URBAN FREIGHT IN DUBLIN: AN INTEGRATED POLICY FRAMEWORK FOR SUSTAINABLE DISTRIBUTION

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DECLARATION

I hereby declare that this thesis, in whole or in part has not been submitted as an exercise for a degree at this or any other university. I further declare that except where reference is given in the text, the work is entirely my own.

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ABSTRACT

Urban goods movement is essential to life in a city. Every product and service we avail of must be transported from where it is sourced to where it is sold. At a wider level, urban freight transport is the engine driving economic activity. Retail trade and industry are dependent on a timely and reliable goods distribution system. However, although urban goods transport is vital in supporting economic development, it also has unsustainable impacts for the environment, for the economy and also for society. There are two key features of urban freight research, which influence this thesis. Firstly, the limited amount of urban freight data available has made it difficult for European cities to devise policies that are grounded in what is actually happening in reality. Secondly, analysis of urban freight has tended to occur in isolation of other transport policies. This has meant urban freight is not integrated with overall transport policy in cities. This thesis examines urban freight in Dublin, however many of the problems and solutions described are applicable to other European cities. Different cities have implemented different approaches for managing urban goods transport. These approaches range from truck access bans to the use of Urban Consolidation Centres (UCCs). In the case of Dublin, a two-tiered approach has been introduced to manage Heavy Goods Vehicles (HGVs) and urban goods deliveries to the city centre. This innovative approach involves a major infrastructure element- the Dublin Port Tunnel- complemented by a strategy for Heavy Goods Vehicle Management in the city. The HGV Management Strategy is used as a control mechanism to optimise the use of the Port Tunnel while simultaneously managing how deliveries to the city centre using five axle plus HGVs are made. Permits are required for deliveries to the affected cordon area by large HGVs and are issued via an online Permit System.

The issue of limited urban freight data availability is addressed in this thesis through a survey of deliveries to Dublin City Centre and an examination of key trends and statistics arising from this survey. It was found that the high delivery generating areas occur in the south west of the city, the south of the city, the north west of the city and the city centre itself. The busiest time for deliveries is between 10:00 and 11:00 with 16% of the total arriving in this period. Night-time deliveries are minimal with only 2% of deliveries occurring between 17:00 and 23:00 and no deliveries between 23:00 and 05:00. Other statistics gathered in the survey relate to vehicles, goods and dwell times. In addition to the delivery survey, a clearer picture of urban freight in Dublin is obtained via an analysis of the impacts of the Dublin Port Tunnel and the HGV Management Strategy for the city.

This analysis is carried out using the data from the online Permit System operated by Dublin City Council. In total over 94,000 permits are analysed providing statistics on characteristics such as delivery vehicles, delivery origins, cordon entry points and cordon exit points. Overall the decrease in the number of HGVs with five or more axles is in the range of 78-91% across the cordon area. A shift to night-time deliveries has not occurred as a result of the HGV Strategy. Consideration in the thesis is also given to the operational aspects of the HGV Management Strategy. One area of concern identified in the thesis is the cost of the Eastlink Rebate Toll Scheme. This scheme was introduced because the HGV Management Strategy imposed a closed cordon around the North and South port areas. The loose implementation of this scheme has resulted in serious monthly costs for Dublin City Council.

One of the main contributions of the thesis is the proposal of a Policy Driven Variable Pricing Model (PDVPM) for the Permit System. The concept of a breakeven cost per cordon crossing for HGVs is introduced. The PDVPM is applied to three transport policies- promotion of cycling, promotion of bus priority and creating a pedestrian friendly environment in the city centre. In essence, the PDVPM allows for the possibility of directing five plus axle HGVs to certain "encouraged" cordon entry points by applying a discount to the breakeven cordon cost and away from "discouraged" cordon entry points by adding a premium to the breakeven cost on the basis of selected transport policies. The PDVPM is tested on permit data and it is proposed that variable pricing based on a 75% cost recovery of the breakeven point is more equitable to users of the permit system than a full cost recovery. It is found that there is no conflict between the three transport policies and therefore it is possible for Dublin City Council to implement a PDVPM that takes all three transport imperatives into account.

Finally, the thesis tests the impacts of potential Urban Consolidation Centre (UCC) scenarios in the city. Locations at Dublin Port and in the South West of the city are selected on the basis of survey data and permit data analysed. The impacts on general traffic and public transport of using smaller vehicles for city centre deliveries are tested using a Q-Paramics traffic microsimulation model. It is found that during peak time, UCC scenarios have serious impacts on traffic, particularly public transport. It is concluded that UCCs may become a more viable option in the future if the bus lane network is extended (to provide more segregation for public transport from general traffic) and if deliveries from the UCCs are done in off-peak hours.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Urban goods movement is essential to life in a city. Every product and service we avail of must be transported from where it is sourced to where it is sold. At a wider level, urban freight transport is the engine driving economic activity. Retail trade and industry are dependent on a timely and reliable goods distribution system. However, although urban goods transport is vital in supporting economic development, it also has unsustainable impacts. Firstly, for the individual, there are adverse health consequences as a result of noise and pollutant emissions. Secondly for retailers, there are issues regarding ease of accessibility of large delivery vehicles in urban areas. Thirdly, for society there are serious environmental consequences, visual intrusion issues and indirect economic costs as a result of the transport of goods in urban areas. To date, the evaluation of urban freight has focused on this range of associated problems rather than the overall role and functions that goods movement in urban areas fulfil. To quote the OECD Working Group on Urban Freight Logistics (2003), "awareness of urban goods transport seems to be rather one-sided, focusing more on its problems than on its importance". Furthermore, to date analysis of urban freight tends to occur in isolation of other transport policies. This has resulted in a "silo" type approach to urban freight rather than an overall integrated policy approach that takes a more holistic view of transport policies in a city.

The importance of urban goods movement will not diminish in the future. Therefore, there is a need to devise innovative solutions for managing freight in urban areas that mitigate its adverse impacts. However, devising urban freight polices that fulfil economic imperatives and are also cognisant of environmental targets is a challenging task. Any solution should involve a multi-dimensional approach taking a wider transport policy view. This thesis takes such an approach by proposing an integrated transport policy framework for managing goods distribution in a medium sized European city using Dublin as a case study. The policy framework is centred on a proposed extension in the scope of a HGV Management Strategy for the city to take account of other transport objectives.

One of the main difficulties associated with devising urban freight policies is the limited data available. A study of major problems, requirements and initiatives concerning urban freight transport was carried out by BESTUFS, a European Commission funded network

(BESTUFS, 2001). One of the key findings of the study was that in most European Cities there is a lack of statistics and data regarding urban freight. In general, the amount of urban freight transport data available is very limited in comparison to passenger transport. The modal split of freight transport in Ireland is 98% road and 2% rail (EEA, 2006) and as a result, any data that is collected tends to have a roads emphasis. The chief sources of information in Ireland relating to urban freight in Dublin are the Central Statistics Office (CSO), Dublin City Council (DCC) and the National Roads Authority (NRA). The CSO compiles an annual survey of goods moved by road by tonnage carried provides a snapshot of national freight movements. DCC carry out annual traffic counts of all vehicles entering and exiting the core city area. The NRA also carry out an annual national roads and traffic flow survey, which provides information on the percentage of Heavy Commercial Vehicles in the national vehicle fleet. However, there is a dearth of information regarding the micro-detail of urban deliveries cities generally and for Dublin particularly. Data such as class of goods delivered, location of suppliers, dwell time of deliveries, type of packaging used, types of organisations receiving deliveries, type of vehicles used, loading/unloading facilities used has been unavailable. This deficiency in data has made it difficult to devise an urban freight policy that is grounded in what is actually happening on the city's road network.

