ANALYSIS OF THE RELATION BETWEEN LAND-USE / URBAN FREIGHT OPERATIONS AND THE NEED FOR DEDICATED INFRASTRUCTURE / ENFORCEMENT – APPLICATION TO THE CITY OF LISBON.

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ABSTRACT

Urban Freight (UF) operations occur within the boundaries of urban areas and include any kind of delivery, pickup or transfer of physical goods. The effects of having loading/unloading bays, and their spatial distribution, on UF operations are debatable. A significant issue is the need for enforcement to deter non-freight vehicles from occupying the bays and limiting their potential. To explore the impact of this phenomenon, usage of loading/unloading bays by freight and non-freight vehicles was assessed during an 8 day observation period. Non-freight vehicles reduced daily freight parking capacity by 14.5%. Assuming differences in the UF parking demand, for various zones in the city, the quantity and spatial distribution of the bays should vary by locations. An exploratory assessment of this relation was performed. In a context of low data availability, a 15.55 Km2 case study zone in Lisbon was analyzed taking into account the locations and sizes of bays and business establishments. Establishments' size was based on floor area and number of employees. Other exploratory demand indicators such as the Number of Equivalent Commercial Stores (Dezi et al., 2010) were used. The main analysis techniques were Global and Local Statistics of Spatial Association. Five clusters of commerce were identified as likely areas of higher demand. Three of these had a higher than average level of service - less establishments served per bay - with the remaining two clusters being within the average of the case study area.

Keywords: Urban Freight; City Logistics; Loading/Unloading bays; Parking Enforcement; Spatial Analysis

INTRODUCTION

Urban freight (UF) can be defined as the activities that, within the boundaries of urban areas, include any kind of delivery, pickup or transfer of physical goods. These movements are subject to urban traffic and urban morphology (Muñuzuri et al., 2005) and are essential to maintain the current urban lifestyle. For Allen et al. (2000) UF activities can include non-physical goods, such as maintenance services that aim to support businesses operating in urban areas. Although UF operations encompass a variety of modes, this research only considers road transport. Relevant freight flows are represented by "last mile" concept (Rodrigue, 2009): the final journey between the distribution centers or warehouses and the customer (establishments or houses), which are characterized by an atomization of the cargo, increased frequency of deliveries and lower capacity vehicles. Low capacity usage by the vehicles is not uncommon (Di Bugno, 2005; Dezi et al., 2010).

Urban freight traffic has evolved, with an increased relevance of light goods vehicles (Browne et al., 2010). Smaller, specialist establishments are the main generators of freight vehicle activity, as larger retailers (>500 m^2 sales area) generally use bigger vehicles, and probably have more streamlined operations (Cherrett et al., 2012). "Establishments" mean retail/business establishments that can be (or be part of) a firm or company. Physically they represent the point of sale of goods or services from businesses to the end-user but could also be business to business.

Freight traffic is considered as a source of pollution far superior to its proportional share in total traffic flows (COST 321Urban Goods, 1998 in Delaître, 2009). Urban freight operations have been acknowledged as creators of a myriad of negative externalities. Negative externalities can be defined as costs that are not transmitted through prices incurred by the agents in the system (Forkenbrock, 1999). Parking policies, and transport infrastructure, are considered the most powerful means that urban planners and policy makers can use, to manage travel demand and traffic / congestion in urban centers (Shiftan et al., 2001; Pendyala et al., 2000). Nevertheless, little is known about the impacts resulting from obstruction and illegal parking by freight and non-freight vehicles.

In the literature, freight-supporting infrastructures are sometimes ignored amongst the myriad of approaches that attempt to minimize the detrimental effects of urban freight transportation. The focus of this research is one type of infrastructure – the loading/unloading bays – specifically those that are on-street/public. These will be defined as *"stops areas, (…) not suitable for parking, where the driver can stop his vehicle to perform freight loading and unloading operations, without disrupting traffic flows, to the commercial and industrial activities in a limited radius"* (Delaître et al., 2007). Bays can have time periods for specific uses, and are commonly composed by more than one parking space.

In the context of an urban area with a deficit of parking supply, without loading/unloading bays, delivery vehicles tend to park in active traffic lanes (double parking), negatively impacting road capacity, safety and freight carriers costs/service levels (Aiura and Taniguchi, 2006). Sometimes vehicles also park on sidewalks interfering with pedestrian traffic. Still, the provision of loading/unloading bays should fit the delivery requirements. Otherwise, the over-provision of bays would generate poorly used public space, which is already scarce.

Allen et al. (2000) have researched which good practice initiatives are more likely to encourage easier to perform, more efficient, goods and service operations in urban areas. Good practices are policy and/or regulations that, even when effectiveness is deemed highly dependent on the context, are considered as generally good approaches to tackle common problems. Amongst the list, the following are considered good practices with the potential to make urban freight operations easier and more efficient:

- Improving on-street loading/parking facilities for freight and service vehicles;
- Better enforcement of parking regulations for private cars (non-freight vehicles).

It is acknowledged that there is a clear link between those good practices. In the framework devised by van Duin et al. (2008) enforcement is pointed as one of the success factors for the correct use of loading/unloading bays. A review of case studies by Aiura and Taniguchi (2006), of previous on-street loading/unloading bays experiments, concluded that there was the need to match the characteristics of bays with the basic needs of logistics companies; to frame the loading/unloading bays in line with legal regulations and to raise the awareness of officers in charge of enforcing their correct usage.

Browne et al. (2008) stated that the mentioned good practices are particularly targeted at the traffic problems in central areas generated by the low level of discipline (e.g.: double and illegal parking) that causes a decrease in network capacity. Still, this has to be seen in the light that delivery drivers' expectations are met by the existence of these good practices. In a survey, the majority of drivers stated that they wished for more delivery areas and parking enforcement far above other measures (Debauche, 2008). Hence, it can be concluded that the problem does not lie solely in the lack of discipline of delivery drivers. The main causes of obstructive or illegal parking are threefold: the lack of delivery areas (IAURIF, 2004 in Delaître, 2009); the lack of adequate and suitable infrastructure (Morris et al., 1998) and the lack of enforcement of correct usage. Further confirmation of these conclusions has been published:

- Between 50% and 86% of freight vehicles are parked illegally and/or in situations prone to cause disturbance (IAURIF, 2004, in Delaître, 2009; Aiura and Taniguchi, 2006; Dezi et al., 2010; Cherrett et al., 2012).
- Between 47% and 54% of loading/unloading bays were illegally occupied (Aiura and Taniguchi, 2006; Mairie de Paris, 2006) with 57% of drivers justified not using bays because of its illegal occupation and 29% because these were inexistent (Dezi et al., 2010).

It is claimed that in cities where there is no UF culture, it is essential to focus on the basics, avoiding radical changes (Muñuzuri et al., 2012b). The optimization of the number, location and size of loading/unloading bays is considered a starting point (Dezi et al., 2010). Loading/unloading bays are a starting point towards creating a culture of organization and consciousness of the impacts due to urban freight traffic, highlighting the needs for streamlining and organizing operations. Various experiments/pilot tests have been performed to prove the link between loading/unloading bays' availability and improvements in logistics operations (Ishida et al., 2006; Muñuzuri et al., 2006).

Considering the chosen case study, Lisbon's current regulation for loading/unloading operations is from 1991, as the latest regulation (CML, 2004) has been suspended. This earlier regulation allowed double parking as long as the vehicle is not disturbing traffic flows excessively (Código da Estrada, 2005). Hence, freight carriers feel that they can park legally (or illegally) for free and should not incur in any additional costs to perform their job. Also, any vehicle can use loading/unloading bays as long as it can validly claim to be performing a loading/unloading operation.

