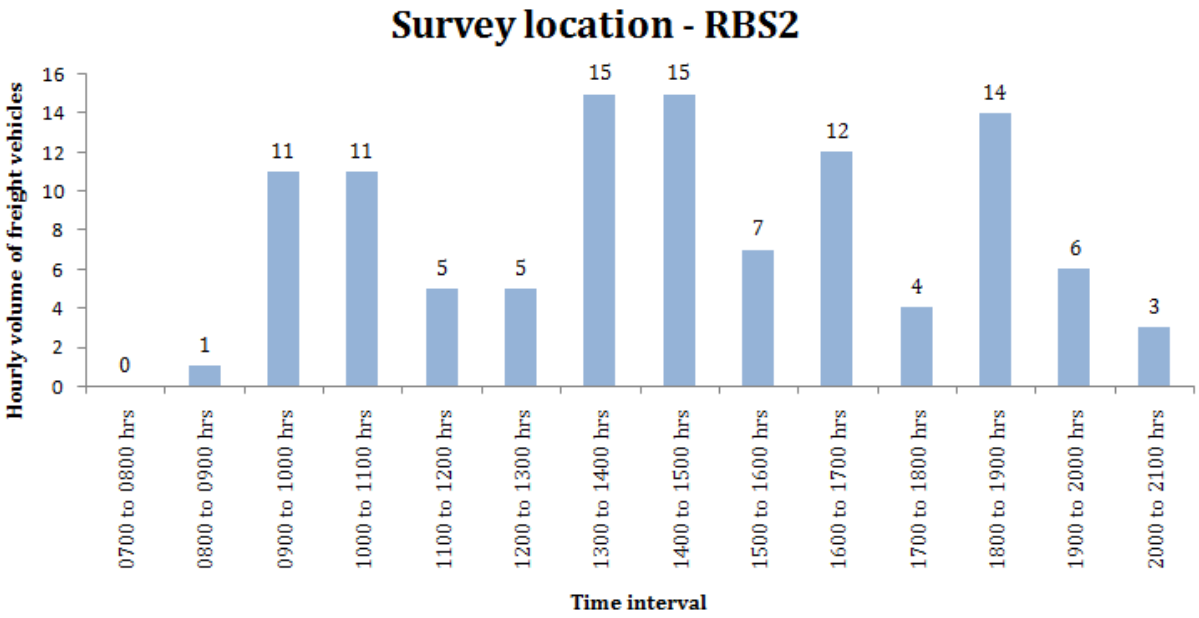

Figure 12: Hourly variation in freight vehicle traffic volume on Raja Bather Street (RBS2)

Figures 13, 14, and 15 present variations in the hourly volume of freight vehicles on Nana Street (NS), Deena Dayalu Street (DDS) and Lakshmikanthan Street (LS) respectively.