Different cities have implemented different approaches for managing urban goods transport. In London, a Freight Transport Unit has been created by Transport for London and the Mayor, and the London Freight Plan was issued in 2008 (TfL, 2008). The Plan sets a context for urban freight in the planning framework and emphasises the need for a partnership approach to goods movement in the city. France has a history of developing freight consolidation centres. These centres are used to consolidate loads and to transfer goods from large trucks into smaller, more eco-friendly vehicles for deliveries into city centre areas. In Paris, trucks above 24 metres in length are prohibited from the city centre between 07:30 and 19:00. In the Netherlands, Urban Consolidation Centres (UCCs) have been identified in national policy as a means to solve the accessibility and environmental problems associated with freight transport in cities (Ministry of Transport and Public Works, 1999). A number of UCCs have been established but have not proved successful (Schoemaker, 2002). In Japan, the Government authorised a set of polices on freight transport called " A Comprehensive Program of Logistics Policies". This programme deals with urban freight transport and includes measures such as voluntary co-operation for joint collection and delivery points in urban areas and investments to improve infrastructure in order to reduce the time and cost of goods transportation.

In the case of Dublin, a two-tiered approach has been introduced to manage Heavy Goods Vehicles (HGVs) and urban goods deliveries to the city centre. This innovative approach involves a major infrastructure element- the Dublin Port Tunnel- complemented by a strategy for Heavy Goods Vehicle Management in the city. The HGV Management Strategy is used as a control mechanism to optimise the use of the Port Tunnel while simultaneously managing how deliveries to the city centre using five axle plus HGVs are made. Permits are required for deliveries to the affected cordon area by large HGVs and are issued via an online Permit System. Entry and exit to and from the cordon must occur at designated points. To date, there has been no comprehensive overall assessment of the impacts of this dual approach to managing urban freight in Dublin. The detailed nature of trips undertaken using permits, along with trends relating to the organisations and vehicles involved has yet to be analysed. Furthermore, as yet, no method has been devised to predict the annual volume of permits.

The other major feature of the HGV Management Strategy, which has also yet to be analysed is the permit charge. A flat fee is charged for making deliveries to the cordon area using five axle plus vehicles regardless of the cordon entry and exit points used and the number of journeys per permit.

Looking at the HGV Management Strategy in a broader transport context, it is also of interest to examine the potential for integrating the Permit System with other transport imperatives. Presently, transport policies for Dublin are discrete and not interlinked. Thus, there is potential for integrating these policies in order to achieve a more coherent and effective approach to transport in the city centre. There is also potential for incorporating other initiatives that have been used in other cities, for example UCCs.

Therefore having regard to the foregoing issues, the research objectives for this thesis are as follows:

1. To address the gap in knowledge that exists regarding urban freight data in European cities by carrying out a comprehensive goods delivery survey in Dublin and analysing the survey data.

2. To evaluate a two-tiered approach to the management of urban freight in a European city by firstly assessing the impacts of the implementation of the Dublin Port Tunnel and the HGV Management Strategy in Dublin through the identification of key trends in relation to the urban HGV fleet and permits; and secondly to examine possible statistical indicators and relationships that may be used to predict the volume of permits on an annual basis

3. To develop a coherent framework for integrating urban freight solutions in a broader transport policy context.

4. To test the impacts of an Urban Consolidation Centre on the speed, journey time and distance travelled by general traffic and public transport in a city where cars are the predominant mode of transport and to apply critical success factors to potential UCC location scenarios in Dublin

1.2 THESIS LAYOUT

This thesis addresses the foregoing research objectives and is organised as follows. Chapter 2 provides a literature review of urban freight developments and initiatives. The importance and also the impacts of urban freight are discussed. The chapter also deals with sustainability strategies for urban freight transport. These strategies include Urban Consolidation Centres and last mile delivery solutions. Urban freight pricing is also discussed in Chapter 2. Furthermore, an overview of urban freight data currently available in Ireland is provided.

Chapter 3 details a survey carried out of deliveries to Dublin City Centre. The chapter sets out the initial approach to the survey, including the consultation mechanisms employed and pilot work undertaken. The obstacles encountered and the actions taken to overcome the obstacles are also described. Finally, a comprehensive analysis of the data gathered is carried out and subsequent findings are presented.

Chapter 4 provides a full description of the dual approach implemented for managing urban freight in Dublin. The chapter describes the implementation of the HGV Management Strategy and outlines how data has been acquired from the Permit System. A comprehensive statistical analysis of the data obtained from the Permit System is presented. Output from the analysis includes:

- measures of permit activity
- extent to which permits are planned for in advance
- characteristics of vehicles used
- details of the organisations receiving five plus axle deliveries
- journey analysis
- examination of the relationship between the location of premises and the cordon entry and exit points used

In addition, data from a number of other sources is assessed in order to provide a traffic context to the statistical results and findings from the Permit System analysis. This data includes Dublin Port Tunnel traffic counts, Eastlink Toll Bridge counts, axle counter data and annual classified traffic counts. Finally, the cost of the permit system is also analysed in this chapter.

Chapter 5 introduces and develops the concept of a policy-based permit system. The chapter analyses the relationship of three key factors with the number of permits produced on an annual basis. A relationship is established between the national Retail Sales Index (RSI) and the number of permits generated. The relationship between the RSI and the number of permits is extended to allow the identification of the cost breakeven point of the Permit System. The chapter also proposes a framework for a revised charging structure for permits. This revised charging structure involves a move towards a breakeven pricing structure for permits and the development of a Policy Driven Variable Price Model (PDVPM). The PDVPM allows the implementation of a more integrated approach to transport policy in Dublin by introducing pricing signals that encourage and discourage use of particular cordon entry and exit points for the Permit System on the basis of national and local policy imperatives.

Chapter 6 focuses on the potential for implementing Urban Consolidation Centres in Dublin. Two locations for UCCs are proposed based on findings from the survey of city centre deliveries carried out in Chapter 3 and the analysis of permit data in Chapter 4. This chapter summarises the critical success factors for UCCs based on international experience. A case study of a privately owned UCC is also evaluated. Finally five UCC scenarios based on the two locations proposed are tested using a Q-Paramics traffic microsimulation model. The results of the microsimulation model runs are presented and the implications for general traffic and public transport are outlined.

Chapter 7 concludes the thesis with a discussion of the main findings and highlights the contribution to knowledge. This chapter also discusses areas for further research.

CHAPTER 2: LITERATURE AND URBAN FREIGHT DATA REVIEW

2.1 INTRODUCTION

An overview of research and the main areas of work carried out to date in the field of urban freight are presented in this chapter. The importance and the impacts of urban freight are examined. The difficulties of obtaining data relating to urban freight are outlined. The extent of freight data available in an Irish context is discussed. A review of potential urban freight solutions and approaches used in different cities is also provided in this chapter. This review includes various examples of Urban Distribution Centres (UCCs) in France, the Netherlands and the United Kingdom. The issue of time of day pricing for urban freight delivery traffic and it impacts on off-peak deliveries is also discussed. Finally, the overarching theme of urban freight is explored in terms of the focus on impacts rather than the wider transport context.

2.2 OVERVIEW OF URBAN FREIGHT CHARACTERISTICS

While research in urban freight transport has become more widespread in the last decade, overall the topic has received little attention in comparison with the movements of passengers in cities (OECD, 2003). There are a number of reasons proposed in literature for the limited research into urban freight transport (Woudsma, 2001). Firstly, passenger traffic is responsible for the majority of vehicles on the road network (DaBlanc, 2007). This has resulted in a focus of transport research on urban passenger transport rather than on urban freight transport. Secondly, the large number of actors and stakeholders involved in urban freight make it a more complex field to research. Thirdly, the extent of detailed and reliable data available on urban freight transport is very limited (Browne and Allen, 2006, Ambrosini and Routhier, 2004).

