Parcel Delivery and Urban Form:
A Case Study of Greater London

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Master of Science in Urban Planning

by

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Abstract

Since the appearance of e-commerce, people’s shopping modes have changed significantly. In the last decade, e-commerce has increased by approximately 15% every year in the UK. In 2015, the value of total e-commerce sales in the UK was £533 billion, which was nearly 20% of all sales. The increasing number of packages has led to a growing number of delivery vehicles in residential areas to deliver the packages to consumers’ homes. The boom of end-to-end delivery was not under the scope of previous urban or traffic plans, which caused unexpected planning and traffic problems. There are two main questions in this research: How does the current road network system adapt to or conflict with the rapid growth delivery traffic trend caused by e-commerce? What are the planning factors that affect delivery transport activity in the Greater London area? The result of statistical test indicates the increase of delivery traffic activities aggravate the traffic congestion. Statistical and spatial analysis show that parcel delivery is affected by the urban form. Some factors such as neighborhood size, population density, number of households, and commercial and retail land use patterns are likely to influence the extent and location of delivery traffic activity.
Acknowledgements

I would like to express my deepest appreciation to my advisor Leah Meisterlin who has guided me throughout my work. Her valuable guidance and advice regarding the research design, methodology development, quantitative and spatial analysis helped and inspired me a lot. I could not have imagined having a better advisor and mentor for my thesis research.

Besides, I would like to thank my thesis reader Luc Wilson for giving me insightful comments, helping me complete and improve the final results. The skill I learned in his class largely improve the efficiency of data processing, it also widens my ideas about how to conduct the analysis with available data.

Finally, I am thankful to my family, professors, and friends who gave me constant support and encouragement.
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<table>
<thead>
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<td>Light goods vehicle</td>
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<td>HGV</td>
<td>Heavy goods vehicle</td>
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<td>UK DFT</td>
<td>United Kingdom Department for Transport</td>
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<td>CBD</td>
<td>Central Business District</td>
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Chapter One

Background

The rapid increase of delivery trips

Since the appearance of e-commerce, people’s shopping modes have changed significantly. In the last decade, e-commerce has increased by approximately 15% every year in the UK. In 2015, the value of total e-commerce sales in the UK was £533 billion, which was nearly 20% of all sales (see Figure 1). Compared to 2008, e-commerce sales have increased by 66% percent, accounting for 14% of all sales. In the retail section of e-commerce, online retail sales experienced a drastic increase from 33.24 billion to 60.43 billion GBP in the 4-year period from 2012 to 2016 (Office for National Statistics, 2016).

![E-commerce turnover in the UK from 2008 to 2015](image.png)

*Figure 1.1: E-commerce turnover in the UK from 2008 to 2015.*

(Source: Office for National Statistics)

The parcels market can be divided into three sectors: business to business (B2B), business to consumer (B2C), and consumer to all parties (C2X). The products sold by businesses
to customers use B2C services. In the UK, the main market leader in this sector is the Royal Mail, which had an almost 34% market share in 2016 (Royal Mail, 2015). B2C has soared as a result of the development of e-commerce. Also, the Royal Mail has forecast that UK parcel volumes in the B2C will grow at approximately 4.5 to 5.5 percent annually, slightly above the rate for GDP growth (Royal Mail, 2016).

The increasing number of packages has led to a growing number of delivery vehicles in residential areas to deliver the packages to consumers' homes. In the UK, approximately 2.8 billion parcels were delivered to customers in 2016 (UK Courier and Express Delivery Market Report, 2017).

Problems caused by parcel delivery

Data from the UK National Travel Survey (see Figure 2) from 2006 to 2015 showed that the average distance traveled for shopping trips has been getting shorter year by year, a pattern which has been attributed to online shopping. Although this new e-commerce trend could supplant some personal shopping trips, it still causes some problems.
First, the greatest proportion of B2B parcel deliveries in the past tended to be delivered via well-connected road networks rather than via secondary or tertiary roads. However, the boom of end-to-end delivery was not under the scope of previous urban or traffic plans, which caused unexpected planning and traffic problems. For instance, the current London comprehensive plan and London transportation master plan which was enacted in 2004, did not anticipate the significant growth in e-commerce. Such traffic demand was not involved in the initial urban roadway network planning, and there is no specific plan dealing with such a large amount of special travel patterns requiring a short dwell time. In the past, light goods vehicles (LGVs) usually delivered goods for groceries and stores as the major traffic tools for small business service; they were assigned special loading docks along streets that were closed at each end. However, with the rapid development of shopping online, the LGVs have become the major carrier of e-commerce packages. When the proportion of LGVs in all traffic modes rose to 12% in 2016 (DFT, 2017), the loading docks were no longer sufficient. To make ends meet, many
LGVs were processing the loading and unloading along the regular curbsides, slowing down the traffic flow or even blocking the roadways.