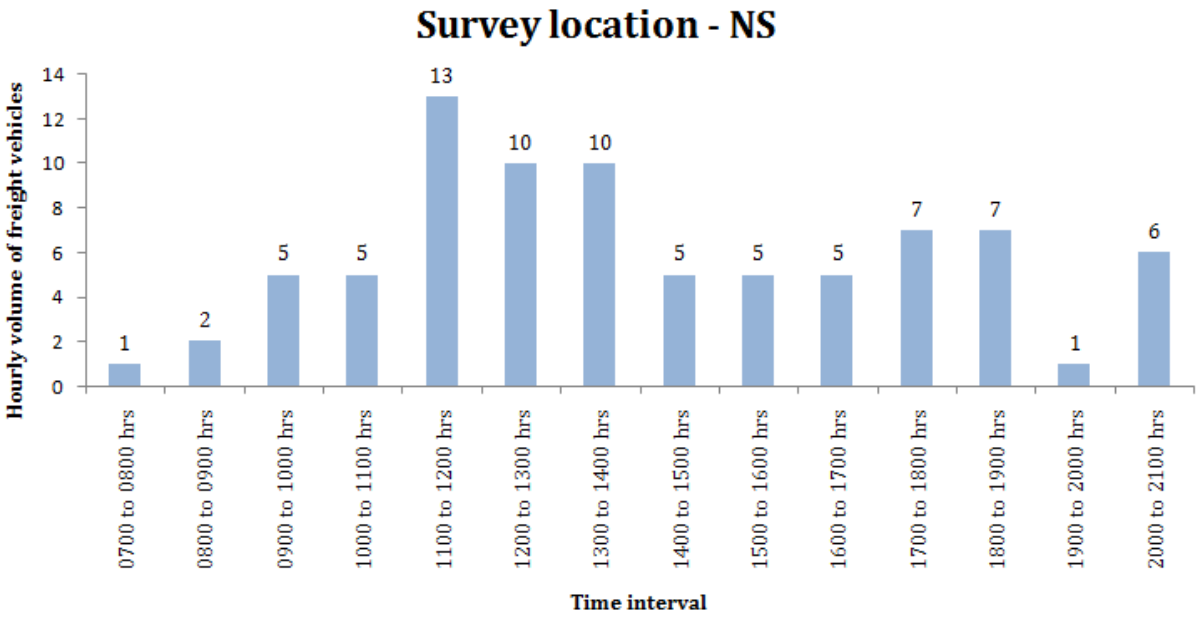

Figure 13: Hourly variation in freight vehicle traffic volume on Nana Street

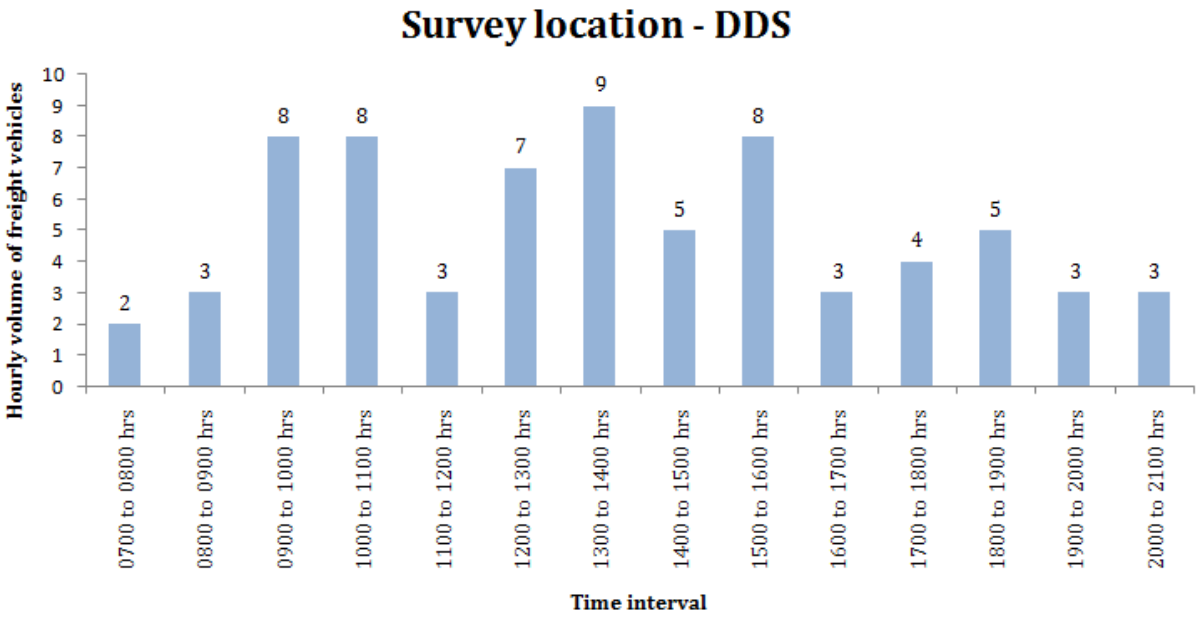

Figure 14: Hourly variation in freight vehicle traffic volume on Deena Dayalu Street