Key to understanding urban freight transport is a clarification of the reasons why the movement of goods occurs in the first instance. Precise definitions of urban goods movement vary by author across different studies. Ogden (1992) defines urban goods movement as “the movement of things (as distinct from people) to, from, within, and through urban areas”. Ambrosini and Routhier (2004) propose an extension of this definition to include “household purchasing trips, urban road maintenance and building, waste collection, etc.”. The OECD (2003) defines urban goods movement as “the delivery of consumer goods (not only by retail, but also by other sectors such as manufacturing) in city and suburban areas, including the reverse flow of used goods in terms of clean waste”. Three distinct reasons for urban freight activities are proposed by Allen et al. (2000). These reasons are:

1. Core goods collections/deliveries to and from the premises
2. Non core goods trips, such as waste collection, postal and money collection
3. Services related trips.

The importance of urban freight transport is derived primarily from its contribution to the economic vitality of a region. The efficient and reliable movement of goods supports urban lifestyles through the retail, leisure, entertainment and tourism sectors (Allen et al, 2003). Overall, urban freight transport is important for a number of key reasons as highlighted by Ogden (1992) and Andeson et al. (2005):

- The total cost of freight transport and physical distribution is significant and has a direct impact on the efficiency of the economy
- The environmental effect of urban freight movements
- The effect of freight transport costs on the cost of commodities consumed in a region
- Freight transport is vital to sustain our lifestyles
- Freight transport plays a role in servicing and retaining industrial and trading activities, which are major wealth generating activities
- The contribution that an efficient freight sector makes to the competitiveness of industry in a particular region
- The adverse impact on a region if its industries are rendered uncompetitive due to poor freight services

A key recurring theme throughout literature is that in spite of the critical role played by urban freight transport in supporting lifestyles and the economy in urban areas, there are a number of undesirable impacts of urban freight, which cannot be ignored. These impacts are categorised in three areas – environmental impacts, economic impacts and social impacts (Anderson et al, 2005, Browne and Allen, 1999, Van Binsbergen and Visser, 2001). Environmental impacts are derived from:

- Pollutant emissions including carbon dioxide, carbon monoxide, nitrogen oxides and particulate matter.
- The use of non-renewable natural resources such as fossil-fuel
- Waste products such as tyres oil and other materials
- The loss of wildlife habitats and the associated threat to wild species.

Browne et al. (2007) note that road freight vehicles operating in an urban environment tend to emit a greater proportion of certain pollutants per kilometre than other motor vehicles such as cars and motorcycles. Furthermore, transport produces 30% of European CO2 emissions with road transport accounting for 84% of emissions (Commission of the European Communities, 2001).

Economic impacts of urban freight transport are related to:

- Congestion and reduced city accessibility
- Inefficiency and waste of resources
- Decrease in journey reliability and delivery punctuality, potentially leading to reduced customer service levels and lost markets
- Decreased economic development

The physical size of urban goods vehicles often leads to congestion, accidents, delays, and manoeuvring difficulties that impact both on other goods vehicles and general traffic. Older urban areas with narrow streets are particularly susceptible to reduced accessibility as a result of goods vehicles.

It is difficult to quantify the cost of noise and emissions produced by urban freight vehicles on the wider community. However, it is estimated that the cost of excess truck noise is equivalent to 1 per cent, and that the cost due to emissions is equivalent to 0.2 per cent of total truck operating costs (Ogden, 1992).

Social impacts of urban freight transport occur as a result of:

- The physical consequences of pollutant emissions on public health levels
- The injuries and deaths resulting from traffic accidents
- The increase in noise disturbance and visual intrusion
- Damage to buildings and infrastructure
- Reduced quality of life due to loss of greenfield sites and open sites in urban areas as a result of transport infrastructure developments

Accidents arising from the movement of goods in urban areas increase the risks on the road network for vulnerable road users such as pedestrians and cyclists. The economic cost of accidents is linked to safety in urban freight transport. Costs include delay cost, accident cost, increase vehicle operating costs due to increased congestion caused by the accident and clean-up costs incurred by local authorities and other agencies.

Van Binsbergen and Visser (2001) emphasise that only a comprehensive set of policy actions that addresses the impacts and problems associated with urban freight transport at different geographical scales and at various functional levels can mitigate the negative impacts of urban goods movement.

2.3 URBAN FREIGHT DATA

In contrast to the comprehensive data sets that are available for passenger transport analysis, there is consensus in the literature that urban freight data is not as widely available to researchers. This is attributable to the private sector's opposition to disclosing information with competitive commercial value (Garrido, 2001). It is also due the large number of stakeholders involved in urban freight– producers, shippers, hauliers and retailers. Because of the large number of stakeholders, it is difficult to obtain details for a full journey from source to end point. In the BESTUFS Consolidated Best Practice Handbook (BESTUFS, 2004), it is noted "In general it can be stated that there is a lack of information and data collection on urban freight transport within the European Countries". It is further noted in the Handbook that only a small proportion of medium and large cities in selected European Countries are formally collecting data on urban freight transport. The BESTUFS study finds that 58% of cities were not collecting data on urban freight transport (25 cities in total). 42% of cities actually collect urban freight data in a structured manner. The study also notes that data collected in cities is often specific to a particular situation or set of measures. The study concludes that in general, surveys and other data gathering exercises relating to urban freight are seldom undertaken in European cities and the overall knowledge regarding urban goods movement is incomplete

In the U.K., the vast majority of the Department for Transport published freight data available, is reported at national scale and does not distinguish between urban and non-urban freight. (Browne et al., 2007). However, it is possible to make inferences regarding urban freight by disaggregating the data to urban levels. For example, The Continuing Survey of Roads Goods Transport provides freight data from which data at an urban level can be extracted. Many local authorities carry out periodic vehicle traffic counts that include goods vehicles but do not carry out surveys of goods vehicle operations (Browne et al., 2007). The only survey work or data collection in the U.K. that focuses on urban freight has been one-off surveys in specific towns or cities.

The situation in Ireland regarding urban freight data collection is similar to the UK. A regional freight study for the Greater Dublin Area notes that there is "limited data available with which to make an assessment of road freight activity" (Carl Bro and Goodbody, 2006). The principal data sources for freight in Dublin are:

- The annual CSO Road Freight Survey
- The annual CSO Statistics of Port Traffic
- The National Roads Authority road traffic count data
- Annual canal cordon counts undertaken by Dublin City Council

The CSO (2009b) compiles an annual survey of goods moved by road by tonnage carried called the Road Freight Transport Survey. The CSO Road Freight Survey provides an origin-destination matrix of tonnes carried. The principle measures used in the survey report to assess transport activity are the weight of goods carried (in tonnes) and the quantity of work done (in tonne-kilometres). Each year the CSO collects data for one-week's transport activity for a random sample of goods vehicles in the country. This sample survey covers a random sample of about 20,000 goods vehicles. The sample is grossed up to the level of the national fleet to provide estimates for freight activity by all goods vehicles for the year in question. Only registered vehicles with an un-laden weight of two tonnes and over come within the scope of the survey. This survey is the only extensive database on freight traffic for the country. Data for particular cities can be extracted from the overall database. However, one weakness in using the Road Freight Transport Survey is that any freight carried by vehicles below two tonnes unlade weight is excluded. This is a major disadvantage in an area such as Dublin where a significant amount of freight is carried by smaller vehicles, particularly for retail distribution. Furthermore the survey does not capture micro-level delivery information such as the dwell time of the delivery, the type of loading/unloading facilities used, and details relating to the receiver of the goods.