Second, there are some indirect traffic increases caused by online-shopping, including failed deliveries, return and exchange activities, and sometimes dispatching shopping. The IMRG has estimated that in 2014 the cost of these failed deliveries to retailers and other traders for goods sold online in the UK was 771 million pounds (IMRG, 2014b). When the first attempt delivery failed due to signature issues, there would be second and third attempts, which created additional delivery trips. Also, return and exchange activities are other important parts. According to Royal Mail research conducted in 2015, 26% of the products bought online were returned, and 89% of them were returned via the same delivery method the merchandiser provided. Another study suggested that 43% of clothing and footwear shoppers in the UK returned items bought online in 2013 with a value of 1.16 billion pounds, while electrical goods returns, which have the second largest returns rate, had a value of 733 million pounds (Clipper, 2014). Approximately 35% of the UK online returns are collected by couriers from home or work and 20% are taken to stores. Returns of online purchases are forecast to grow by 50% over the next 5 years (Allen, 2016). It has been estimated that return rates in the UK vary from 20 to 50% of total goods purchased, depending on the retail sector. This added-up traffic volume, which increases the current traffic volume by 20% to 50%, can hardly be ignored. What’s more, when people are making physical shopping trips, they tend to plan their trip chains in the most efficient way to avoid unnecessary detours, but when they are shopping online for several items, they may go to several websites and place different orders, which adds a few parcel delivery trips. This may increase the actual trip distance although personal trips have been replaced.
Third, the urban-wide delivery time almost totally overlaps with regular working hours (see Figure 1.3), which not only adds great pressure for rush hour road systems but also increases the possibility of failed delivery because people are not available.

![Traffic distribution on all roads by time of day and day of the week, 2016.](source: UK DFT)

**Figure 1.3:** Traffic distribution on all roads by time of day and day of the week, 2016.

(Source: UK DFT)

**Research questions**

It is very hard to simply determine whether the delivery traffic generated by e-commerce really releases traffic congestion or aggravates the problems. More factors need to be taken into consideration and weighed in a scientific way. Those problems have raised the attention of the policymakers in many urban areas. Several regulations and measures have been proposed and implemented, such as an off-hour delivery policy and mandatory loading space requirement for a
new building with over 25,000 square feet in New York City, a congestion charge system in the center of London, and the appearance of self-service parcel pickup machines. By making these policies and regulations, these cities are trying to reduce or mitigate the impact brought by delivery. Nevertheless, those problems brought by delivery transport activity persist, and the conflicts between current urban planning patterns and increasing delivery traffic demand remain unsolved. The research objective of this thesis is to explore the relationship between urban planning patterns and delivery traffic activities so that people can implement an effective policy or measure to balance the exploding delivery traffic issues.

There are two main questions in this research: How does the current road network system adapt to or conflict with the rapid growth delivery traffic trend caused by e-commerce? What are the planning factors that affect delivery traffic activity in the Greater London area in the UK? To answer these two main questions, several questions are going to be explored: How much traffic was newly brought by delivery traffic after the boom of e-commerce? How are the traffic conditions related to delivery traffic activity?

The thesis is structured as follows. First, data collection efforts and results are described. Second, with the quantitative method, the relationship between the delivery traffic trend and traffic congestion in the Greater London area are explored. Finally, using spatial analysis tools, planning pattern factors, including land use, and road networks, are analyzed with the delivery traffic activity in the Greater London area.
**Literature Review**

**Traffic congestion**

Traffic congestion is a term that is hard to be defined as it can have very different meanings in different situations. However, the Department for Transport in the UK uses the definition which interprets traffic congestion as the vehicle interactive way to impede the progress of each other. These interactions and their effects on the vehicle journey as the demand for the available road space approaches its design capacity. Also, factors influencing the congestion include slower speeds, longer journey times, increased queuing at junctions or bottlenecks, and increased stopping and starting.

In order to study the impact of the delivery traffic trend on traffic congestion, the factors mentioned above that affect traffic should be clarified. The occurrence of congestion can be defined by co-effects of three basic macroscopic elements of traffic state: speed, flow, and density (May, 1990). When traffic demand is great enough that the interaction between vehicles slows the speed of the traffic stream, this results in congestion. To prevent congestion and to keep traffic flow stable, theoretically, the number of vehicles entering the control zone must be smaller or equal to the number of vehicles leaving the zone at the same time.
Figure 1.4: Relationship between speed-flow, speed-density, and flow-density

(Source: Fundamentals of Transportation Engineering)

The relations between flow and density, density and speed, and speed and flow can be represented by some curves, but they need to be calibrated in the traffic model according to different situations and analysis objectives. Previous work has shown that congestion can be considered as the result of five root causes: traffic incidents, work zones, weather, fluctuations in normal traffic, and traffic control devices, and these roots often interact with one another (Traffic Congestion and Reliability, 2017). In this case, either the increase in traffic demand or the constraints of the roadway capacity will lead to traffic congestion. However, the research on the relationship between parcel delivery and traffic congestion is sparse. Some researchers have concluded that some impacts caused by delivery movement include traffic congestion (Allen, 2012; Lindholm, 2010).