The generalized lack of culture of the carriers, and inhabitants, for abiding the parking rules has been acknowledged. Viegas (2003) and the City Council (CML, 2005) characterized urban freight operations by the:

1. Usage of the road itself to perform loading/unloading operations;
2. Superimposition between freight distribution schedules and traffic peak hours;
3. Frequent usage of loading/unloading bays by non-authorized vehicles (even by establishment owners);
4. Inadequate availability of infrastructure (loading/unloading bays' supply) to support logistic activities, especially regarding small /medium distributors due to small load consolidation;
5. Excessive concentration of commerce and services in streets/avenues whose capacity has not increased to match that demand;
6. Lack of information regarding the distribution process, the flows, the needs, the logistic profiles, the planning of dedicated infrastructures and the definition of the rules for loading/unloading operations.

The focus of this research will be the exploration of the statements in point (3), that there is frequent usage of loading/unloading bays by non-authorized vehicles; and points (4) and (5), that the capacity to accommodate freight demand has not been matched in the areas where commerce is highly concentrated. The paper is structured as follows. The methodology to assess the validity of statements (3) and (4)/(5) is shown in "Methodology". In the "Results" section the main outputs of the analysis are presented. Finally, in the "Conclusions", the main outputs of this research are consolidated and suggestions for future developments are put forward.

METHODOLOGY

The methodology presented here has been developed in a context of low data availability. In Portugal, as in several other countries, data sources suitable for urban freight research purposes are not only significantly difficult to be obtained but can also be considered scarce, regarding the minimum data requirements needed to characterize urban freight activities. The report by Melo (2006), part of the BESTUFS II project, regarding the available urban freight data in Portugal remains relevant, according to our knowledge. Thus, this section should be interpreted as presenting a methodology that allows a practical application, in a context of data scarcity. Most of the analysis was carried out with ArcGIS/ArcMap® software, a tool of increasing relevance in the process of revealing spatial patterns in urban contexts, as proved by Mazzulla and Forciniti (2012).

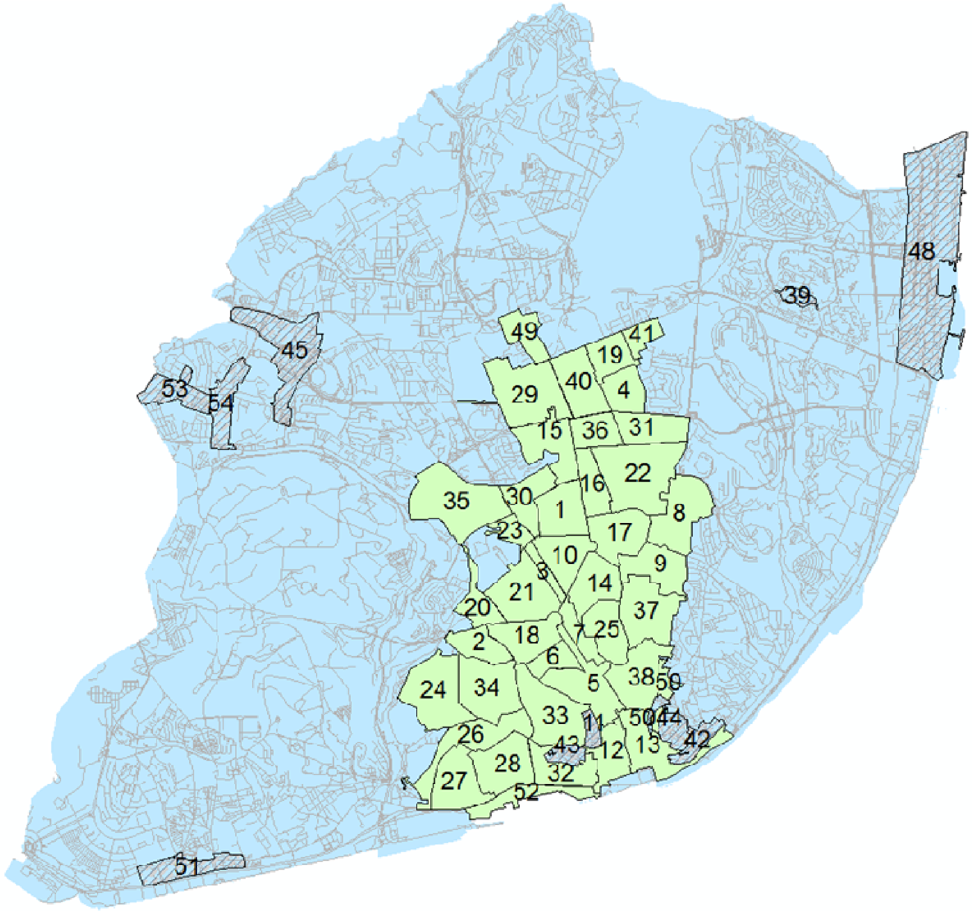
The methodology and subsequent analysis is split in two distinct, but complementary, sections. The first part develops on the hypothesis that illegal parking has an impact on the availability of loading/unloading bays. It regards an observation-based analysis of the illegal usage of loading/unloading bays. The effect of interference between illegal parking by non-freight vehicles and freight vehicles was not taken into account. The second part develops on the hypothesis that despite the existence of clusters of commerce, the level of service – considered as the number of establishments served by a single loading/unloading bay – is not optimized. We assumed that a lower number of establishments per bay are equivalent to a higher level of service. Hence, this part is related to the geographical analysis of the location of loading/unloading bays, considering the spatial distribution of establishments.

Case-study

The case study was within the Parking Authority / Mobility Company (EMEL) operating area (Figure 1). The main reasons that led to this choice were:

- It is where the majority of loading/unloading bays are located;
- It comprises the city center, assumed where worse traffic problems could be generated by inappropriate parking practices;
- Solely within these zones would make sense to consider variations in the level of enforcement.

Zones outside the main block (identified in Figure 1 as zones 39, 45, 48, 51, 53, 54) have been ignored for simplification purposes in the spatial analysis. Zones 11, 42, 43 and 44 were also ignored as these are of restricted access, making them worth of case studies on their own. Besides the parking authority zoning, two other zoning methodologies were used. Global and local statistics of spatial analysis were calculated using the “Sections” zoning. “Sections” constitute an official aggregation of blocks by groups of 300 dwellings (“Secção Estatística” in INE, 2012). The analysis of a commercial homogeneity variable was not possible at this aggregation level, due to a limitation in database software used to deal with very large crosstab queries. For that reason an intermediate size zoning, based on a virtual fishnet, was created to allow this specific analysis. The fishnet was composed by 225 elements, each with an area of 0,117Km^2.