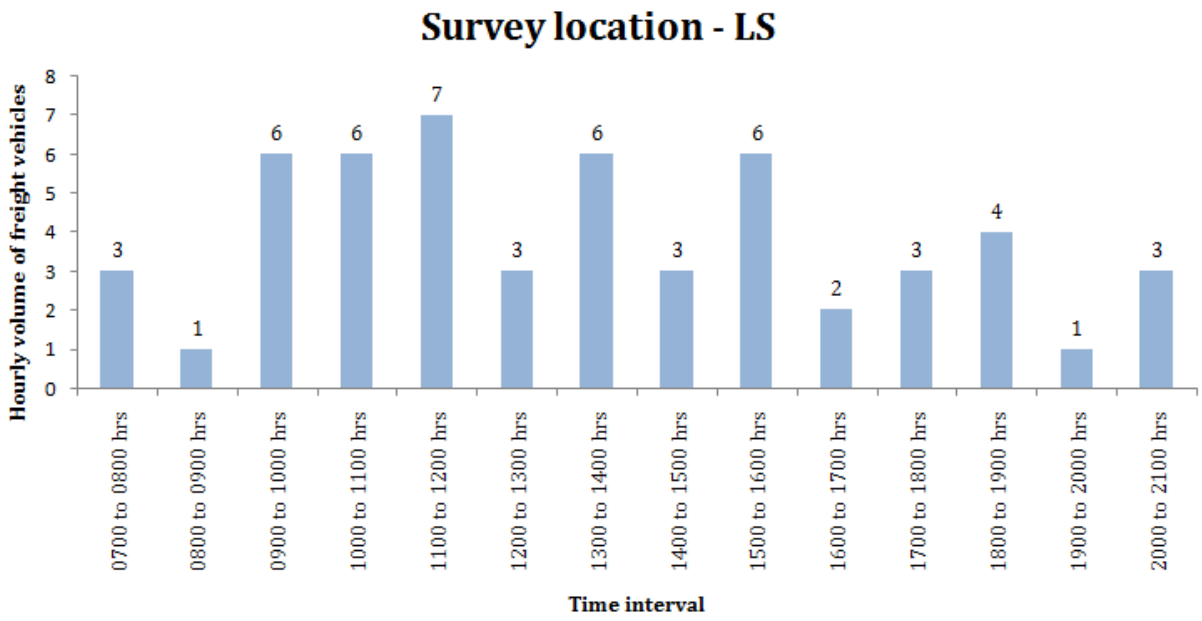

Figure 15: Hourly variation in freight vehicle traffic volume on Lakshmikanthan Street

It is evident from the above figures that on an average hourly 40 freight vehicles travel along Sir Theagaraya Road and the peak period is from 1000 to 1200 hrs. The side streets, namely Raja Bather Street, Nana Street, Deena Dayalu Street and Lakshmikanthan Street were observed to have a relatively low average hourly volume of 7, 6, 5, and 4 respectively. Peak freight traffic on Raja Bather Street was from 1300 to 1400 hrs, and it was similar for other side streets as well.

4.3 Freight Vehicle Parking Volume and Duration

The total number of vehicles parked on a given stretch of road during a unit time period is parking volume. Based on the difference in interception time of freight vehicles at different survey locations (refer section 3.2) and travel time between respective locations, parking volume and duration were determined. For the ease of analysis, Sir Theagaraya Road was divided into three sub-segments as shown in figure 16 and details are listed in table 4.

Table 4: Study stretch details

Stretch Code	Stretch Details
S1	Sir Theagaraya Road (Panagal park to Srinivasa road junction)
S2	Sir Theagaraya Road (Srinivasa road to Thanikachalam road junction)
S3	Sir Theagaraya Road (Thanikachalam road to S Boag road junction)

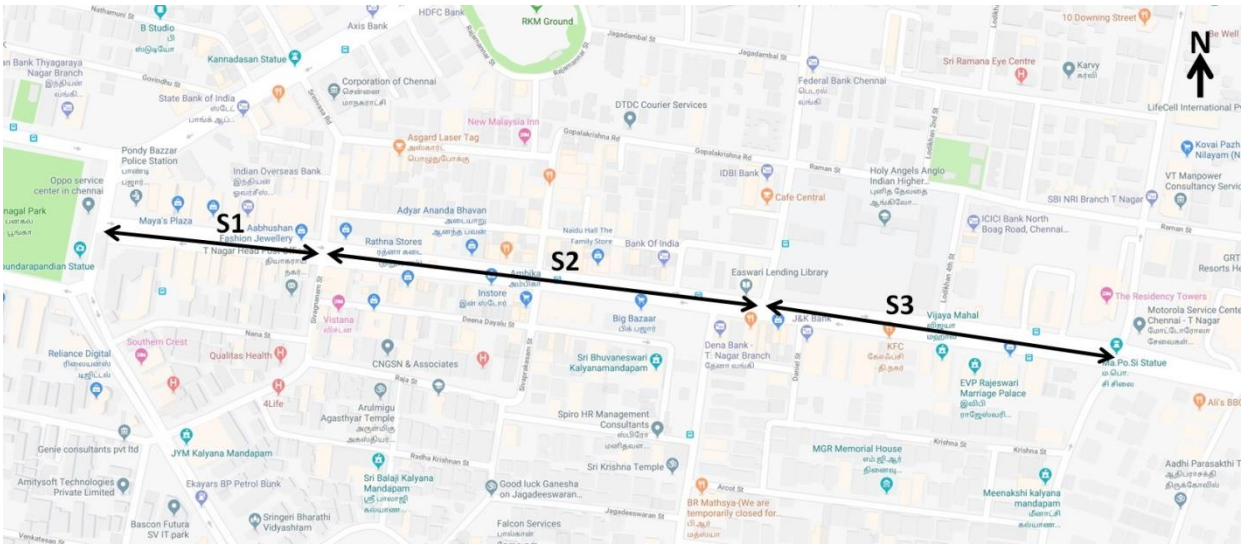

Figure 16: Study stretch details (source: Google Maps™)

Freight vehicle parking volume along Sir Theagaraya Road is summarized in table 5, and the hourly variation is depicted in figure 17.