DFT uses the average delay travel time to measure the congestion on local “A” roads. The delay travel time is relative to free flow, which is calculated by the formula shown in Figure 1.4. Unlike the average speed, average delay travel time considers different free flow speeds,
which are design speed and different speed limits on each road, allowing road segments to be compared more easily and accurately (analysis of travel time). The data are generated by a GPS equipped with a fleet of probe vehicles with 10-second location reports to make the data highly accurate. Also, the data are matched with every specific road segment which has traffic count points between two junctions on local “A” roads.

An INRIX report revealed that the main factor which contributes to traffic congestion in London is the growing number of trucks. INRIX is a global traffic data company that publishes traffic report every year. It uses vehicle GPS data, including speed, travel time, and travel. The study found that private vehicles are decreasing in congestion zones; however, van traffic has risen significantly (INRIX, 2017). The analysis and the methodology cannot be referred since the GPS data are collected from its products. Its market share is over 50% in the UK. The conclusions of the report have adopted by the UK government.

Planning Pattern and Traffic

Land use is often associated with demographic and economic attributes. It is hard to link specific transportation modes with specific land use patterns. However, in the e-commerce era, due to the rise of personal shopping and online spending, the number of LGVs carrying parcels to consumers that pass through residential areas has increased significantly.

The relationships between transportation and land use are rich in theoretical representations that have contributed much to regional sciences. Since transportation is a distance-decay altering technology, spatial organization is assumed to be strongly influenced by the concepts of location and distance. Several descriptive and analytical models of urban land use have been developed over time, with increasing levels of complexity (May, 1990). All
involve some consideration of transport in the explanations of urban land use structures. The following is a non-exhaustive categorization:

![Figure 1.5: Road network types.](source)

(Source: Street Network Types and Road Safety)

The conventional street grid is mostly the outcome of the streetcar suburbs that emerged in the early 1900s when private vehicles were not common. It conferred optimal accessibility and use of available space. The diffusion of the automobile was a driver in the shift of the street network toward a more curvilinear pattern. This implied a reduction in the level of connectivity as well as in the density of land use. This was part of a paradox where, while the automobile was becoming the dominant support of urban mobility, it was also increasingly associated with local disturbances. Planners responded by developing cul-de-sac suburban patterns with the goal to reduce and even eliminate through movements on a large number of residential streets and having them occur on main arterials. By the 1950s, the conventional cul-de-sac pattern became
prevalent in suburban developments. Although this pattern minimizes non-local circulation, it also generates more movements and energy consumption (Marshall, 2010).

Many land use patterns visible in London resemble the “classic” urban location theory models: there is an extreme Alonso-type density gradient; retail uses retain a central-place hierarchy; and there are distinct radial corridors, with many residential areas developing along this radial geometric.

Some researchers have identified that traffic is also affected by planning patterns and geographical features, like the size and density of the city, city morphology, land use patterns, and the road network (Allen et al., 2012). The length of the roads, the width of the roads, and even the intersections of the roads are all related to traffic congestion. In the congested segments of the roads, vehicles are consuming more fuels and producing more greenhouse gas emissions (Lindholm, 2010). However, the peak hour of the delivery process almost coincides with the peak of the commuting process (DFT, 2015). In this light, when delivery trucks pass through congested areas, they will cause double parking, and seeking for an available space to stop will hinder the traffic flow (Allen, 2011; Morris, 2009). The delivery trucks thus become contributors to the traffic congestion. Despite some research that has analyzed spatial features and traffic, few research has focused on the impact of the delivery traffic trend on planning patterns due to the rapid growth of the B2C e-commerce mode in recent years. In addition, Allen’s (2016) research investigated urban factors related to traffic and considered the differences between passenger transportation and freight transportation. With the rising land prices, more and more warehouses are moving to suburban areas with lower land prices. This process led truck travel distance to increase dramatically.
Parcel delivery in London

Allen (2016) analyzed the UK parcel industry in his research, which covered the UK parcel market, the operational practices of UK parcel carriers in making last-mile deliveries and collections, and operation depots and practices used by parcel carriers in London. He pointed out that 3% (3.3 million tons) of mail and parcels were delivered by HGVs to, from, and within London in 2014. HGVs usually transferred goods between different warehouses or distribution centers, rather than the deliveries and collections to customers (most of which are using LGVs) (Allen, 2016). The authors argued that the efficiency of delivery was also based on the density of the deliveries to be made in the area. The average traffic speeds had been declining at all times of the day between 2008 to 2015 in London, and road traffic vehicle delays also rose 17% to 31% in central London at different times of day. The main findings of this article is used in the methodology part of the thesis.