The Statistics of the Port Traffic Survey carried out by the CSO (CSO, 2009c) collects quarterly data from 22 ports and harbours around the country. The statistics gather detail the movement of goods in sea going vessels by type of cargo and region of trade in addition to the type and size of the vessels used to carry out the transportation.

The NRA also carry out an annual national roads and traffic flow survey, which provides information on the proportion of Heavy Commercial Vehicles (HCVs) in the national fleet. Also, traffic counts on the canal cordons, which provide a natural, geographical boundary for the city centre are carried out annually by Dublin City Council. These counts are carried out in November each year between 07:00 and 10:00 and provide an indication of the proportion of lorries leaving and entering the area within the canals.

2.4 KEY TRENDS IN FREIGHT TRANSPORT

The extent of road freight transport in Europe is reflected in the statistics available relating to the area. In 2001, the volume of road transport in the EU is estimated to have been 1329 billion tonne-kilometres. Of this total, national transport accounted for 75 %, international transport 22% and cross-trade for 3%. Ireland recorded the largest rise in road transport for the period 1990-2001 with a jump of 135% from 3978 million tonne kilometres (tkm) to 9122 tkm (EuroStat, 2005). By 2007, road freight transport in Ireland had risen further to 14,428 tkm (EuroStat, 2009). Overall a growth rate of 4% in road freight transport was observed in the EU from 2006 to 2007. National haulage by vehicles registered in Ireland increased by 46% from 12,300 million tonne-km in 2000 to 17,900 million tonne-km in 2005, while freight by rail fell by 40% from 500 million tonne-kilometres in 2000 to 300 million tonne-kilometres in 2005 (DG-TREN, 2006). Goods carried by Irish registered goods vehicles increased by 203% from 103,836,000 tonnes in 1997 to 314,826,000 tonnes in 2007 and the average number of goods vehicles increased by 169% from 45,256 in 1997 to 121,697 in 2007. Tonne-kilometres increased by 174% from 6,998 million in 1997 to 19,146 million in 2007 and vehicle-kilometres increased by 120% from 1,208 million in 1997 to 2,662 million in 2007 (CSO, 2008). The NRA (2003) forecast that light goods vehicle (LGV) kilometres will increase from 0.76 billion in 2002 to 1.67 billion in 2020 and to 2.2 billion in 2041 on national primary roads and from 0.28 billion in 2002 to 0.63 billion in 2020 and to 0.82 billion in 2041 on national secondary roads. Table 2.1 below shows NRA forecasts for HGV and car kilometres on national primary and secondary roads.

	2002	2020	2041
HGV Kilometres – National Primary Roads	1.11	1.61	2.09
HGV Kilometres – National Secondary Roads	0.31	0.45	0.58
Car Kilometres – National Primary Roads	10.03	14.51	16.53
Car Kilometres – National Secondary Roads	3.63	5.26	5.99

Table 2.1 National Roads Authority Forecasts (billion-kilometres) (NRA, 2003)

Table 2.2 below shows the modal split of internal freight for 2006 and 2007 in the EU and indicates the strong dependence on road freight in Ireland. The modal split of freight transport in Ireland in 2007 was 99% road and 0.7% rail (EEA, 2006). This compares with the EU-27 average of 76.5% road, 17.9% rail and 5.6% inland waterways in 2007.

	2006 Roads	2006 Rail	2006 Inland Waterway	2007 Roads	2007 Rail	2007 Inland Waterway
Belgium	71.1	14.2	14.7	71.1	13.2	15.7
Bulgaria	69	27.1	3.9	70	25.1	4.8
Czech Republic	76.1	23.8	0.1	74.7	25.3	0.1
Germany	65.9	21.4	12.8	65.7	21.9	12.4
Denmark	91.9	8.1	-	92.2	7.8	-
Estonia	34.7	65.3	-	43.2	56.8	-
Greece	98.1	1.9	-	97.1	2.9	-
Spain	95.6	4.4	-	96.1	3.9	-
Finland	72.8	27.1	0.2	73.9	25.9	0.3
France	80.9	15.7	3.4	81.4	15.2	3.4
Hungary	71.6	23.9	4.5	74.4	21.0	4.6
Ireland	98.8	1.2	-	99.3	0.7	-
Italy	88.8	11.2	-	88.3	11.6	-
Lithuania	58.4	41.6	-	58.5	41.5	-
Luxembourg	91.5	4.6	4	92.5	4.1	3.3
Latvia	39	61	-	41.9	58.1	-
Netherlands	63.1	4.8	32.1	61.4	5.7	33.0
Poland	70.4	29.4	0.2	73.5	26.4	0.1
Portugal	94.9	5.1	-	94.7	5.3	-
Romania	70.5	19.4	10.0	71.3	18.9	9.8
Sweden	64.2	35.8	-	63.6	36.4	-
Slovenia	78.2	21.8	-	79.2	20.8	-
Slovak Republic	68.8	30.9	0.3	71.8	25.5	2.7
United Kingdom	86.2	13.7	0.1	86.6	13.3	0.1
Norway	85.6	14.4	-	84.9	15.1	-
EU-27	76.3	18.1	5.7	76.5	17.9	5.6

Table 2.2 Modal Split of Inland Tonne-km (%)

2.5 ROLE OF POLICY MAKERS

The role of policy makers is also discussed in urban freight literature. Dablanc (2007) points out that as a general principle, "local public policies regarding freight are scarce and out of date". Furthermore, it also stated that most cities plan and implement urban freight policies in the same manner as was done 20 years ago. Most cities view truck traffic as something that should be banned or regulated at the very least. Very few cities consider freight activities as a service that they should help to organise in a more efficient manner. Traditionally national governments and local authorities have not placed a great deal of emphasis on urban freight requirements in urban development strategies and local development plans (Browne et al, 2007). Consultation between local authorities and hauliers and other stakeholders has been often kept to a limited consultation exercise.

However, in the U.K. in the last number of years, it has become common practice to establish a formal working relationship between public and private sector urban freight stakeholders to discuss practical details of deliveries and other freight matters. These formal relationships are known as Freight Quality Partnerships (FQPs) and may be thought of as "a means for local government, businesses, freight operators, environmental groups, the local community and other interested stakeholders to work together to address specific freight transport problems". They provide a forum to achieve "best practice in environmentally sensitive, economic, safe and efficient freight transport" (DfT, 2003). The U.K. government has been promoting FQPs since 1999 (DETR, 1999). The guidance on Full Local Transport Plans (DETR, 2000) emphasizes how Government expects local authorities to place greater importance on promoting sustainable distribution within Local Transport Plans (LTPs). One of the minimum requirements of the LTPs is to show "clear evidence of effective partnership with navigation authorities, rail infrastructure providers and freight operating companies to promote greater use of alternative modes for freight distribution". The guidance on LTPs goes on to state that one characteristic of a "good" LTP is "evidence of progress in establishing freight quality partnerships, identifying key organisations and companies involved". Approximately 50 local authorities have made reference to FQPs in the LTPs to date (Browne et al, 2007).

In London, a Freight Transport Unit has been created by Transport for London and the Mayor and the London Sustainable Distribution Partnership has been used as a forum to consult a wide range of urban freight stakeholders. The London Freight Plan was issued in 2008 (TfL, 2008). The Plan sets a context for urban freight in the planning framework and explains why there is a need for a partnership approach in the city.