Table 5: Hourly Freight vehicle parking volume

Time Interval	Freight Vehicle Parking Volume		
	S1	S2	S3
0700 to 0800 hrs	7	4	9
0800 to 0900 hrs	6	5	8
0900 to 1000 hrs	5	8	12
1000 to 1100 hrs	5	7	20
1100 to 1200 hrs	9	7	15
1200 to 1300 hrs	11	6	12
1300 to 1400 hrs	8	8	16

1400 to 1500 hrs	6	7	11
1500 to 1600 hrs	4	10	11
1600 to 1700 hrs	5	12	3
1700 to 1800 hrs	1	6	6
1800 to 1900 hrs	2	7	7
1900 to 2000 hrs	2	8	7
2000 to 2100 hrs	1	10	2
Total	72	105	139

It can be observed that maximum freight vehicles were parked at stretch S3 (139) followed by S2 (105) and least are noticed at S1. An average of 30 freight vehicles is found parked during the peak period of 1000 to 1400 hrs.

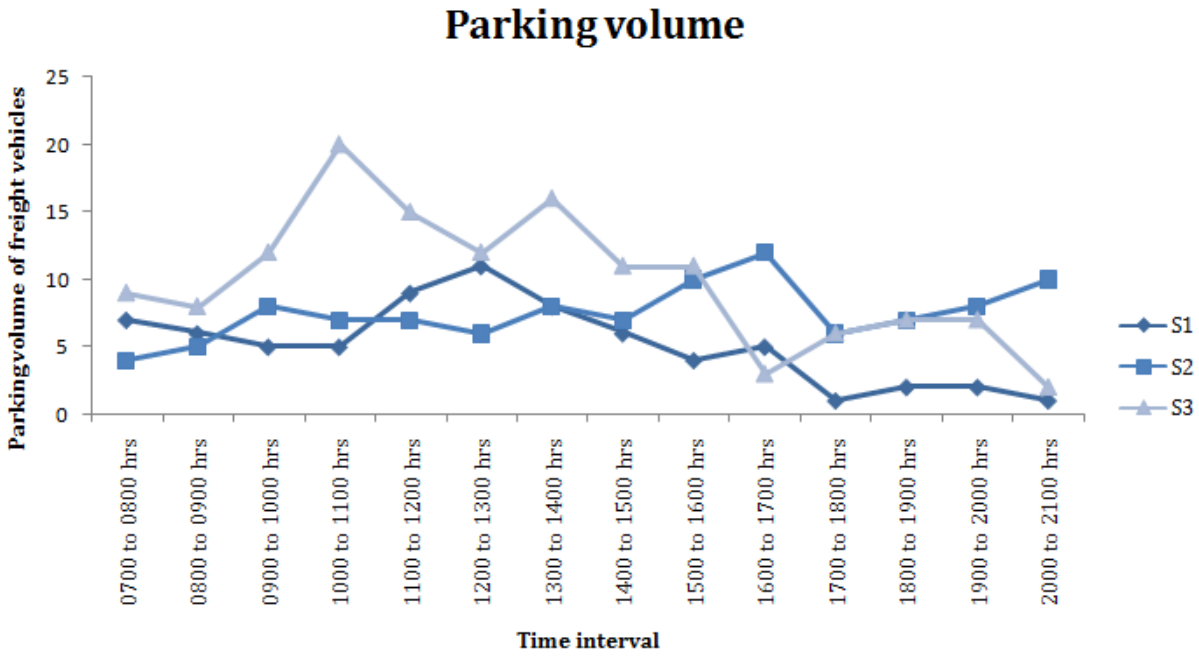

Figure 17: Hourly variation in freight vehicle parking volume

Parking duration of freight vehicles on Sir Theagaraya Road is summarized in table 6, and figure 18 presents the distribution of freight vehicles w.r.t their parking duration.

Table 6: Freight vehicle parking duration

Parking Duration (minutes)	Number of Freight Vehicles		
	S1	**S2**	**S3**
00 to 10	27	55	21
11 to 20	10	14	20
21 to 30	06	10	14
31 to 40	00	11	13
41 to 50	02	04	07
51 to 60	02	00	00
61 to 90	07	01	11
91 to 120	03	01	11
121 to 180	04	03	13
> 180	11	06	29
Total	72	105	139