Allen, Browne, and Cherrett (2012) examined road freight transport activities and their relationships with facility location and urban form through an analysis of 14 areas in the UK. The main findings included: over the last decade, warehousing had a relatively low growth, and it was usually located in suburban areas. This origin and destination of delivery rides increased the distance. The length of haul on journeys to and from urban areas studied was found to be greatest for those areas with a major seaport. Allen et al. (2012) analyzed 14 urban areas in the UK that were the same as those studied in this thesis. The researchers examined the traffic situation in the planning pattern by using population sizes, population density, loaded vehicles’ travel distance, warehousing floor-area, and changing and commercial land use changes (Allen, 2012). However, they explored freight activities and intensity in different urban features. This thesis would incline to traffic congestion in different urban features. With the basic relationship
in traffic congestion models, the thesis will use speed data, traffic volume data, and free flow data released by the UK Department for Traffic to determine the relationship between delivery trucks and traffic congestion.
Chapter Two

Data

The thesis relies on spatial analysis to figure out the relationship between the LGV traffic activity caused by e-commerce and urban planning patterns. Table 2.1 lists the data used in the thesis, and they are further explained below.

Table 2.1

Summary of Data Sources

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<th>Dataset</th>
<th>Years</th>
<th>Category</th>
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<td>AADF</td>
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<td>Excel</td>
<td>UK DFT</td>
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<tr>
<td>Average Speed</td>
<td>2012-2016</td>
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<td>Average Delay time</td>
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<td>2011</td>
<td>Excel</td>
<td>GLA</td>
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<tr>
<td>London Land Use</td>
<td>2014</td>
<td>Shapefile</td>
<td>GLA</td>
</tr>
<tr>
<td>Road Network</td>
<td>2016</td>
<td>Shapefile</td>
<td>Highways Agency</td>
</tr>
</tbody>
</table>

The number of licensed vehicles and the travel distance by different types of vehicles are produced by the Department for Transport of the United Kingdom, and they provide a basic sense of the share changing of LGVs which are basically used for delivery and show how many increments are brought by parcel delivery and the boom of e-commerce.

The annual average daily flow (AADF) data shows the volume of vehicles which drive on a stretch of road on an average day in a year. From these data, this study extracts several segments to compare with the traffic speed.
Average journey time data and traffic speed data all include start junctions and end junctions. Combining these two types of data, the key indicators of this study, will allow calculation of the congestion situation during the study period and quantification of the congestion level.

The LGV traffic activity data includes the LGV counts and the number of LGVs in the study area. Average delay travel time data compared to free flow data are used to show the traffic conditions. Regarding traffic conditions, DFT data is used. The geographic information helps to evaluate the urban planning patterns and LGV traffic activity. The most available data sources for the information are open data that all public can access online. These data were published by the UK DFT and the Office for National Statistics in the UK. The London Authority is recognized as a leader in smart city and open data, allowing planners to use their data to analyze and plan. However, the e-commerce distribution data uses the trips made by delivery vehicles (LGVs), since it is hard to access the detailed e-commerce data.

To remove the effect of the financial crisis, which has a great influence on e-commerce, the study period from 2012 to 2016 is selected. During this period, the economic conditions had stabilized and recovered in the UK.

The Greater London Authority is considered to be made up of 32 boroughs and the City of London (See Figure 2.1). Inner London includes the boroughs of Camden, Greenwich, Hackney, Hammersmith and Fulham, Islington, Kensington and Chelsea, Lambeth, Lewisham, Southwark, Tower Hamlets, Wandsworth, and Westminster. Outer London is like a ring around inner London; it is made up of Barking and Dagenham, Bromley, Croydon, Enfield, Harangue, Hovering, Hillingdon, Kingston upon Thames, Merton, Redbridge, Waltham Forest, Brent, Ealing, Harrow, Hounslow, New Ham, Richmond upon Thames, and Sutton. The Greater
London Authority is surrounded by the Greenbelt, on which new development is banned. The Greenbelt is a very important symbol of London urban planning, which was first proposed in 1935 for controlling the urban sprawl and protecting agriculture and forestry. The Greenbelt ranges from 10 to 20 miles wide (GLA, 2011).

Figure 2.1: Greater London, Outer London, Inner London, and Central London.
(Source: GLA)

Methodology

The procedure for analyzing the research questions comprised two steps: (a) performing statistical tests to determine the relationship between LGV and traffic conditions in London and
(b) performing statistical tests to determine the impact of LGV traffic trend brought by e-commerce on different urban planning patterns. Although the e-commerce turnover data was available, there was no e-commerce data at the resident level. The research methodology is designed to impose all the LGV impact on the traffic and urban planning side to reflect the impact of e-commerce, instead of analyzing e-commerce data directly. The spatial analysis focuses on exploring the relationship between different urban planning patterns and the LGV traffic activity to answer the question of how LGV traffic increases its effect on or is affected by the urban planning patterns. The quantitative data is used to analyze the influence of LGV traffic activity on the traffic performance, including the travel distance and average delay travel time.