At a national level in the UK, the Government's Sustainable Distribution Strategy Report (DoT, 1998) provides an overall policy framework, emphasising the twin goals of increased efficiency and reduced environmental impacts. The document fulfils the government's commitment in the White Paper " A New Deal for Transport" to set out a comprehensive integrated strategy for the sustainable distribution of goods and services in the UK. It deals with supply chain management as well of modes of transport. In the report, it is stated that the UK government's objectives are to:

- Improve the efficiency of distribution
- Minimise congestion
- Make better use of transport infrastructure
- Minimise pollution and reduce greenhouse gas emissions
- Manage development pressures on the landscape-both natural and man-made
- Reduce noise and disturbance from freight movements
- Reduce the number of accidents and cases of ill-health associated with freight movement

More recently, the publication of "Delivering a Sustainable Transport System: The Logistics Perspective" has set out how Government and industry can work together to facilitate efficient freight movement and mitigate its impacts (DfT, 2008).

In the Netherlands, the Ministry for Transport and Public Works supports a consortium of towns and cities to develop innovative solutions for managing urban freight, known as the Forum for Physical Distribution in Urban Areas (PSD, 2003). These forums focus on night deliveries and on low noise vehicles and ancillaries. The policy agenda of these forums is developed in co-operation with both the public and private sector. The government seeks co-operation with the private sector and develops policies in full consultation with the private sector, in order to create win-win situations. This means that instead of regulation, local, regional and national governments now sign covenants with organisations representing business or directly with businesses. In these covenants the private sector agrees to behave in a particular way, while the public sector either provides facilities, finances or reassesses and alters regulations.

In 1997 the government of Japan authorised a programme entitled the "Comprehensive Program of Logistics Policies" which includes urban freight transport (Visser, 1999). The objectives of the program are to:

- Enable Japan to offer one of the most attractive logistics services in the Asian-Pacific Region
- Provide logistics services at a reasonable cost
- Cope with the energy, environmental issues and safety problems arising from freight logistics.

The policy measures that were implemented as part of the program include:

- Improving the infrastructure
- Providing subsidies for investments in logistics-related facilities
- Encouraging shared consolidation, collection and delivery points in metropolitan areas
- The development of logistics hubs in the vicinity of major highway interchanges, and in industrial and port side zones.
- The development and standardisation of the ITS logistics applications
- Providing road traffic information through bringing a standard Vehicle Information System (VIS) into nationwide use

In 2001, a revised version of the programme was introduced. Urban freight transport is considered an important area in which to achieve efficient and environmentally friendly logistics systems in Japan. Two quantitative targets were set on the load factors and peak-hour average travel speed in three major metropolitan areas: from the current 45 percent to a target of 50 percent, and from the current 21km per hour to a target of 25 km per hour respectively. In order to meet these targets, the program emphasises the importance of co-ordination and cooperation between public and private sectors, and between national and local governmental agencies. The programme requested that local agencies establish an independent organisation to plan local logistics policies and forums to exchange information on local logistics policies inviting private representatives from the associations of carriers, retailers and other concerned stakeholders.

2.6 EXAMPLES OF URBAN FREIGHT SOLUTIONS

There are a number of policy measures for managing urban freight, which have been implemented. This thesis focuses on Urban Consolidation Centres, Last Mile Solutions and Pricing Initiatives.

2.6.1 Urban Consolidation Centres

The terms Urban Consolidation Centre (UCC), Urban Distribution Centre (UDC) and Freight Platform are all used in the literature examined to describe situations where a logistics centre located close to an area (typically a city centre or other busy commercial area) is used to manage delivery into that area. Since the terms UCC and Freight Platform do not necessarily imply that consolidation of part loads occurs at these logistics centres in order to reduce delivery trips, Urban Consolidation Centre is the term, which is used throughout this thesis. The primary function of a UCC is to allow freight transport to be split into two parts: the part inside the city and the part outside the city. Figure 2 below illustrates the Urban Consolidation Centre Concept. One of the important advantages for the UCC is that it makes it possible to benefit from the advantages of large vehicles for long haul transport outside the city without having the disadvantages of these large trucks in urban areas since smaller. The UCC allow potentially more environmentally friendly vehicles can be used to transport goods from the UCC to the city centre.

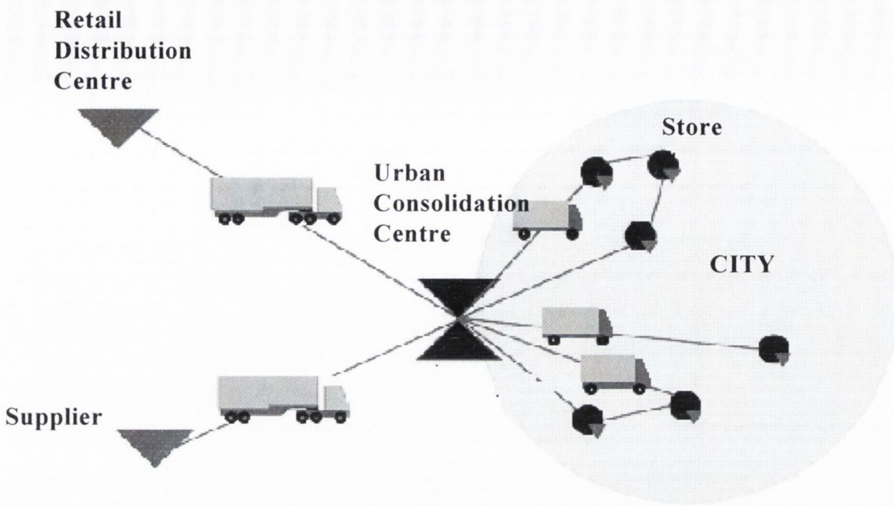


Figure 2.1 The Urban Consolidation Centre Concept

There are a number of advantages and disadvantages of UCCs, which are emphasised throughout the literature (BESTUFS, 2004, Whiteing and Edwards, 1996 and Beuthe and Kreutzberger, 2001). Some of the main advantages of UCCs include:

- Environmental and social benefits of less intrusive transport operations in urban areas
- Better planning and implementation of logistics operations
- Potential to link in with wider policy and regulatory initiatives
- Opportunity for carrying out value-added activities
- Potential to allow better use of resources at delivery locations
- Spatial concentration of freight facilities and distribution operators around the selected site, possible leading to economies of agglomeration and external economies of scale

Potential disadvantages of UCCs on the other hand include:

- Additional costs caused by transhipment through additional handling and warehouse costs
- Some freight is already subject to considerable consolidation such as express parcel couriers and major retailers with their own regional consolidation depots

- Many companies wish to operate dedicated supply chains for their products and are not happy to use shared distribution facilities
- Loss of direct interface between suppliers and customers
- Lack of enforcement of regulations for vehicles not included in the consolidation scheme

A number of examples of Urban Consolidation Centres with mixed success are described in the following section.

2.6.2 International Examples of UCCs

A number of international examples of UCCs are discussed in this section. They include case studies in Leiden, La Rochelle, Fukuoka and Kassel.

2.6.2.1 Leiden

Leiden is a historical city in the Netherlands with 117,000 inhabitants and a road structure dating back to the middle ages. In February 1994, the municipality of the city started to plan for a UCC as part of a number of measures to improve congestion in the city centre (Schoemaker, 2002). The city distribution centre commenced operations in 1997 and was expected to provide:

- A daily reduction of the number of commercial vehicles
- A sharp reduction in pollution in the city centre
- Improved accessibility in the city centre
- Improved road safety
- A template for other cities in the Netherlands and Europe

The primary working area of the UCC was initially the city centre of Leiden. However, this was later expanded to the whole of Leiden and the city's surroundings. In addition, the original location for the centre (close to an important motorway) had to be abandoned due to opposition of citizens' organisations. The new location was in Leiderdorp outside of Leiden.