ID	ZONE NAME	ID	ZONE NAME	ID	ZONE NAME
1	Berna/Valbom	19	Alvalade	37	Anjos
2	Amoreiras	20	Campol´de	38	Socorro
3	Parque	21	Castilho	39	Olivais
4	Rio de Janeiro	22	João XXI	40	Igreja
5	Av. Liberdade	23	Bairro Azul	41	Av. Brasil
6	S. Mamede	24	Campo Ourique	42	Alfama
7	Santa Marta	25	Campo Santana	43	Sta. Catarina
8	Alameda	26	Infante Santo	44	Castelo
9	Chile	27	Lapa	45	Quinta da Luz
10	Avenidas Novas	28	Santos	48	Parque Nações
11	Bairro Alto	29	Campo Grande	49	Museu da Cidade
12	Chiado	30	Gulbenkian	50	Mouraria - A
13	Baixa	31	Roma	50	Mouraria - B
14	PJ Fontana	32	São Paulo	50	Mouraria Total
15	Entrecampos	33	Pr´ncipe Real	51	Belém
16	Campo Pequeno	34	Santa Isabel	52	Av. Brasília
17	Estefânia	35	Praça de Espanha	53	Mercado de Benfica
18	Marques de Pombal	36	Bairro S. Miguel	54	Benfica - Av. Uruguai

Figure 1 - EMEL controlled zones in Lisbon city and case study area (in green)

Non-freight parking in loading/unloading bays

Illegal parking by non-freight vehicles was observed for an important commercial street located in Zone 22, named Avenida Guerra Junqueiro. It is a single lane, one-way street, with various and diverse commercial establishments on both sides of the street. It has a total freight parking capacity of 17 single loading/unloading bays plus 213 paid parking places. Some loading/unloading bays, considered large enough for 3 vehicles, could not be occupied by more than 2. This led to a practical number of loading/unloading bays equal to 14.

The observation period was from 21/11/2011 to 25/11/2011 (Monday to Friday) and from 28/11/2011 to 30/11/2011 (Monday to Wednesday), between 9AM and 7PM. Loading/unloading bays are reserved for freight from 9PM to 7PM but in some days, after 6PM all loading/unloading bays were permanently occupied by non-freight vehicles. Occupation of paid parking places has not been assessed quantitatively but varied during the day, ranging from medium to full occupation. The chosen indicators to describe illegal non-freight parking (inside loading/unloading bays) across the study period were:

- Non-freight Vehicles
  - Count of illegally parked vehicles;
  - Average duration and the standard deviation of illegal parking;
  - Median of the duration of illegal parking;
  - Maximum duration of illegal parking;
  - Average reduction of bays availability for freight operations, by non-freight vehicles. Based on the total daily availability for freight operations, in minutes, as equal to 10hours*60minutes (=600minutes/bay) * 14bays = 8400 minutes in the sample area.
- Freight Vehicles
  - Count of parked freight vehicles;
  - Average duration and the standard deviation of collection/delivery operations;
  - Median of the duration of collection/delivery operations;
  - Maximum duration of collection/delivery operations;
  - Average usage of bays for freight operations.
- Other indicators
  - Ratio of freight vehicles/non-freight vehicles in loading/unloading bays;
  - The time a delivery area is entirely free during the observation period (based on total dedicated usage time minus the occupation by non-freight and freight vehicles).

All indicators were calculated for each day of observation and, if possible, averaged across the observation period.

Loading/unloading bay system

Aiura and Taniguchi (2006) derived, from a survey, the maximum distance that delivery drivers were willing to walk from loading/unloading bays to their destination. 17% answered "within 50m", 63% chose distances smaller than 50m. Dezi et al. (2010) derived from interviews and questionnaires a maximum walkable distance of 70m but assumed 50m as the optimal radius in their optimization process for loading/unloading bays number, location and size. To assess the number of establishments reachable from a loading/unloading bay we also assumed a maximum walking distance of 50m. The ratio of commercial establishments per loading/unloading bays was calculated, as well as the ratio of Number of Equivalent Commercial Stores – NECS (Dezi et al., 2010) - per loading/unloading bays. Dezi et al. (2010) used NECS concept to add a weight to businesses as an attractor/generator of loading/unloading operations.

Geographical analysis of zones

To characterize the establishments a geo-referenced database with a non-official establishment classification, area and employee estimates was used (Martínez, 2010). This database has two establishment classifications, with the first consisting of 9 types:

1. Education (1.48% of the total)
2. Public Services (3.70%)
3. Private Services (39.48%)
4. Health (7.53%)
5. Retail (35.00%)
6. Restaurants and Leisure (10.39%)
7. Industry (0.56%)
8. Agriculture and livestock (0.41 %)
9. Hotels (1.44%)

The second option, a disaggregated 761 establishment types' classification, will not be listed due to its length. Ideally the chosen establishment classification would be Lisbon City Council's (CML, 2009), allowing the validation of the establishments distribution in the database. Matching membership without an equivalencies table led to under or over-estimation, in each category, and this option was discarded. Only establishments of types 5, 6 and 9 with less than 500m2 (Cherrett et al., 2012), and located inside the case study area, were selected. This led to a total of 9957 records of establishments.

The logistics infrastructure was represented by the geographical location of loading/unloading bays. These are commonly composed by more than one parking space. Parking spaces have been acknowledged to vary in dimension but the standard is around 2m x 5m. For EMEL's counting purposes, multiple parking spaces are only considered as so when in multiples of the standard measure. The same assumption was adopted except for the situation mentioned in the previous section "Non-freight parking in loading/unloading bays". It must be noted that Dezi et al. (2010) point these dimensions as smaller than a typical delivery van (<3.5 tons) or box truck (>3.5 tons; < 7.5 tons). The advised minimum dimensions for a single loading/unloading bay are of 2,5m x 7,0m. This is in line with the conclusion that, in the observation area, 3 adjacent single loading/unloading bays were never occupied by more than 2 vehicles (even non-freight).

A representative sample of establishment surveys would be the ideal primary data source for delivery/parking needs. An alternative approach was devised to avoid the considerable costs and time to obtain this type of survey. This methodology consists in five sequential analyses.

Point Density

Measures of commercial density have already been used to prioritize the location of loading/unloading bays (Muñuzuri, 2012a). Hence, the chosen indicators to characterize the zones with higher commercial predominance were:
Commercial density based on the number of establishments;

- Commercial density based on number of establishments and weighted with the number of employees per establishment;
- Commercial density based in number of establishments and weighted with establishments' areas;
- Commercial density based on the number of establishments and weighted with the following NECS:
    - Hotels / Restaurants / Catering (1,5 establishments);
    - Non-food (3);
    - Clothing (1);
    - Fresh (4);
    - Dry (5,5);
    - Frozen (1,5).

Point densities, representing the magnitude per unit area from point features that fall within a neighborhood around each cell, have been calculated for all the mentioned indicators. It was expected that if a (comparatively) smaller share of points had a high proportion of area, employment or NECS this approach would make such set of points stand out.

Commercial Homogeneity

It is hypothesized that zones with different levels of commercial homogeneity might have different delivery patterns. For that reason we propose to explore an indicator of commercial homogeneity. Based on the most disaggregated classification of establishments (in the sample equal to 326 establishment classes) a homogeneity indicator was applied, derived from an entropy concept. Entropy is commonly used to measure uniformity, but has been applied to reveal the diversity of land-use (Cervero et al., 1989; Kockelman, 1996; Zhang et al., 2002; de Abreu e Silva, 2006):

$$Entropy = \sum_j \frac{|P_j \times \ln(P_j)|}{\ln(J)}$$

P_j is either the proportion of establishments of type *j*, or the proportion of the total establishment area belonging to each establishment type. This indicator is normalized varying between one (balance of uses) and zero (presence of only one use). Entropy was estimated for the following two data definitions, 326 establishment classes and: a) count of establishments per zone; b) sum of establishments' areas per zone.