**Statistical Procedures**

The purpose of choosing statistical tests is to evaluate how current road network systems adapt, or conflict, with the rapid growth delivery traffic trend caused by e-commerce. What are the planning factors that affect delivery transport activity through a study of the Greater London area in the UK? The analysis aimed to find out what kinds of planning patterns would benefit the delivery traffic trend. The first part of the analysis assessed the relationship between delivery activity and traffic congestion. To determine that, a regression analysis is conducted to quantify the association between these two objectives. The second part of this study concentrated on evaluating the geometric features of many subjects related to delivery activity and planning patterns.

The number of registered LGVs, which is usually used for parcel delivery, increased every year from 2000 (see Figure 2.2). But the average travel mile for each LGV decreased constantly. In this light, the study chose data from 2012 to 2016 to analyze the relationship between the development of e-commerce and the traffic patterns.
As the Figure 2.2 shows, the supply of the new LGVs would have an impact on the traffic patterns. For the demand part, the annual average daily flow (AADF) and number of licensed LGVs were the main factors that were taken into consideration. From the supply side, the thesis mainly considers the development of infrastructure, including road length by different types. Both journey time and travel speed are used as indicators of traffic congestion. The following data were used for composing the correlation analysis: number of licensed vehicles by type, travel distance by vehicle type, London traffic counts data and AADF, average journey time data, traffic speed data, and road length by road type.

With the data of weighted average travel speed, LGV counts and the average travel distance of light commercial vehicles, Stata is used to explore the inner relationships of these three factors based on data from 2008 to 2016. As the correlation table shows, there is little relationship between LGV counts and average speed or the average distance of the light commercial vehicles, but the weighted average travel speed is highly correlated to travel distance.
of LGVs. The correlation coefficient is -0.95. This result proves that the change in the LGV counts would not cause significant changes in the average speed of all vehicles or the travel length of the LGVs. The two factors are impacted by other elements.

\[
\text{. cor speed distance lgv} \\
(\text{obs=9})
\]

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<th></th>
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Figure 2.3: Correlation result.

To further explore the relationship of speed and travel distance, linear regression is conducted in Stata. The result indicates that under 99% confidence level, these two factors are related, and 90% of the change in speed can be explained by the traffic distance change. The shorter travel distance will cause higher travel speed.

\[
\text{. reg speed distance}
\]

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<td>Adj R-squared = 0.8897</td>
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<tr>
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<td>8</td>
<td>0.070031204</td>
<td>Root MSE = 0.08789</td>
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| speed | Coef.   | Std. Err. | t     | P>|t|  | [95% Conf. Interval] |
|-------|---------|-----------|-------|------|----------------------|
| distance | -1.803889 | .2228354 | -8.10 | 0.000 | -2.330811 -1.276967 |
| _cons  | 19.47595 | .5306624 | 36.70 | 0.000 | 18.22113 20.73076 |

Figure 2.4: Regression result.
Spatial Analysis Methods

After the correlation test, the study focuses on evaluating and comparing the traffic congestion situation (AADF data and the average journey time data) in different geometric patterns of London. To inquire how urban planning would influence the delivery traffic trend, the analysis includes several aspects of planning patterns.

The methodology for the geometric analysis at the neighborhood scale is based on calculating the proportions of different categories of land use, residential land use density, retail and commercial land use density, length of the road, traffic signals and crossings density, and the population density. The neighborhoods to be compared are selected by the similar number of residents in the area as a fixed value. Additionally, by comparing the traffic congestion data in different areas, the thesis explores more in-depth findings.
The data used in this part includes land use by borough and ward in London, London population data for 2011 (the census data is taken every 10 years in the UK; the next update will be 2021), and Shapefiles for London 2014.

Findings

The purpose of examining the variation of LGV counts in different areas of the study period is to see the spatial distribution of LGVs in the Greater London area for further analysis.

2.3.1 Comparison of number of LGV from 2012 to 2016 vs. travel distance

Road is by far the dominant mode for goods transport in London in terms of the weight of goods lifted, accounting for around 90% of all tonnage (DFT, 2017). The 2012 to 2016 LGV numbers are shown in Figure 2.2. The tendency of the number of LGVs signifies an increasing volume of LGV traffic in London. LGVs stand out on the list of the fastest growth in all types of vehicles in London since 2010. The growth during the 5-year period was 16%, and the growth from 2013 to 2014 was 7%, after which the growth rate slowed to 2%.

Figure 2.6 illustrates the variation of the LGV travel distance. In the Central London area, which comprises the City of London and Westminster, the LGV travel distance increased sharply from 2012 to 2014 and fell back to a similar level in 2012. LGV travel distance in Outer London had the fastest growth rate, which has been about 26% since 2012. Growth in 2014 was a bit slower, at 12%. It increased to 22% in 2016, from 20% as recently as 2013. As the analysis above shows, LGV travel distance and traffic congestion are strongly positively related.
Figure 2.6: Trends in LGV traffic in central, inner, outer and Greater London.