Although the project in Leiden was a public-private partnership, only one transport company signed up to participate in the UCC. Reasons for non-participation given by transport companies included (BESTUFS, 2002):

- Unwillingness to collaborate with competitors for fear of losing their own customers
- Traffic regulations in Leiden's city centre at the time still accommodated deliveries and therefore no urgency for new distribution systems existed

The regulation for city distribution centres in the Netherlands stipulate that a recognised city distribution centre must, at the end of the first year deliver or collect 100 shipments on average per working day in the city centre. In the case of Leiden, this figure was not achieved and at best 26 deliveries in the city centre were made. This meant that the scheme was not a commercial success since the breakeven point was 600 shipments per day (BESTUFS, 2002). The project also had a negligible effect on traffic volumes. A comparison of truck traffic in September 1996 and October 1999 revealed little difference in incoming truck levels in the two years. As a result of poor performance, the UCC finally stopped operations in 2000.

2.6.2.2 La Rochelle

Another prominent European example of a UCC can be seen in La Rochelle in France. La Rochelle, a city of 135,000 inhabitants on the Atlantic coast, was one of the first European cities to implement a sustainable traffic policy. The municipality has promoted the widespread use of electric passenger cars and delivery vehicles in conjunction with an urban consolidation centre within the historic city centre (Vermie et al, 2002). The UCC was established using a considerable starting subsidy. For goods deliveries a central consolidation and dispatching centre located on the periphery of the walled city centre comprising 750 square metres was established by the city authorities. Goods are transferred from HGVs and large vans into smaller electric vehicles (4 vans and larger vehicles for pallet loads). There have been a number of problems associated with the initiative. Firstly there has been a lack of enforcement of regulations for vehicles not included in the consolidation scheme. Secondly the limited range of the electric vehicles used has resulted in more vehicle trips and an increase in congestion. Thirdly, there has been an apathetic response from carriers to the tender for the UCC management. This is attributed to the difficulty to demonstrate the economic viability of the project (Monami et al, 2007).

2.6.2.3 Fukuoka

A centralised delivery and collections service began in the Tenjin district of Fukuoka City in Japan as far back as 1978 (Taniguchi, 2002). At this time twenty-nine freight carriers participated in a centralised delivery system under the supervision of the Regional Transport Office of the Ministry of Transport. More recently however (1994), thirty-six freight companies established the Tenjin District Joint Distribution Company in order to facilitate centralised distribution. The central business area in Tenjin district is 370,000m^2 in size and accommodates 2,200 offices. The joint distribution programme operates within the central business area. Freight carriers bring their goods to a consolidation centre operated by the Joint Distribution Centre located in the suburbs of Fukuoka City, close to an interchange of urban expressways. The Joint Distribution Company deliver goods from member carriers to each receiver in Tenjin district after sorting goods for each destination. The Joint Distribution Company also collects goods from customers in Tenjin district and unloads them at the distribution centre where the freight carriers deal with them individually. Nemoto (1997) finds that the total impacts are minor because the consolidation centre traffic only constitutes a small portion of the total traffic in Tenjin and furthermore, the consolidation centre only covers a limited part of the Tenjin area.

2.6.2.4 Kassel

In August 1994, in the city of Kassel in Germany, a scheme known as " City Logistik Kassel" was founded. Kassel has about 200,000 inhabitants and is located in Northern Hessen with good access to the A7 (North-South Motorway) and A44 (connection to the Ruhr area). The implementation of an urban distribution centre was part of the city logistics approach in Kassel initiated by the municipality, the regional Chamber of Commerce and Industry and the association of road haulage companies. The primary aim of the scheme is to organise route consolidation distribution. A single, independent city logistics operator delivers to the inner city on behalf of seven freight-forwarding companies. Between the hours of 6:00 and 8:00 five vehicles are employed to collect the consignments delivered at the forwarders' depots during the night. At the distribution centre, the consignments are sorted according to their exact destination. At about 10:00 urban deliveries commence using two or three 7.5 tonne vehicles.

Payment to the logistics operator for services provided is based on a specific city logistics tariff and each freight forwarder is invoiced separately. According to statements made by the companies and surveys carried out, the UCC approach involves no significant change in terms of costs for the freight forwarders (BESTUFS, 2002). Other benefits of the scheme include the fact that consignees in the inner city (who receive deliveries through the scheme) do not report any differences in service quality compared to the former delivery system. By joining forces the forwarding companies, have reduced their number of trips in the city by 80% from 3,900 to 800 per year. Vehicle mileage has been reduced from 6,500 to 2,600km per year (60%). Mileage per day per vehicle has decreased from 25 km to 10 km because of a concentration of deliveries in the same area (EPE, 1999). The motivation of all of the partners involved has been critical for the success of the scheme. The public-private partnership approach used in Kassel ensured that the scheme was operated in a commercial viable manner while simultaneously producing wider benefits in terms of congestion, emissions and noise.

2.6.3 U.K. Examples of UCCs

There are a number of recent examples of UCCs in the U.K. including Bristol Freight Consolidation Centre, Heathrow Airport Consolidation Centre, Meadowhall Shopping Centre Sheffield and the London Construction Consolidation Centre. Each of these examples is discussed below.

2.6.3.1 Bristol Freight Consolidation Centre

Bristol City Council and Exel DHL have been operating a consolidation centre in Bristol since May 2004 serving the city's core retailing area Broadmead. The consolidation project aims to reduce the number of delivery vehicle trips to Broadmead, thereby reducing congestion and pollution in the area (Hapgood, 2009). The scheme operates from a 5,000 square foot warehouse, approximately 25 minutes (10 miles) from the city centre and employs six staff. The scheme currently serves 59 retailers and results published by the operators indicate a vehicle movement reduction of 75% for participating retailers. This equates to a total saving of almost 7,000 lorry trips into the city centre during the first four years of the scheme (WSP, 2008). There has also been a saving of 30 tonnes of carbon dioxide and 970 kilograms of nitrogen oxides (Hapgood, 2009). The trial phase of the scheme was funded entirely through the EC CIVITAS VIVALDI project. Bristol City Council is currently subsidising 60% of scheme costs. The remaining 40% of costs have be raised from retailer contributions in addition to cross subsidy work expanding the remit of the consolidation centre.

2.6.3.2 Heathrow Airport Consolidation Centre

A consolidation centre at Heathrow Airport has been in operation since 2001. The objectives of the scheme are to reduce goods vehicle movement and improve goods and waste handling systems within the terminal areas. The consolidation facility is managed by Exel DHL and involves goods destined fro Terminals 1 to 4 being delivered to the centre which is located remotely from the terminal buildings. As a central point for all incoming deliveries, all unpacking, handling, security scanning and sorting activities are at the freight consolidation centre. 50% of the cost of operating the facility is covered by retailers paying for the consolidation service. 10% of the cost is covered by income generated from value added services such as off-site storage and the remaining 40% of cost is covered by the British Aviation Authority as the landlord. Outcomes of the scheme include a reduction of approximately 54,000 delivery vehicle trips. This equates to 130,000 vehicle kilometres saved, 134 tonnes of carbon dioxide saved and 1200 kilograms of nitrogen oxide saved (Hapgood, 2009).