Global Statistics of spatial association

In this step the census statistical “Sections” zoning was used (“Secção Estatística” in INE, 2012) as the EMEL zoning proved to have no spatial association significantly different from random. Two Global Statistics of spatial association were calculated, High/low Clustering and Spatial Autocorrelation (Global Moran’s I), for the following variables:

1. Count of establishments,
2. Sum of establishment areas,
3. Sum of employees,
4. Sum of NECS,
5. Establishment density,
6. Area density,
7. Employees density,
8. NECS density,
9. Homogeneity based on the count of establishments per zone,
10. Homogeneity based on the sum of establishments’ areas per zone.

Variables values were spatially joined to each zone. High/low Clustering measures the degree of clustering for either high values or low values using the Getis-Ord General G statistic, more details about this type of analysis can be found in ESRI (2012a). The Spatial Autocorrelation (Global Moran's I) tool measures spatial autocorrelation based on both feature locations and feature values simultaneously. Given a set of features and an associated attribute it evaluates whether the pattern expressed is clustered, dispersed, or random. More details about this type of analysis can be found in ESRI (2012b).

Local Statistics of spatial association

Following the confirmation that there is spatial clustering in the values of the chosen variables, two further analyses were performed in order to map the hot spots/clusters: Hot Spot Analysis (Getis-Ord Gi*) and Cluster and Outlier Analysis (Anselin Local Moran's I). Hot Spot Analysis was used to reveal statistically significant hot and cold spots based on the Getis-Ord Gi* statistic. Hot spots exist where a feature has a high value and is surrounded by other features with high values. More details about this type of analysis can be found in ESRI (2012c). Cluster and Outlier Analysis, given a set of weighted features, identifies statistically significant hot spots, cold spots, and spatial outliers using the Anselin Local Moran's I statistic. More details about this type of analysis can be found in ESRI (2012d).

For all tools, the Fixed Distance Band Method was chosen conceptualize the spatial relationships, as it is recommended for polygon data where there is a large variation in polygon size (as in “Sections”) but also because it was decided that neighboring features outside the specified critical distance have no influence on the calculations (also applicable to the “fishnet”). Other methodologies were attempted, such as Zone of Indifference or Inverse Distance (in automatic and manual modes). None were considered to improve the results of the Fixed Distance Band. For the first iteration of the analysis, the distance band was calculated automatically to ensure that every feature had at least one neighbor. In the second iteration, we calculated the distance band value that maximized z-scores with the Incremental Spatial Autocorrelation tool (ESRI, 2012e). This means an increased detail of the analysis at the cost that some features might not have neighbors.

Matching of Higher Demand zones with the Loading/Unloading bay configuration

All outputs from the previous four analyses were visually compared in an attempt to prioritize zones of intervention. For the hot spots of commerce, believed to have a higher potential demand for loading/unloading bays, the percentage of establishments/NECS within 50m of an loading/unloading bay were once again calculated. This allows assessing the difference in level of service compared to the average in the case study. Level of service is considered higher if there is a smaller number of establishments' per single loading/unloading bay.

RESULTS

Non-freight parking in loading/unloading bays

Table 1 summarizes the usage of loading/unloading bays. Reporting average results, for the case study street, 52 non-freight vehicles were parked in loading/unloading bays per day. This represents 1 non-freight vehicle per 1,8 freight vehicles. Non-freight parking duration averages 24 minutes but the maximum reached 6 hours and 40 minutes. The total duration of the occupation of bays by non-freight vehicles represents on average 14.49% of total loading/unloading bays' daily availability. Average parking time for non-freight vehicles is superior to that of freight vehicles. Standard deviation is also higher, probably inflated by high duration parking. The occupation of loading/unloading bays availability by non-freight vehicles is around ¾ of the freight demand. 64% of total bay capacity goes unused.

Illegal parking durations' frequency, in Figure 2, shows a high concentration on the lowest values. Still, it must be stressed that drivers who parked illegally close to the end of the reserved time period for freight (e.g.: 20 minutes or less before 7PM), also contributed towards the low values of illegal parking frequency.

In Figure 3, it can be observed that non-freight illegal parking is fairly stable during the morning period, across the peak of freight demand (10-11PM). The number of illegal occurrences rises throughout the afternoon after the second freight demand peak (2-3PM) and subsequent decline.

Table 1 – Parking statistics

Date	Non-freight					
	Count	**Average Parking Time**	**Standard Deviation**	**Median**	**Maximum**	**Ocupation (% availability)**
21-Nov-11	58	0:25	0:51	0:13	5:18	17,33
22-Nov-11	34	0:26	0:51	0:12	5:00	10,75
23-Nov-11	50	0:28	1:09	0:14	6:40	17,21
24-Nov-11	50	0:20	0:33	0:09	3:40	11,93
25-Nov-11	47	0:33	0:54	0:15	4:55	18,87
28-Nov-11	55	0:15	0:23	0:11	3:00	10,42
29-Nov-11	52	0:22	0:48	0:07	5:00	14,17
30-Nov-11	66	0:19	0:25	0:12	2:43	15,21
Average	**52**	**0:24**	**0:44**	**0:11**	**-**	**14,49**
Date	**Freight**					
	Count	**Average Parking Time**	**Standard Deviation**	**Median**	**Maximum**	**Ocupation (% availability)**
21-Nov-11	88	0:24	0:27	0:11	2:21	25,37
22-Nov-11	92	0:19	0:20	0:12	1:52	21,12
23-Nov-11	87	0:19	0:30	0:10	3:49	19,83
24-Nov-11	88	0:18	0:19	0:10	1:31	19,51
25-Nov-11	93	0:25	0:58	0:11	8:19	28,75
28-Nov-11	87	0:18	0:25	0:10	3:20	18,94
29-Nov-11	100	0:16	0:23	0:10	3:03	20,00
30-Nov-11	101	0:15	0:17	0:08	1:30	18,24
Average	**92**	**0:19**	**0:27**	**0:10**	**-**	**21,47**
Date	**Unused Bay (% available time)**			**Ratio freight/private vehicles**		
21-Nov-11	57,30			1,52		
22-Nov-11	68,13			2,71		
23-Nov-11	62,95			1,74		
24-Nov-11	68,56			1,76		
25-Nov-11	52,38			1,98		
28-Nov-11	70,64			1,58		
29-Nov-11	65,83			1,92		
30-Nov-11	66,55			1,53		
Average	**64,04**			**1,84**		