(Source: UK DFT)
Comparison of traffic signals and crossing vs. road networks

Figure 2.7: Traffic signal lights and road networks.

(Source: UK DFT, GLA)
All UK roads are divided into four categories. Motorways are the majority inter-urban roads in the UK. Local “A” roads are major roads that connect within or between areas with large-scale design capacity. Local “B” roads are the roads which concatenate the traffic between “A” roads and smaller roads. Minor roads are smaller roads intended to connect the unclassified roads with “A” and “B” roads and to connect villages (DFT, 2012). It can be seen from Figure 2.7 and Figure 2.8 that the road network in Greater London is a radial grid rather than a circular grid and the road network is gradually denser in central London.
It can be seen from Figure 2.8 that there are more traffic signal lights and crossings in central London than at the edge, while extending to the northwest, north, and west, the southern boroughs, and that the density of the main road network corresponds with the traffic signal and crossing density. It can be seen that outside the center of London, the density of traffic lights is less than the density of crossings.

**Comparison of LGV counts from 2012 to 2016**

As shown in Figure 2.9, the three clusters of LGV distribution in London are concentrated in and around Hillingdon, Harrow, Brent, Tower Hamlets, and Bexley. The counts of LGVs have been increasing in these areas. After rising from 2012 to 2015, the distribution of LGV counts changed dramatically in 2016. This highlights the large change in the middle east part of Greater London, where the cluster of LGV distributions became smaller. A new cluster appeared in Havering, and some clusters moved to the southeastern part of Greater London, around Sutton and Croydon.

Figure 2.10 shows the proportion of the local “A” road network that have been maintained in 2016. Hackney, Southwark, Camden, Westminster, Hammersmith, Wandsworth had greater than 7% and less than or equal to 10% local ‘A’ road under maintenance. Other boroughs in northwest, middle east and south also had 4% to 7% proportion of local “A” road under construction. This road condition may make LGVs use lower level roads for delivery to avoid the impact of the local “A” road maintenance. This led to a reduction in the number of LGV counts in the boroughs around Hillingdon, Harrow, Brent, Tower Hamlets and Bexley in 2016. It also explains why the number of LGV counts increased in 2016, but the distribution was more widely.
Figure 2.9: LGV counts from 2012 to 2016.

(Source: UK DFT)
Figure 2.10 Road maintenance condition, 2016

(Source: UK DFT)
Comparison of variation of LGV counts vs. the percentage change of LGV from 2012 to 2016

Figure 2.11: Variation of LGV counts, 2012 to 2016
(Source: UK DFT)

Figure 2.12: Percentage change of LGV counts, 2012 to 2016
(Source: UK DFT)
Figure 2.11 and 2.12 show the variation of LGV counts and the percentage of variation of LGV counts from 2012 to 2016. Over the 5-year term, the LGV counts in the Greater London area, Haringey, Islington, the east part of Westminster, Lambeth, Merton, and most parts of Havering decreased from 24% to 7%. Bexley had the fastest growth among all boroughs, reaching a 64% increase in LGV counts. Similarly, Enfield, Barnet, Harrow, Newham, Tower Hamlets, and Greenwich experienced an increase in LGV counts of 45%.
Comparison of average delay travel time vs. LGV counts from 2012 to 2016

Figure 2.13: Average delay travel time hotspot map, 2012 to 2016.

(Source: UK DFT)
Figure 2.13 shows the Getis-Ord Gi* analysis result of the average delay travel time from 2012 to 2016, which can illustrate the traffic congestion conditions in Greater London. The clusters from dark blue to dark red areas are the geographic distribution clusters. The darker blue areas indicate areas with longer average delay travel times, while the darker red areas indicate boroughs with less average delay travel time. Hillington, Enfield, Lewisham, Tower Hamlets, and Lambeth are the areas with most increase in average delay travel time. Sutton, Redbridge, Barnet, and Kingston are the boroughs with least increase average delay travel time.
Chapter Three

Discussion

It can be seen from Figure 2.11 that the LGV counts in the Central London area have decreased, and the counts in Bexley, Hillingdon, Harrow, Barnet, Enfield, and Sutton have increased from 15% to 45%. Bexley had the highest increase rate, reaching 64% in a 5-year period, but the average delay travel time only increased about 7%. In fact, through the hotspot map (Figure 2.13), it is apparent that the areas with the greatest increase in delay travel time (about 10% to 17%) were clustered in Hillington, Enfield, Lewisham, Tower Hamlets, and Lambeth. The areas with less increase in delay travel time (about 2% to 7%), were Harrow, Sutton, Kingston, and Redbridge. The white areas were in the middle level of delay travel time (about 7% to 10%) and not clustered. In the regression analysis, it is determined the positive correlation between LGV travel distance and delay travel time, so the influence of urban planning patterns on traffic conditions and LGV traffic activity will be discussed.
Figure 3.1: Proportion of land use in different boroughs.