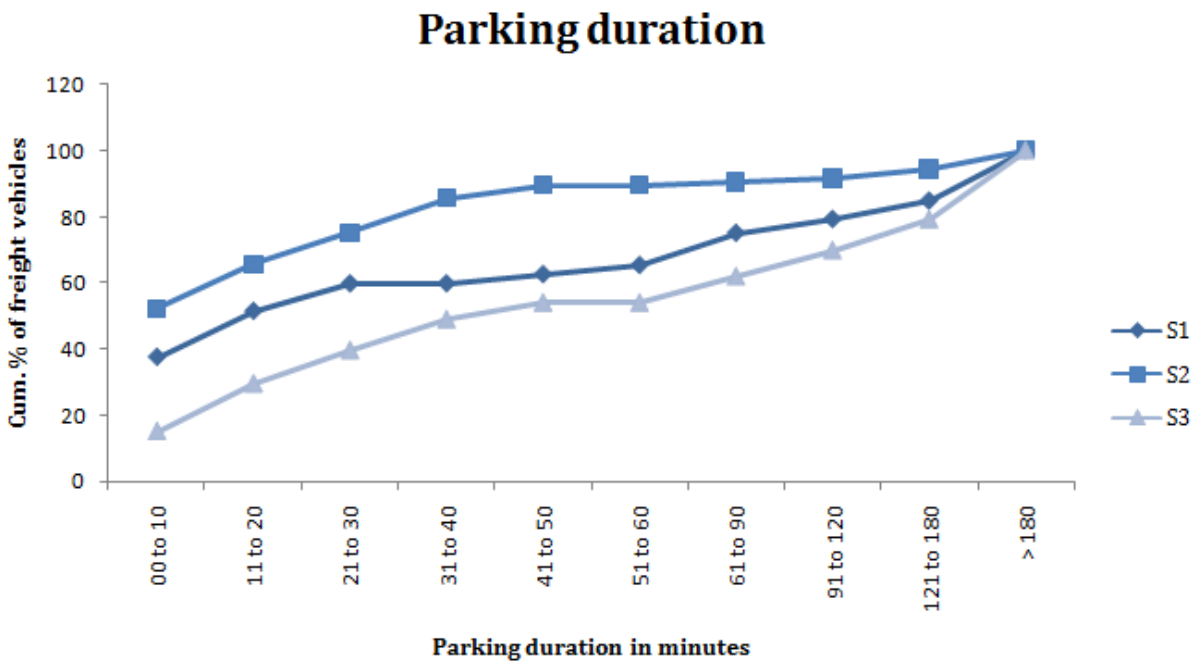

Figure 18: Freight vehicle parking duration

It can be observed that in all the three stretches, most freight vehicles were parked for 10 mins or less. On average, 50% of freight vehicles were found to be parking for less than or equal to 20 minutes. This data was utilized in simulation, which will be discussed in the latter part of this report.

4.4 Parking Plan using VISSIM

In this section, traffic simulation performed to evaluate the current parking practices, including double parking of freight vehicles and the results obtained, are discussed. A scenario with proposed dedicated freight parking spaces is simulated, and the results are compared to double parking case.

Network, Input data and Calibration: Sir Theagaraya road was 4-lane divided carriageway with two lanes for each directional traffic. Pondy Bazar, which is part of Sir Theagaraya road, underwent modifications under a Smart City project called '*Pedestrian Plaza*' project. Pedestrianization of Pondy Bazar ensured comfortable walking with wider footpaths, thereby reducing the carriageway to 3.5m for each direction of traffic (total carriageway width 7m). Due to the reduction in carriageway width, concerned authorities limited the traffic movement on Sir Theagaraya road to uni-directional traffic (one-way) from Panagal park to Thanikachalam road junction. These modifications were adopted in the simulation.

Freight vehicle traffic volume, parking volume and duration obtained from primary data collection were used. Passenger vehicle traffic data from secondary sources were incorporated into the simulation. Dimensions collected as part of a rodo meter survey enabled realistic road network editing in the simulation platform and helped estimate the correct supply of parking lots. The total number of parking lots in the study stretch was estimated to be 103, bearing dimensions of 2m width and 5m length. It is to be noted that adopted dimensions fall within limits prescribed for parallel parking lots in IRC 35, which are width 1.7 to 2.5m and length 4.5 to 6m. Simulation parameters were changed to meet the Indian driving conditions[14] ().

4.4.1 Freight Parking Scenarios

Two broad scenarios were analyzed with the help of traffic simulations using VISSIM.

- *Scenario 1: Existing freight parking practice*

Current parking practices along the study stretch are covered in this scenario, wherein all parking lots are commonly available for both passenger vehicles (cars) and delivery vans (freight vehicles). This scenario was similar to the first-come, first-serve principle, as a vehicle arriving/parking first gets to use the parking lot. Parking duration of cars was set to 90 minutes and that for freight vehicles was set to 20 minutes catering to 60% (approximately) of the freight vehicle parking demand as observed during field studies. Freight vehicles in case of non-availability of a parking lot in the vicinity of the establishment (shop) they are to serve, will double park in order to complete the delivery/pick-up in-time. This double-parking scenario with varying duration of parking, i.e., 10 min, 15 min, and 20 min was simulated, and its effect was observed.

- *Scenario 2: Designated freight parking spaces*

A proposed scenario wherein 10% of the parking lots are earmarked exclusively for freight vehicles was simulated. Freight vehicles were not allowed to park in the parking lots reserved for passenger vehicles and vice versa. Dedicated parking lots for freight vehicles were located carefully to cover all the establishments and at the same time making sure no establishment is farther than 150 meters from the nearest freight parking lot, also care was taken to avoid placing parking lots in front of ramps leading to off-street parking facilities

[14] Siddharth, S. P., & Ramadurai, G. (2013). Calibration of VISSIM for Indian heterogeneous traffic conditions. Procedia-Social and Behavioral Sciences, 104, 380-389

and entry/exit gates of establishments (figure 19). Table 6 summarises the two scenarios with details.