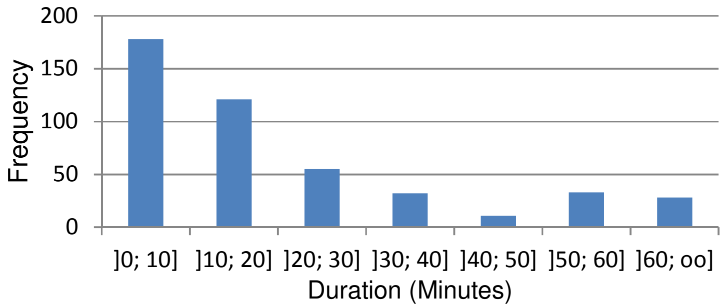


Figure 2 – Illegal parking duration

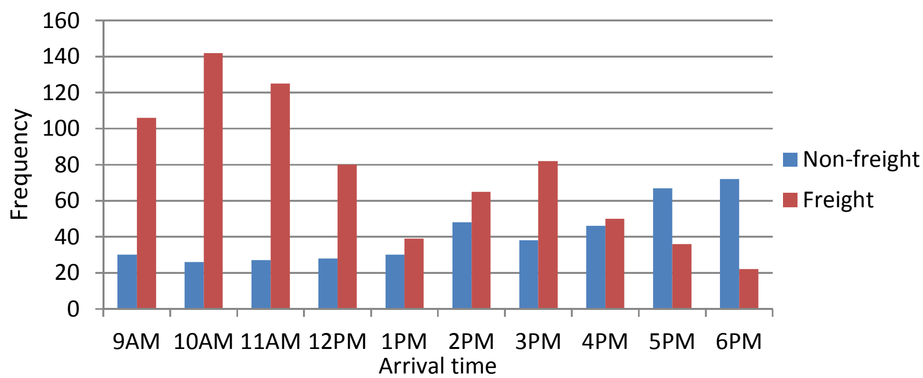


Figure 3 – Aggregated hourly parking demand

Loading/unloading bay system

The distribution of single freight loading/unloading bays varies significantly, between 0 and 120 per EMEL zone. The ratio of establishments served per single bays (per zone) varies between 0 and 53, with the average being 9 and the standard deviation is 8,18. Although, there is no significant variation of the average NECS per zone: between 2,13 and 3,01, with the average of 2.55 and standard deviation of 0,18. The number of establishments that were outside the thresholds of walking distance from loading/unloading bays were calculated with 50m buffer zones. Out of the selected sample, of 9957 establishments, 48.5% (4834 establishments) were not within 50m of a loading/unloading bay. The same sample represented approximately 25296 NECS. Similarly, 48.1% (12161 NECS) were not within 50m of a loading/unloading bay.

Geographical analysis of zones

Point Density

The Point Density function was applied to the geo-referenced establishment map considering the four different approaches to commercial density.-The distribution of establishment's area, or employees, was skewed to the left with a long tail towards higher values. This reflects the general idea that commerce in Lisbon is predominantly small and local. The Standard Deviation classification method was chosen for visualization as it emphasizes values above the mean (shown in red) and values below the mean (shown in blue), with n=1,5. This value was chosen as n=1 did not enable distinguishing known medium-high to high commercial presence areas, and n=2 under-represented these same areas.

Despite minor changes in the maps, the results are very similar as it can be seen in Figure 4. A preliminary conclusion is that the contribution towards increased commercial activity is primarily due to the high concentration of establishments, and not as much due to characteristics of the establishments such as the number of employees, area or type.

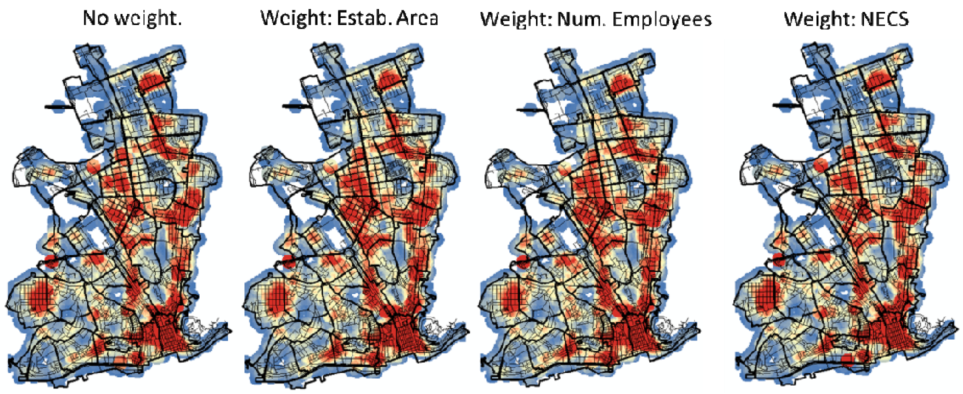


Figure 4 – Point Density Function with Different Population Field Weights

Commercial Homogeneity

The distribution of the indicators' values is skewed to the right, and is characterized by a higher concentration of high values for both indicators (establishments' count and area sum). This indicates a predominance of a medium to high heterogeneous mix of establishment types (that is, with more variety of establishments). Thus, the selected quantification technique for visualization was Natural Breaks (Jenks) as class breaks are identified to group similar values and maximize differences between classes. A visual comparison shows that the more heterogeneous zones are overlapping with the zones of higher point density, regardless of the indicator (Figure 5).

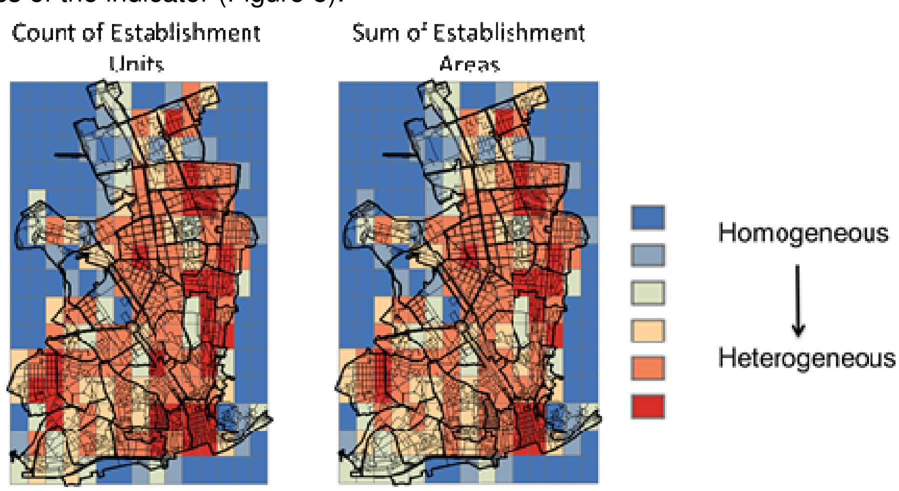


Figure 5 – Plot of Homogeneity indicator with two different variables

Slightly lower values of heterogeneity for the same zones are achieved using the indicator based on the sum of the establishment areas. This could be related to the fact that most establishments' areas are distributed along the lower ranges in the scale (20 to 120m2), making them more homogeneous regarding area than type.

Global Statistics of spatial association

The results of the High/low Clustering and Spatial Autocorrelation tool can be seen in Table 2.

Table 2 – High/low Clustering and Spatial Autocorrelation Summary

Zoning	Variable	Distance Band	High/low clustering Summary					Conclusion
			Observed General G	Expected General G	Variance	Z Score	p-value	
Sections	Estab. Count	300	0,020051	0,014538	0,000001	5,378774	0	High-Clusters
	Estab. Emp. Sum	500	0,050320	0,039810	0,000003	5,942981	0	High-Clusters
	Estab. Area Sum	500	0,050471	0,039810	0,000003	5,927408	0	High-Clusters
	Estab. NECS Sum	300	0,019750	0,014538	0,000001	5,268509	0	High-Clusters
	Estab. Density	500	0,053762	0,039810	0,000005	5,986546	0	High-Clusters
	Emp. Density	500	0,050999	0,039810	0,000005	4,813822	0	High-Clusters
	Area Density	200	0,009378	0,005603	0,000000	6,337379	0	High-Clusters
	NECS Density	500	0,052523	0,039810	0,000005	5,627534	0	High-Clusters
Virtual Fishnet	Homog. (Estab. Count)	274.31	0,012292	0,008333	0,000000	11,401648	0	High-Clusters
	Homog. (Estab. Area Sum)	274.31	0,012356	0,008333	0,000000	11,460554	0	High-Clusters
Zoning	**Variable**	**Distance Band**	**Spatial Autocorrelation Summary**					**Conclusion**
			Moran's Index	**Expected Index**	**Variance**	**Z Score**	**p-value**	
Sections	Estab. Count	300	0,205087	-0,002404	0,000747	7,592217	0	Clustered
	Estab. Emp. Sum	500	0,164668	-0,002404	0,000265	10,266634	0	Clustered
	Estab. Area Sum	500	0,154649	-0,002404	0,000263	9,690743	0	Clustered
	Estab. NECS Sum	300	0,192512	-0,002404	0,000748	7,125795	0	Clustered
	Estab. Density	500	0,113282	-0,002404	0,000253	7,267201	0	Clustered
	Emp. Density	500	0,226580	-0,002404	0,001951	5,184418	0	Clustered
	Area Density	200	0,099262	-0,002404	0,000233	6,665120	0	Clustered
	NECS Density	500	0,100100	-0,002404	0,000257	6,396597	0	Clustered
Virtual Fishnet	Homog. (Estab. Count)	274.31	0,668075	-0,002404	0,004752	9,755677	0	Clustered
	Homog. (Estab. Area Sum)	274.31	0,673325	-0,004464	0,004753	9,831654	0	Clustered