2.6.3.3 Meadowhall Centre Sheffield

A freight consolidation centre has been operational in the Meadowhall Shopping Centre in Sheffield since 2002. Around 100 retailers, representing 50% of the total participate in the initiative, which is operated by Clipper Logistics. The scheme operates from three warehouses with 30,000 square feet of space. Around 10 truck deliveries per day are made and five staff work on site with a number of staff from retailers carrying out pre-retail duties on an ad hoc basis (WSP, 2008). This example of a UCC is particularly interesting as it has become self-sustaining through income generation from retailers fro use of all facets of the scheme. Benefits arising from the scheme for retailers include a notable reduction in back of house space. However the results in terms of reduction in delivery trips are unclear to date.

2.6.3.4 London Construction Consolidation Centre

The London Construction Consolidation Centre commenced operations as a two-year pilot project from 2005 to 2007. The consolidation centre based in Bermondsey serves four central London developments under construction. It is located outside the congestion charging zone approximately three miles to central London construction sites. Vehicles travelling from the consolidation centre to building sites use alternative fuels such as Liquid Petroleum Gase (LPG) and bio-diesel. A key objective of the pilot scheme was to provide an operational model for supporting the construction projects of the Olympic and Paralympic games in 2012. £3.2 million was provided by the project partners involved in the pilot (Transport for London, Wilson James, Bovis Lend Lease, Stanhope PLC). Results of the trial scheme indicate a 70% reduction in construction vehicle trips. A 94% accuracy rate of goods delivered correctly first time has also been achieved, in comparison to the industry average of 50% (WSP, 2008). Overall a time saving of approximately two hours per journey for delivery drivers has been achieved by removing the need to travel into central London and reducing the unloading time once on site. However, there has been a lower than expected take up by other construction projects to make use of the consolidation facility.

2.6.4 Lessons Learned From Case Study UCCs

Overall, there is mixed experience arising from the use of UCCS. In the cases of Leiden and La Rochelle, congestion resulting from the limited range of the vehicles used has been problematic. Public support for the UCCs in these cases has been low as a result of the increased congestion levels experienced. Furthermore, there has been a reluctance amongst private transport companies to participate in the schemes and this is also a source of concern.

In the case of the U.K. examples of UCCs, some modest success has been experienced. Participation by professional transport companies has been a key factor in this success. In addition, although some of the U.K. examples have received initial project funding and many continue to be subsidised by local authorities or other authorities, there is an emphasis on providing value added services in order to create an additional revenue stream.

2.6.5 Managing the Last Mile of Deliveries

Last mile solutions are another approach for managing deliveries in an urban context. Although the last mile delivery approach does not feature in this thesis as a potential solution for urban freight problems, a summary of the approach is provided for completeness below. Last Mile Delivery Solutions form part of the e-Commerce delivery chain and home deliveries. The "last mile" refers to the link between the ordering process and the delivery of a product to a particular point. The most common practice is to deliver goods to a home, collection point or a convenience store (BESTUFS, 2004). There are a number of issues to take into account in organising the last mile delivery. These include, delivery time, reliability of the delivery, flexibility in terms of alternative delivery addresses or delivery time window, point of delivery (home or pickup point) and delivery service quality.

An example of a local customer collection point for the last mile of deliveries can be seen in Germany where Deutsche Post/DHL has introduced unmanned "PACKSTATIONS" for parcels deliveries and collections in high-density locations such as office complexes, universities and institutions (BESTUFS, 2003). A "PACKSTATION" is a machine-based parcel and mail retrieval system that enables registered customers to retrieve and to send small consignments. Customers are notified by text message or by e-mail when a delivery arrives. Parcels are collected by customers with the appropriate cards and PIN codes 24 hrs per day (DHL, 2004). Following three years of trial, PACKSTATIONS were established at Dortmund, Mainz and Cologne. The scheme has been extended to Hanover, Bremen, Darmstadt and Wiesbaden.

While last mile solutions can result in a net reduction of overall vehicle trips and vehicle kilometres, there are a number of difficulties associated with this approach. One such difficulty is the impact of failed first-time home deliveries on additional carrier journeys and customer trips (Song, Cherrett et al., 2009). A potential way to combat this difficulty is by using networks of post offices, supermarkets and railway stations as substitute collection and delivery points. Song, Cherrett et al. (2009) demonstrate the potential that exists for using these networks instead of repeated delivery attempts to the home.

2.7 TIME OF DAY PRICING FOR URBAN FREIGHT TRAFFIC

The main function of road pricing is to make scarce road capacity subject to market cost valuation to spread traffic volume over time periods to reduce congestion in line with local or national policy. Many of the pricing initiatives relating to urban freight described in the literature are not actually implemented in practice. For example, Allen et al. (2004) and Anderson et al. (2005) present a hypothetical scenario where road pricing is introduced in Birmingham, Hampshire and Norfolk. The expected response to the congestion charge by seven companies that are affected in different ways is used to evaluate the impacts on the initiative. These impacts are dependent on the fee charged, the size of the geographical area to which the fee applies and the resulting reduction in congestion (Allen et al., 2003).

An example of a road pricing scenario with a freight focus that is implemented in practices can be seen in the New York and New Jersey region. Holguin-Veras et al. (2006) evaluate the actual behavioural change of carriers due to a road pricing initiative in the New York and New Jersey region based on a survey carried out. The argument is presented that road pricing alone is not successful for moving freight transport from peak to off-peak periods. The nature of the response to road pricing is determined by the balance of power between the carrier and the receiver. If the carrier is the most powerful, then it is likely that policies that affect the receiver are implemented. For example, the carrier might simply pass on the additional cost to the receiver. If the receiver is the most powerful, the carrier has no choice but to continue delivering during peak hours without passing on the costs to the receiver. However, the study also points out that carriers stand to benefit from delivering during off-peak hours, but can only do so if receivers are willing to receive goods during these hours. Overall the study notes that 15% of carriers change behaviour because of time of day pricing.

A further study focusing on New York (Holguin-Veras, 2007) discusses the economic conditions required to move urban freight delivery traffic to off-peak hours, and the effectiveness of alternative polices to accommodate such a move in competitive markets.

This study builds on the Holguin-Veras et al. 2006 work and examines a policy where road freight pricing is combined with financial incentives in order to produce a shift to off-peak deliveries. The paper suggests the use of tax incentives to receivers willing to accept off-peak deliveries combined with road freight pricing as a revenue generation mechanism. Large traffic generators are proposed as an ideal target for such an approach because they can cater for off-hour deliveries at a minimal incremental cost. It is noted in the research that because of marginal cost pricing, toll schemes based on distance and/or time spent in a tolled region enable the carriers to pass toll costs on to receivers. The research concludes that since neither road freight pricing nor a "laisez-faire" approach will lead to a significant switch to off-hours deliveries, the best option is provided by road freight pricing in combination with financial incentives to receivers.

Another study that looks at pricing in an urban freight environment is the work done by Friesz et al. (2008). A game theoretic model of dynamic pricing in an urban freight environment is proposed. Further work on the potential for off-hour deliveries in New York is done by Brom et al. (2009). The research uses data for the New York City Metropolitan area to determine which market segments show the greatest potential regarding a shift to off-hour deliveries. A behavioural microsimulation model is used to determine the shift in market shares for market segments being considered. The analysis revealed that the wholesale trade and food segments generate a significant portion of daily deliveries and more specifically, the food segment is more likely to perform off-peak deliveries when presented with a tax deduction as an incentive.

2.8 DISCUSSION

Overall, this chapter has examined urban freight from a number of perspectives. Firstly, a broad definition of urban freight transport is proposed from the literature examined that takes into account core deliveries and collections, other non-core trips such as waste collection and finally service related trips. The importance of urban goods movement to the economy of a region is emphasised. In addition, the environmental, economic and social impacts of urban freight are also discussed in the chapter.