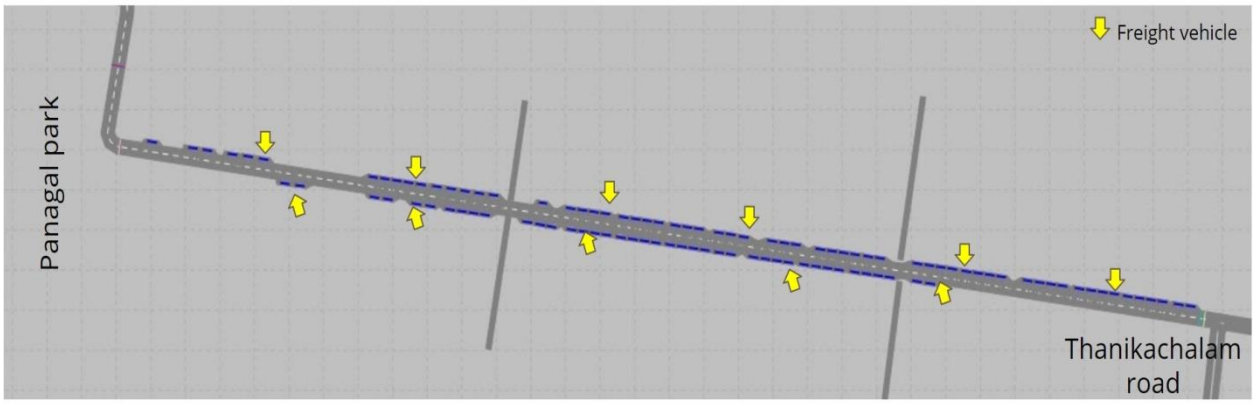

Figure 19: Dedicated freight parking lots

Table 6: Details of Scenarios

Scenario	**Parking Lots**	**Parking Duration (in minutes)**	**Double Parking Duration of Freight Vehicles (in minutes)**
Existing/ double parking	Common to both passenger and freight vehicles	Passenger vehicles: 30 to 90 Freight vehicles: 20	Three sub-cases a) 10 b) 15 c) 20
Dedicated freight parking	~10% of parking lots exclusively for freight vehicles	Passenger vehicles: 30 to 90 Freight vehicles: 20	NA

The simulation was performed for four hours of morning peak, i.e. 0800 to 1200 hrs and a commercial traffic simulation tool (PTV VISSIM) was used. Multiple iterations of the two scenarios as listed in table 7 were carried out.

4.5 Result / Outcome

Results from simulations of both scenarios are compared in this section. Travel time of cars along the study stretch an output from simulations was used as a metric for comparison. The simulation was validated as travel times obtained were comparable to those from real-world (Google Maps). Travel times obtained in the dedicated freight parking scenario were compared to three sub-cases of double-parking scenario and are tabulated in table 7.

Savings in travel time at the corridor level are presented in figure 20. Since multiple iterations are carried out, average, minimum and maximum values are presented instead of a point value.