(Source: GLA)
Through the average delay travel time and the variation percentage of LGV counts (see Figure 2.13 and Figure 2.12), Hillington, Enfield, Lambeth, Lewisham, Tower Hamlet, Sutton, Kingston, Redbridge, Harrow, Havering, and Bexley are found to have a significant relationship between traffic delay and LGV change, and therefore they are selected to compare their basic urban planning patterns. Figure 3.1, Table 3.1, and Figure 3.2 listed the population density, land use, road network density, area of road networks, and the number of traffic signal lights and crossings for comparison purposes. It can be inferred from Figure 3.1 that there are mainly four categories: central CBD areas; typical rural areas with 70% to 85% green land and rare retail and commercial land use, such as Hillington, Kingston, and Bexley; mixed use urban development areas, with a high proportion of residential land use, 15% to 25% commercial and retail land use, and about 30% to 40% green land, such as Havering, Lambeth, Harrow, and Tower Hamlet; residential rural areas with a high proportion of residential land use, assorted commercial and retail land use, and 50% to 60% percent of green land, including Lewisham, Sutton, and Redbridge.
### Table 3.1

**Urban Planning Patterns of Different Boroughs**

<table>
<thead>
<tr>
<th>Borough Name</th>
<th>Hillington</th>
<th>Enfield</th>
<th>Lambeth</th>
<th>Lewisham</th>
<th>Tower Hamlet</th>
<th>Sutton</th>
<th>Kingston</th>
<th>Redbridge</th>
<th>Harrow</th>
<th>Havering</th>
<th>Bexley</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Area (km²)</strong></td>
<td>132.6</td>
<td>40.4</td>
<td>26.1</td>
<td>35.2</td>
<td>19.4</td>
<td>22.3</td>
<td>25.4</td>
<td>56.4</td>
<td>67.2</td>
<td>112.3</td>
<td>60.56</td>
</tr>
<tr>
<td><strong>Population Density (per km²)</strong></td>
<td>4621</td>
<td>7365</td>
<td>13143</td>
<td>9092</td>
<td>16550</td>
<td>6211</td>
<td>6285</td>
<td>7742</td>
<td>6606</td>
<td>2301</td>
<td>4110</td>
</tr>
<tr>
<td><strong>Household</strong></td>
<td>100214</td>
<td>119916</td>
<td>130017</td>
<td>116091</td>
<td>101257</td>
<td>78174</td>
<td>63639</td>
<td>99105</td>
<td>84268</td>
<td>97199</td>
<td>92604</td>
</tr>
<tr>
<td><strong>Household Density (per km²)</strong></td>
<td>755.5</td>
<td>2970.5</td>
<td>4977.5</td>
<td>3302.7</td>
<td>5223.4</td>
<td>3503.2</td>
<td>2510.2</td>
<td>1756.8</td>
<td>1253.1</td>
<td>865.5</td>
<td>1529.1</td>
</tr>
<tr>
<td><strong>Road Density</strong></td>
<td>8.80%</td>
<td>9.80%</td>
<td>19.60%</td>
<td>16.70%</td>
<td>17.10%</td>
<td>11.80%</td>
<td>12.10%</td>
<td>12.50%</td>
<td>11.90%</td>
<td>12%</td>
<td>11.60%</td>
</tr>
<tr>
<td><strong>Crossing Number</strong></td>
<td>1309</td>
<td>755</td>
<td>747</td>
<td>1471</td>
<td>1103</td>
<td>341</td>
<td>363</td>
<td>688</td>
<td>300</td>
<td>342</td>
<td>301</td>
</tr>
<tr>
<td><strong>Crossing Density (per km²)</strong></td>
<td>10</td>
<td>19</td>
<td>29</td>
<td>42</td>
<td>57</td>
<td>15</td>
<td>14</td>
<td>12</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

(Source: GLA)

[Two minimal values][blue]

[Two maximal values][orange]
Figure 3.2: Population density (2014).

(Source: GLA)
Five boroughs which have longer delay travel times take most of the highest index in Table 3.1 (light yellow color). Hillington and Enfield have similar land use patterns defined by suburban development. The household density in Enfield is higher than it is in Hillington. Heathrow Airport is located in this borough, and many parcel distribution centers and warehouses have been built in this area. Road A4 is the only local “A” road connected with other boroughs. Lambeth and Tower Hamlet are both mixed-use development areas comprising nearly 40% residential land use, 15% retail and commercial land use, and about 15% industrial patterns. Road network density in these two areas is over 15%, which will generate more traffic crossings. Since the delivery peak times on weekdays almost coincide in London, the deterioration of the traffic condition is reasonable.