The null hypothesis that “there is no spatial clustering” could be rejected for all variables. There is less than 1% likelihood that the clustering of high values could be the result of random chance. Assuming that there is spatial clustering, for all variables, allowed the continuation of this analysis.

Local Statistics of spatial association

The used distance bands were always the Z-Score Maximizing Distance Band, except for the homogeneity variables, where the maximum Z-Score (or the alternative first peak) was too big for the scale of the analysis. Hence, the software-recommended Automatic Fixed Distance Band was chosen. Distance bands are detailed in Figure 6 and Figure 7.

Hot Spot Analysis aimed to consolidate the findings over priority intervention zones for further analysis. The chosen numerical field classification was Natural Breaks (Jenks) as class breaks are identified to group similar values and maximize differences between classes. A Standard Deviation representation was confirmed as valid but not as clear as the chosen classification to represent the results. In Figure 6 it can be seen that, despite some differences, the biggest cluster is around zones 12, 13 and part of 5 and 38. The core of the secondary cluster - zones 1 and 10 (and possibly 14) - can be seen in variables 1, 4 and 6. Three smaller clusters are present around zones 19, 24 and the group 8, 9 and 37. Density related variables show more refined clusters. Most Employee and Area variables (2, 3 and 7) discriminate negatively the smaller cluster in zone 24. Hot Spots were fairly consistent with the outputs of the Point Density analysis, proving the existence of statistically significant hot spots. Increased heterogeneity also shows consistent overlap with the five clusters of establishments

The output of the Clusters and Outliers analysis (Figure 7) was used to identify statistically significant spatial clusters and outliers. High-High clusters were present in the centroids of the main and secondary clusters for variables 1 to 4, just as well as for one of the smaller clusters (19) in variables 1, 4 and 8. Variables 5 to 7 only represented the main cluster. Zone 24 was considered not significant. The output for the homogeneity variables was not very clear; it solely distinguished the main cluster and also part of zones 9 and 14.

We hypothesize that the underrepresentation of clusters beyond the main one, is due to various factors. First, the transition from the hot spots to the cold spots is gradual, and not sudden, particularly in the central region of the case study area. Also, analyzing Figure 6 we can see that the hot spots are fairly homogeneous within the average-high and high level (5^{th} and 6^{th} levels on the color chart), except in the center of the main cluster. This spatial distribution contrasts with the purpose of this tool, more suited to reveal situations such as high-high, high-low, low-high or low-low. These factors could have had an effect in the definition of clusters using this tool, and on the predominance of the main cluster and “zone 19” as a High-High outlier. The High-Low outlier in variables 2 and 3 (Figure 7) is a shopping mall.