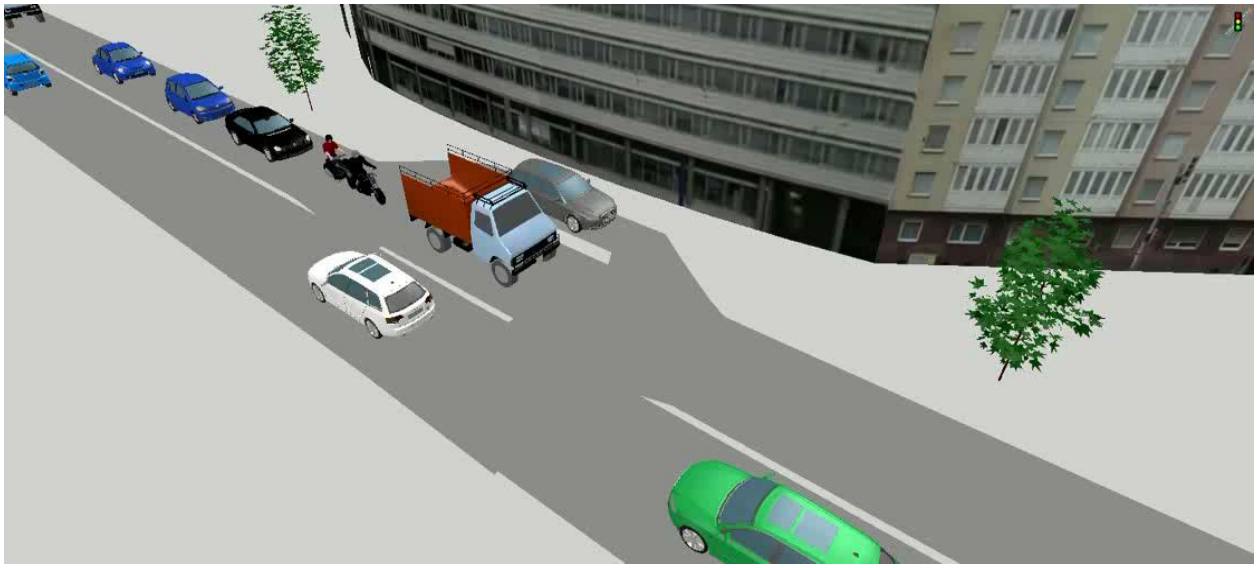

Figure 20: Simulation showing double parked freight vehicle

Table 7: Percentage savings in travel time due to dedicated freight parking

Double parking duration (minutes)	10	15	20
% savings in travel time Average (Min. - Max.)	13.67 (7.10 - 31.60)	19.33 (15.04 - 31.44)	21.64 (15.29 - 34.35)

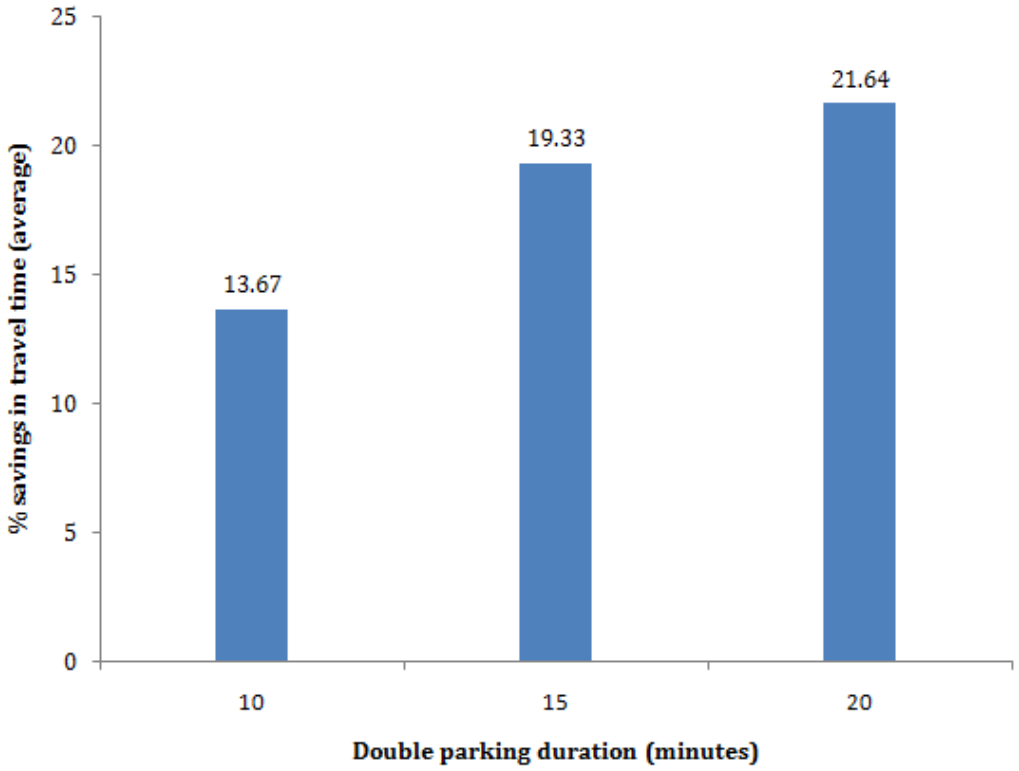

Figure 21: Percentage savings in travel time due to dedicated freight parking

Even at the least double-parking duration of 10 minutes, minimum savings in travel time of ~ 7% can be noticed. If freight vehicles double-parked for the same duration as they would in case of parking at a lot, average saving in travel time resulted is 21.64%. Dedicated freight parking resulted in savings in travel times when compared to all three cases of double parking.

4.6 Emission savings due to dedicated freight parking

Rapid urbanization has led to higher air pollution in cities owing to emissions from factories, industries, households, and vehicles, among many others. Internal Combustion Engine (ICE) vehicles which use fossil fuels emit pollutants like carbon monoxide, carbon dioxide, hydrocarbons, and oxides of nitrogen. Increased use of personal vehicles and higher freight trips to meet the demand for goods with the rise in population has worsened the situation. Parking infrastructure influences distance travelled, fuel consumption, cost of transportation, and thereby has a bearing on energy and emissions as discussed in section 2. In the present study emissions (as a function of speed) are compared between double parking and dedicated parking scenarios based on simulation results.