Among the boroughs with less delay travel time, the urban planning patterns of Sutton and Redbridge can be seen to be broadly similar, and other indicators stay at the same level. Kingston has a greater proportion of green land than others but a lower proportion of residential, retail, and commercial land use in the less delay travel time cluster. Harrow is a typical mixed-use development area with 48% residential land use and 12% retail and commercial land use. However, the density of traffic crossings and signal lights is only 3%, less than a fifth than the other three boroughs.

It can be found from Table 3.2 that the population density of Havering and Bexley is relatively low at 2,300 people per square km and 4,110 people per square km, respectively, less than a fifth of the density of Lambeth and Tower Hamlet. The population density of the boroughs which have longer delay travel times is higher among these boroughs; the same is true of their household density. This means a higher population produces more parcels need to be delivered, and the LGVs will generate more routes for delivery, especially in rural areas where the
residential neighborhoods may be separated by long distances.

By extracting the geometric configurations of the areas with less delay travel time, the residential neighborhoods are found to be mainly made up of two to three single-family homes. The typical building pattern of rural areas is the single-family house, so the van drivers need to start and stop more frequently to deliver the same number of parcels in denser areas, which results in slowing down the traffic flow speed. Drivers need to find parking places while arranging deliveries and collections. Many parcel operations in busy urban environments leave vehicles on-street while carrying out their operations. A driver can use a barrow to carry more parcels; the higher the density is, the more parcels the driver carries and the less the van stops and starts.
Conclusions

An efficient freight network supports the functions of a city. GLA seeks to facilitate sustainable freight movement in London through consolidation, modal shift, and promotion of deliveries at different times of day and night in order to reduce the impact on road congestion and air quality as well as conflict with other users (Mayor’s Office, 2010).

Parcel delivery is affected by urban form. Some factors such as neighborhood size, population density, number of households, and commercial and retail land use patterns are likely to influence the extent and location of delivery traffic activity.

In rural areas, low-density households may cause longer LGV delivery distances. Due to the longer distance between customers, the number of starts and stops may slow the traffic flow, causing more traffic congestion. In urban areas, LGVs’ contribution to traffic congestion in the CBD area is relatively small, since some LGVs pass through this area, and the rest of them are engaged in B2B delivery, which usually builds loading docks for specific purposes.

Traffic lights and intersections have a great influence on traffic conditions. The more traffic lights and intersections there are, the worse the traffic conditions are. Road network density also has a relatively high impact on LGV traffic activity; a higher density causes traffic congestion.
Implication and Recommendation

This study focuses on analyzing the impact of the delivery traffic activities caused by e-commerce on urban planning patterns. In the new era, these two elements will have a major impact on the city. In Greater London, we can see the relationship between traffic conditions and delivery traffic activities from 2012 to 2016 through the study. At the same time, it analyzes the urban planning pattern in each borough to find the links with delivery traffic activities.

This study provides an example of how planners could use open data to design a research methodology that uses LGV related data instead of detailed e-commerce delivery data which hardly access to assess the impact of delivery traffic activities caused by e-commerce on cities. It is now a common strategy in urban planning research that uses open data to obtained related information.

In future, delivery traffic activities will exist for a long time. Even if there are new technologies, such as the delivery autonomous vehicles, the specific traffic mode of delivery will continue. In the new master plan of a city, it is a nonnegligible factor that city planners need to consider.

Greater London, as the study area of this thesis, contains a variety of urban forms, mixed use, suburban, residential, and central CBD areas. Greater London also has various kinds of road network connection systems. The conclusions of this thesis can be extended to many urban areas, such as high-density cities like New York City and Paris with similar characteristics of road networks.

This study indicates that in the suburban areas, centralized low-density residential areas are more helpful to reduce the impact of delivery traffic activities on traffic conditions. However, in the other hand, mixed used development areas may reduce the efficiency of delivery to a
certain extent. For these places, self-service parcel pickup machines, such as Amazon Locker and UPS access point, will be a good solution. In high density urban residential area, special parking space and loading docks will benefit parcel delivery by eliminating starts and stops and saving the time looking for parking spaces. Relying on central fulfillment distribution center, as the current strategy of courier companies, causes longer average delivery distance, but the rational establishment of neighborhood-level depots in high population density areas will significantly improve the delivery efficiency and alleviate urban traffic pressure.

Urban planning, as a traditional study discipline, must keep up with the technology development. How to deal with urban issues caused by the massive evolution of people’s lifestyle becomes one of the most important and difficult problems. This requires urban planners to understand the new challenges under the scope of the city planning, transforming emerging issues to different aspects and seeking the right solutions using different strategies. The impact of e-commerce on cities are too broad to analyze but converting one part of its effects on roadway network to the LGV’s impact on the traffic is applicable and reasonable. With qualitative and quantitative analysis, we could find out the relationship between the new technology and urban patterns from an ambiguous start, which gives the planners a direction and instruction to make the city plan more comprehensive and adaptable in the future.
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