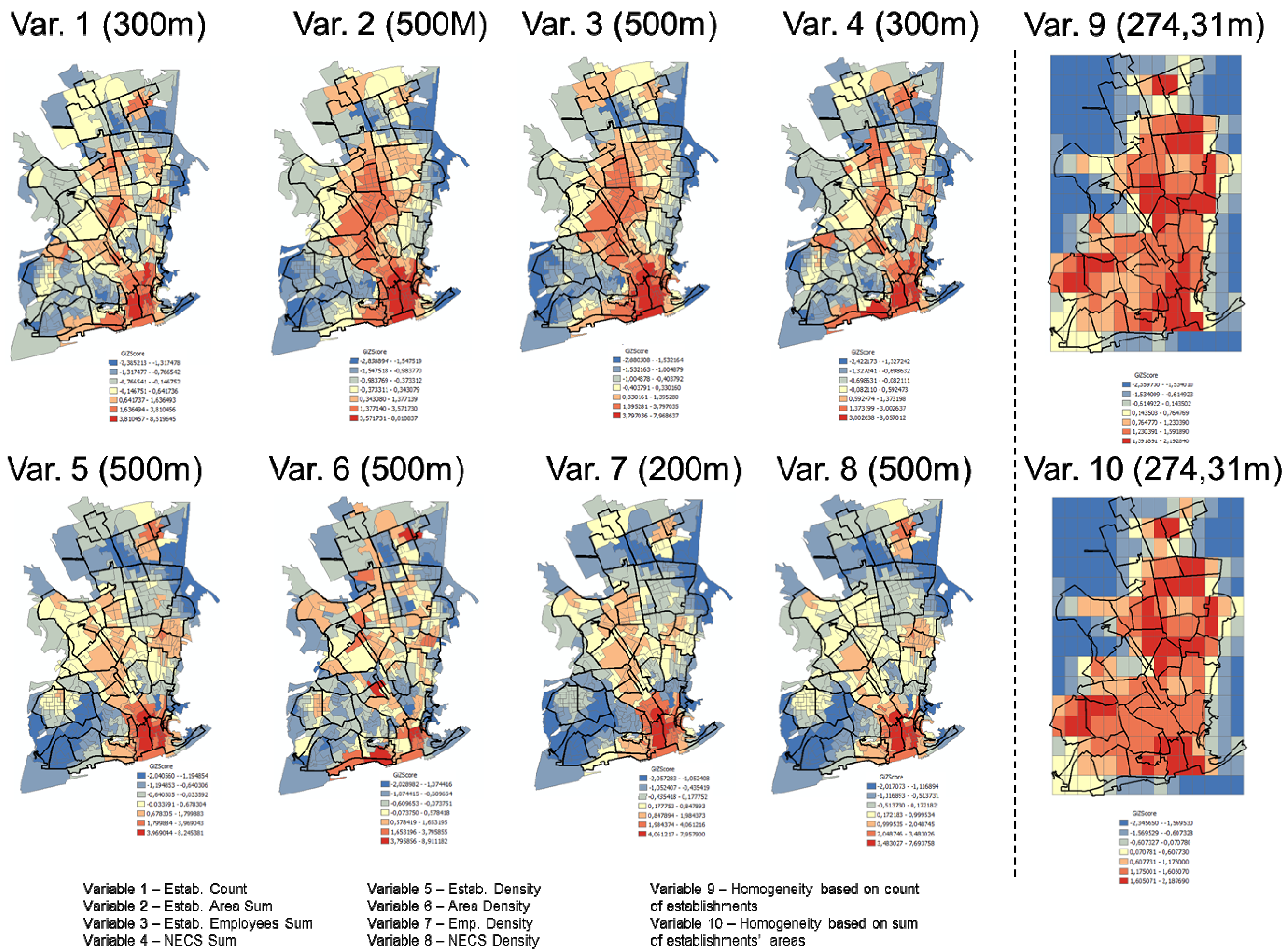


Figure 6 – Hot Spot Analysis Output

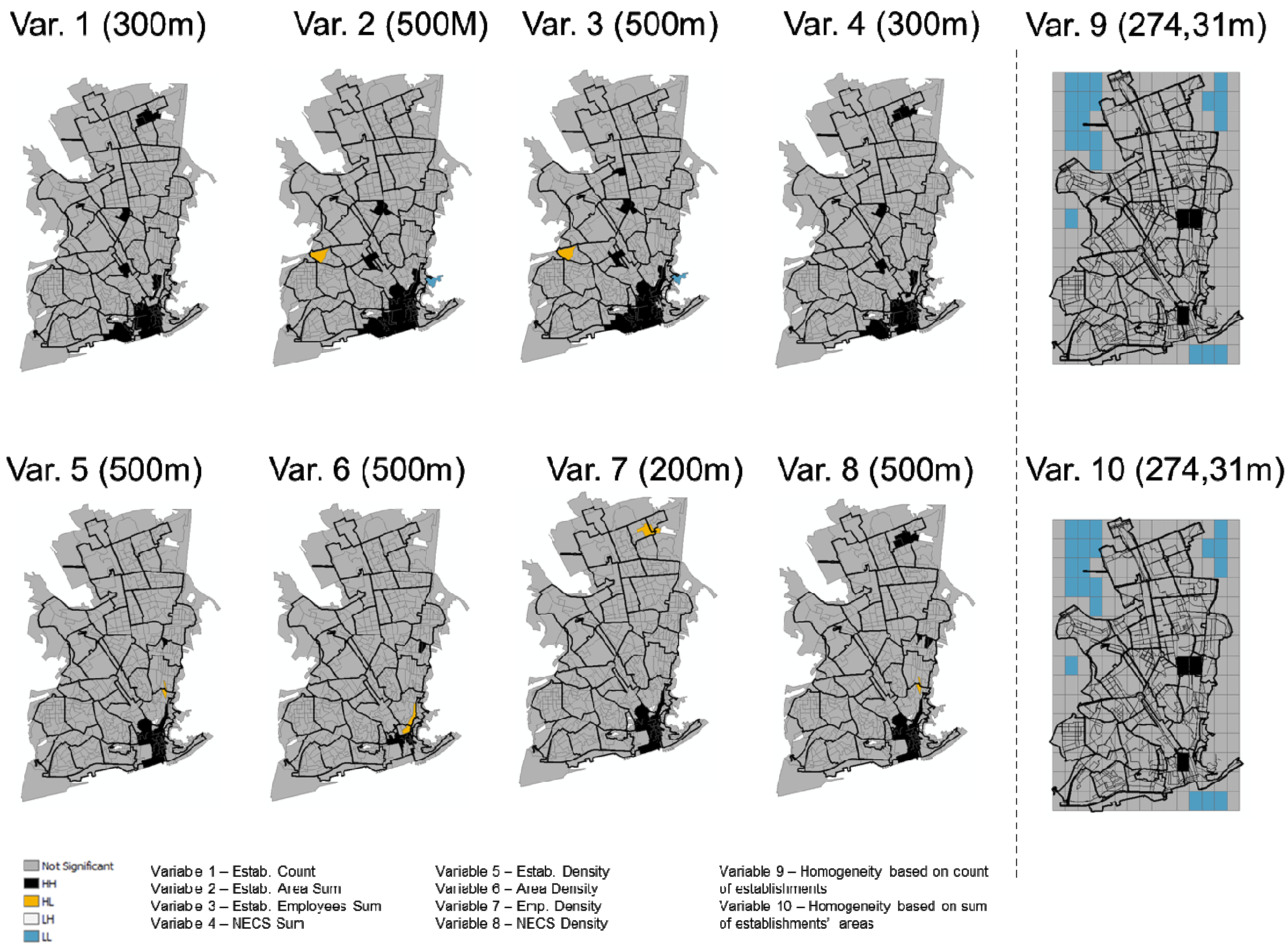


Figure 7 – Cluster and Outlier Analysis Output

Matching of Higher Demand zones with the Loading/unloading bay configuration

The last step involved selecting the groups of zones with higher presence of commerce to assess the difference (if any) in the level of service (LOS) as defined before. The chosen (groups of) zones and the results are shown in Table 3.

Table 3 - Level of service

Zones	Without a loading/unloading bay in a range of 50m	
	Percentage of Establishments	Percentage of NECS
19	15%	15%
24	26%	25%
1, 10	32%	31%
1, 10 and 14	29%	27%
8, 9 and 37	47%	46%
12, 13	40%	45%
5, 12, 13, 38	45%	55%

The LOS is considerably higher for the peripheral clusters (single zones 19 and 24), using both indicators. For zones “1, 10” the LOS is better than average. Grouped with zone “14”, with a likely better combination of number/location of bays, the LOS improves. All these situations can be associated with a system of loading/unloading bays closer to the optimal solution. Group “8, 9 and 37” were within the average values.

Finally, when considering the core of the main cluster “12, 13”, there is a slight improvement versus the average, but when considering the full cluster “5, 12, 13 and 38” there is a considerable (10%) higher percentage of NECS, versus establishments, without a bay in a range of 50m. This can be associated with a non-optimized loading/unloading bay configuration.

Considering the higher heterogeneity of commerce in the chosen (groups of) zones, it was expected that an increased coverage of NECS versus establishments could be achieved. As this was not shown by the calculations, the following hypothesis could be thought of:

- There is not enough variation in the NECS classification,
- The NECS classification is not appropriate to be applied to the case study area,
- Loading/unloading bays are not closer to establishments with potentially higher demand.

CONCLUSIONS

This research was an attempt to, in a situation of low data availability, produce a practical analysis of the relation between land-use / urban freight operations and the need for dedicated infrastructure / enforcement. The hypothesis that illegal parking has an impact on the availability of loading/unloading bays could not be rejected. Non-freight vehicle parking in loading/unloading bays was related to an average reduction of freight parking availability around 14.5%. The usage of bays by non-freight vehicles was characterized by a parking duration below 20 minutes. This occupation is relatively stable during the morning and mid-day period, with a gradual rise from 3PM onwards. Further developments could be related to investigating if the reduction of loading/unloading bays availability has a significant impact on freight operations, and how enforcement could reduce this impact.

The geographical analysis of zones allowed deriving various conclusions. It was considered that freight demand could be represented by the number of establishments, number of employees, area of establishments and Number of Equivalent Commercial Stores (NECS). 48.5% of establishments and 48.1% NECS were not within 50m of a loading/unloading bay. The null hypothesis that "there is no spatial clustering" could be rejected for all variables. The case study area revealed five hot spots of commerce. They have all been confirmed as zones of increased commercial heterogeneity, through an application of a homogeneity indicator derived from an entropy concept. The second hypothesis, which stated that despite the existence of clusters of commerce, the level of service – considered as the number of establishments served by a single loading/unloading bay – is not optimized, could not be rejected. Whilst three out of the five hot spots were associated with a higher level of service versus the average of the case study area, one of the remaining two is the most important center of commerce in Lisbon.

It is concluded that if any improvement is to be derived in this urban freight system, it is likely to be related to the optimization of the location/size of loading/unloading bays. The two clusters where the level of service was similar to the average were considered as priority intervention zones. The confirmation of the illegal parking statistics with another observation-based case-study is an option. For the second part of the analysis, the next step would be to validate the results with an establishment survey. This would allow extrapolating parking demand per establishment with a mathematical model.