Vehicular emissions from different cases of double parking are compared with dedicated parking scenario in this section. Instantaneous speed of different vehicles from the

simulation was used to compute combined emissions (CO+HC+NO) using the available models-which are based on real-world emission measurements[15]. Combined CO+HC+NO emissions calculated from speed data of 04 hours-simulation are tabulated in table 8; the average values of multiple iterations are presented. Figure 22 shows the percentage increase in emissions due to double parking compared to dedicated parking. Emissions from double parking scenarios with 10, 15, and 20 minutes were found to be 8.06%, 9.53%, and 12.50% higher compared to dedicated freight parking scenario respectively.

Table 8: Comparison of emissions from different scenarios

Scenario	Double parking (20 minutes)	Double parking (15 minutes)	Double parking (10 minutes)	Dedicated freight parking
Emissions (CO+HC+NO) in grams	50871	49529	48865	45220

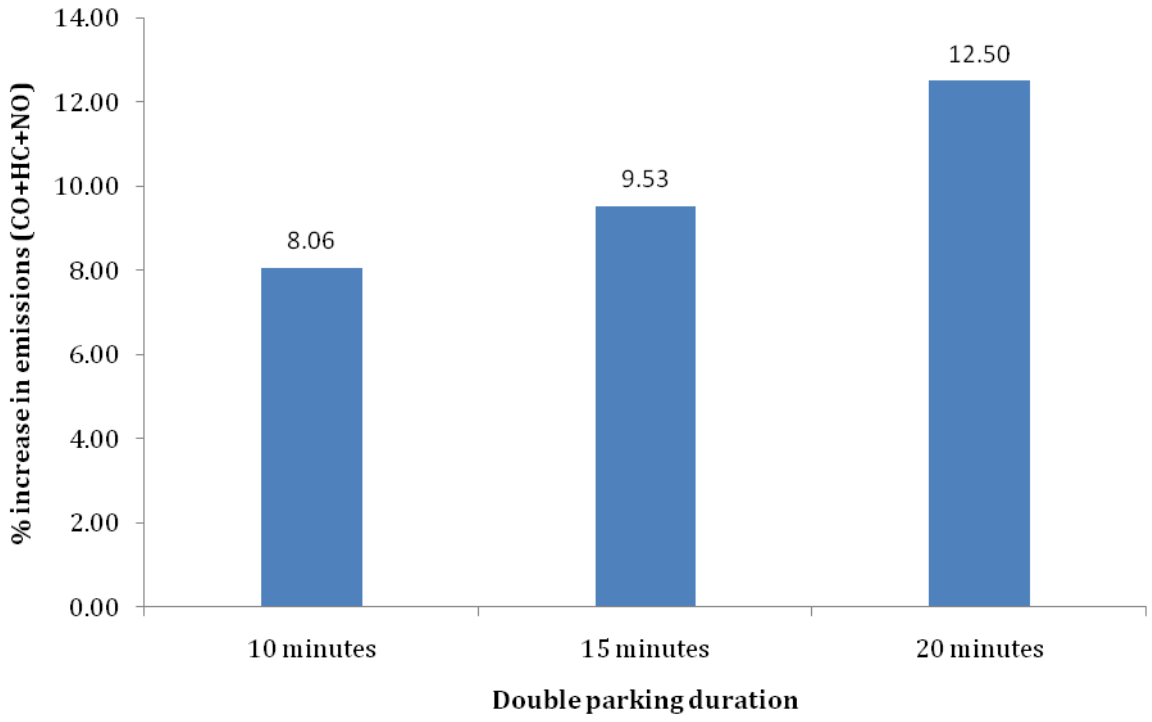

Figure 22: Increase in emissions due to double parking compared to dedicated parking

[15] Mahesh, S., Ramadurai, G., & Nagendra, S. S. (2019). On-board measurement of emissions from freight trucks in urban arterials: Effect of operating conditions, emission standards, and truck size. Atmospheric Environment, 212, 75-82. Mahesh, S., Ramadurai, G., & Nagendra, S. S. (2018). Real-world emissions of gaseous pollutants from diesel passenger cars using portable emission measurement systems. Sustainable Cities and Society, 41, 104-113

4.7 Recommendations

Providing dedicated freight vehicle parking lots is recommended as it results in reduced travel times/congestion. Also ensures the elimination of double parking of freight vehicles and thereby rendering minimal hindrance to traffic flow. The strategy comes with a limitation that proper scheduling of freight vehicle arrivals and departures from parking lots has to be ensured. Also, strict enforcement is essential on the ground to avoid usage of dedicated freight parking lots by passenger vehicles and vice versa.

Conclusion

Freight parking is a less researched topic than passenger parking. However, the effects of non-availability of dedicated parking slots for freight vehicles such as double parking, congestion, and emission due to idling of piled up vehicles can be observed in commercial areas. The results of the simulation of the T Nagar traffic and parking data shows that about 14 to 21% decrease in average travel time in the study stretch due to the provision of dedicated parking slots. About 8 to 13% increase in emission is caused by congestion and idling of loading/unloading freight vehicles double-parked on the road. This emphasizes the necessity for the provision and implementation of on-street freight parking slots in commercial streets.