REFERENCES

Aiura, N. and Taniguchi, E. (2006) Planning on-street loading-unloading spaces considering the behaviour of pickup-delivery vehicles, in (Eds.) Thompson, R. G., and Taniguchi, E., *Recent Advances in City Logistics* (2006) Elsevier, Oxford.

Allen, J., Anderson, S., Browne, M. and Jones, P. (2000) *A framework for considering policies to encourage sustainable urban freight traffic and goods/service flows: summary report.* Project Report. University of Westminster.

Browne, M., Allen, J., Nemoto, T., Visser, J. and Wild, D. (2008) City access restrictions and the implications for goods deliveries; pp.17-36 in Thompson, R. G., and Taniguchi, E., *Innovations in City Logistics* (2008) Nova Science Publishers Inc., New York.

Browne, M., Allen, J., Nemoto, T.and Visser, J. (2010) Light goods vehicles in urban areas. *Procedia - Social and Behavioral Sciences*, 2(3):5911–5919.

Cervero, R. (1989) Jobs-Housing Balancing and Regional Mobility, UCTC no 50, Reprinted from APA Journal, pp.136-150

Cherrett, T., Allen, J., McLeod, F., Maynard, S., Hickford, A. and Browne, M. (2012) Understanding urban freight activity – key issues for freight planning. *Journal of Transport Geography*, 24(2012):22–32.

CML (2004) Regulamento Municipal de Cargas e Descargas e das Bolsas de Estacionamento para Comerciantes.

CML (2005) Lisboa: o desafio da mobilidade.

CML (2009) Número de estabelecimentos de comércio a retalho e restauração da cidade de Lisboa, por sector de actividade económica.

Código da Estrada (2005) Código da Estrada. Alterado e republicado pelo Decreto-Lei nº 44/2005, de 23 de Fevereiro. Diário da República nº 38, Série I-A, pp.1585-1625.

de Abreu e Silva, J., Golob, T. F. and Goulias, K. G. (2006) The effects of land use characteristics on residence and employment location and travel behavior of urban adult workers, *Transportation Research Record* 1977, pp.121-131.

Debauche, W. (2008) An investigation into the delivery of goods to the city centre of Liege; pp. 261-276 in Thompson, R. G., and Taniguchi, E., *Innovations in City Logistics* (2008) Nova Science Publishers Inc., New York.

Delaître, L., Awasthi, A., Breuil, D. and Molet, H. (2007) An entropy based characterization of medium sized cities for selecting urban freight solution. National Urban Freight Conference - December 4 - 5, 2007, Westin Long Beach Hotel Long Beach, CA 90802.

Delaître, L. (2009) A new approach to diagnose urban delivery areas plans. *Computers & Industrial Engineering*, pp.991–998.

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

Di Bugno, M., Guerra, S., Ambrosino, G., Boero, M. and Liberato, A. (2008) A Centre for Eco-Friendly City Freight Distribution: Urban Logistics Innovation in a Mid-size Historical City in Italy; pp.531–544 in Thompson, R. G., and Taniguchi, E., Innovations in City Logistics (2008) Nova Science Publishers Inc., New York.

ESRI (2012a) High/Low Clustering (Getis-Ord General G) (Spatial Statistics). Online ArcGIS 10.0 Help.

ESRI (2012b) Spatial Autocorrelation (Global Moran's I) (Spatial Statistics). Online ArcGIS 10.0 Help.

ESRI (2012c) Hot Spot Analysis (Getis-Ord Gi*) (Spatial Statistics).. Online ArcGIS 10.0 Help.

ESRI (2012d) Cluster and Outlier Analysis (Anselin Local Moran's I) (Spatial Statistics). Online ArcGIS 10.0 Help.

ESRI (2012e) Incremental Spatial Autocorrelation (Spatial Statistics). Online ArcGIS 10.0 Help.

Forkenbrock, D. (1999) External costs of intercity truck freight transportation. *Transportation Research - Part A: Policy and Practice*, 33(7-8):505-526.

INE (2012) Base Cartográfica.

Ishida, H., Taniguchi, E., Hyodo, T., Sasaki, A., Ando, H. and Ikeda, K. (2006) Transportation Demand Management: Experiments In Akihabara in (Eds.) Thompson, R. G., and Taniguchi, E., *Recent Advances in City Logistics* (2006) Elsevier, Oxford

Kockelman, K. M. (1996) Travel Behavior as a function of accessibility, land use mixing, and land use balance: Evidence from the San Francisco Bay Area. M.Sc. Thesis. University of California, Berkeley.

Mairie de Paris (2006) Charte de bonnes pratiques des transports et des livraisons de marchandises.

Martínez, L. M. (2010) *Financing Public Transport Infrastructure Using the Value Capture Concept*. Doctoral thesis, IST - Technical University of Lisbon, Portugal.

Mazzulla, G. and Forciniti, C. (2012) Spatial association techniques for analysing trip distribution in an urban area. *European Transport Research Review*, 4(4):217-233.

Melo, S. (2006) Report on urban freight data collection in Portugal. BESTUFS WP 3.1. August.

Morris, A.G., Kornhauser, A.L. and Kay, M. J. (1998) Urban freight mobility: collection of data on time, costs, and barriers related to moving product into the central business district. *Transportation Research Record: Journal of the Transportation Research Board*, 1613(1):27–32.

Muñuzuri, J., Cortés, P., Grosso, R. and Gaudix, J. (2012a) Selecting the location of minihubs for freight delivery in congested downtown areas. Journal of Computational Science, 3(4):228-237.

Muñuzuri, J., Cortés, P., Grosso, R. and Gaudix, J. (2012b) City logistics in Spain: Why it might never work. *Cities*, 29(2):133–141.

Muñuzuri, J., Larraneta, J., Nibanez, J., Montero, G. (2006) Pilot Demonstration of a web-based load zone reservation system, in (Eds.) Thompson, R. G., and Taniguchi, E. *Recent Advances in City Logistics* (2006) Elsevier, Oxford

Munuzuri, J., Larraneta, J., Onieva, L., and Cortes, P. (2005) Solutions applicable by local administrations for urban logistics improvement. *Cities*, 22 (1):15-28.

Pendyala, R.M., Shankar, V.N. and McCullough, R. G. (2000) Freight travel demand modeling: Synthesis of approaches and development of a framework. Transportation Research Record: Journal of the Transportation Research Board, 1725(1):9–16.

Rodrigue, J., Comtois, C. and Slack, B. (2009) The Geography of Transport Systems, Second Edition, New York: Routledge.

Shiftan, Y. and Burd-Eden, R. (2001) Modeling response to parking policy. *Transportation Research Record: Journal of the Transportation Research Board*, 1765(1):27–34.

van Duin, J.H.R., Quack, H. and Visser, J. (2008) City logistics over the years...lessons learned, research directions and interests, pp. 37-54 in Thompson, R. G., and Taniguchi, E., *Innovations in City Logistics* (2008) Nova Science Publishers Inc., New York.

Viegas, J. M. (2003) Proposta de Regulamento de Circulação de Veículos de Distribuição de Mercadorias e de Operações de Cargas/Descargas na Cidade de Lisboa. Sessão de Representantes dos Comerciantes e Distribuidores com a TIS.pt

Zhang, M. (2002) Conditions and effectiveness of Land Use as a Mobility Tool. Phd Thesis. Massachusetts Institute of Technology.