A particular area of note from the literature is the absence of comprehensive urban freight data for cities. Freight data available for Ireland is presented and the point is made that micro-details of delivery trips is not collected on a periodic basis in the country. Urban freight estimates are based on extrapolated data from the National Road Freight Survey.

Following on from the urban freight data issue, the chapter also assesses the role of policymaker at local and national level in influencing urban freight in cities. Traditionally national governments and local authorities have not placed a great deal of emphasis on urban freight requirements in transport and development strategies. However in the U.K, Government expects local authorities to place greater importance on promoting sustainable distribution within Local Transport Plans. (LPTs) Furthermore, freight quality partnerships also feature strongly in LTPs.

The chapter also discusses UCCs as an approach for managing urban freight. Case studies from Leiden, Kassel, La Rochelle, Fukuoka, Bristol, Heathrow, Sheffield and London are presented. The mixed success of the various UCCs is discussed. In the cases of Leiden and La Rochelle, congestion resulting from the limited range of the vehicles used for deliveries from the UCC has been problematic. Public support for the UCCs in these cases has been low as a result of the increased congestion levels experienced. Furthermore, there has been a reluctance amongst private transport companies to participate in the schemes and this is also a source of concern. In the case of the U.K. examples of UCCs, some modest success has been experienced. Participation by professional transport companies has been a key factor in this success. In addition, although some of the U.K. examples have received initial project funding and many continue to be subsidised by local authorities or other authorities, there is an emphasis on providing value added services in order to create an additional revenue stream.

A discussion of last mile solutions as an approach for managing urban goods is also presented in this chapter. The "PACKSTATION" example from Germany is discussed. Furthermore the impact of failed first-time home deliveries on additional carrier journeys and customer trips is highlighted along with a solution to this problem proposed in the literature involving the use of a network of substitute collection and delivery points.

Finally, the issue of urban freight pricing is discussed. It is noted that many of the pricing initiatives relating to urban freight described in the literature are not actually implemented in practice. In fact, there is only limited research carried out on the area of urban freight pricing. However work in New York evaluates the actual behavioural change of carriers due to a road pricing initiative in the region. The argument is presented that road pricing is not successful for moving freight transport from peak to off-peak periods

Overall, it is noted that urban freight literature tends to focus on the problems of goods movement in cities problems and solutions to these problems. This approach does not lend itself to taking a wider view of urban freight in a broader transport policy context. This thesis addresses this issue.

CHAPTER 3: SURVEY OF DELIVERIES TO DUBLIN CITY CENTRE

3.1 INTRODUCTION

While extensive data is available on national freight movements, there is very limited data available on urban freight in Dublin City Centre. This information is needed in order to develop a comprehensive understanding of urban freight in Dublin City Centre, and assist the development of an integrated policy framework. It was therefore necessary to undertake a comprehensive survey of goods deliveries. The objectives of the survey were in broad terms to obtain information on the vehicles used, the types of organisations receiving deliveries, class of goods delivered, loading facilities used and delivery time profiles.

The chapter sets out in detail the initial approach to the survey, including the consultation mechanisms employed and pilot work undertaken. It also describes the obstacles encountered and the actions taken to overcome these obstacles. Finally, it presents a comprehensive analysis of the data gathered and outlines the main findings.

3.2 SURVEY PREPARATION

The preparatory work prior to carrying out the survey of deliveries to city centre organisations involved a number of consultation meetings with various organisations, undertaking a pilot survey of deliveries to Trinity College Campus and designing a suitable survey questionnaire for city centre businesses.

3.2.1 Consultation Meetings

Consultation meetings were held with a range of different participants with a vested interest in freight transport in Dublin in order to encourage participation in the survey of deliveries to city centre organisations. Parties who provided input into the survey included the following trade associations and other organisations:

- Dublin City Centre Business Association (DCCBA)

- Retail Grocery, Dairy & Allied Trades Association (RGDATA)
- Licensed Vintners Association (LVA)
- Irish Business & Employers Confederation (IBEC)
- Restaurant Association of Ireland (RAI)
- Fastrack
- SDS
- Dublin City Council (DCC)
- Department of Transport (DoT)

Obtaining the support of the various trade associations was a crucial step in ensuring that a sufficiently high response to the overall survey was achieved. These associations expressed their willingness on behalf of their members to participate in a survey and indicated their willingness to provide a mailing list of members to allow for inclusion in the survey of city centre businesses. Furthermore, the associations also provided letters of support for the survey. These letters can be viewed in Appendix A.

Consultation meetings with the above parties provided feedback on freight distribution issues in Dublin City Centre. Trade associations provided an overview of difficulties experienced by their members in relation to receiving deliveries. The availability of loading bays proved to be a major issue for businesses. The DCCBA representative expressed the view that more stringent policing of loading bays is needed in order to clamp down on illegal parking in the bays. Night-time deliveries to business premises are another major issue raised during the meetings. The point made by the trade associations consulted was that cost is the deciding factor on whether or not to accept nighttime deliveries. Staffing and security costs can be a considerable impediment to receiving deliveries outside regular working hours.

Companies making deliveries (SDS and Fastrack), on the other hand, provided a different perspective to freight distribution. A representative of SDS highlighted the areas in Dublin where company vehicles are most likely to be delayed in traffic. These routes include the N4 (national route from the west into the city centre), the North and South Quays of the River Liffey, and a number of core streets in the city centre. When the issue of eco-friendly vehicles was raised, the SDS response was that as long as it can be proved that a vehicle is cost effective, reliable and suited to city centre driving conditions, then that vehicle merits consideration for future vehicle acquisitions.

3.2.2 Setting Out the Objectives of the Survey

The primary aim of the survey was to obtain a snapshot of delivery information from a core set of city centre organisations. Prior to the construction of the survey form, a list of essential data requirements, which would require attention in the delivery survey was compiled. These data requirements include the following:

- Type of goods carried
- Quantity of goods
- Packaging used
- Type of delivery vehicle used
- Location of supplier
- Dwell time of delivery
- Location of loading/unloading of goods
- Location of business
- Type of business

All of this data is necessary in order to create a detailed picture of delivery trends in the city centre.

3.3 TCD PILOT SURVEY

As part of the overall survey of 150 city centre businesses, it was decided to carry out a delivery survey in Trinity College Dublin (TCD). The purpose of this survey was two-fold. Firstly, it was useful as a pilot study to perfect the method of data collection which would be used for the main survey. Secondly, the TCD survey constitutes a substantial individual case study as part of the larger survey. This is mainly due to the fact that the TCD campus is a predominantly non-commercial environment, occupying some 47 acres of land in Dublin City Centre, and as such is uniquely placed as a delivery destination. The survey of deliveries to TCD provides an opportunity to examine delivery patterns to a self-contained campus.

The College has two gate entrances- Lincoln Gate, which remains open all day from 7:00 – 00:00 and Pearse Street Gate, which opens for morning and evening peak periods. Following a successful trial run, it was decided to carry out the survey during the college 'Green Week'. Green week was a College wide promotion of environmental awareness. This week was selected in order to maximise awareness among students and staff. Companies that deliver frequently to the college were notified about the survey and were asked to cooperate.

The survey itself was carried out by the author and a number of other college students. Two survey attendants were located at Lincoln Gate, the main delivery entrance. Following discussions with College authorities, it was decided to use security camera footage instead of survey attendants at the Pearse St. Gate. This decision was taken for two reasons: firstly, the gate is only open for a total of four hours a day and secondly trial runs of the survey indicated that a minimal number of commercial vehicles use this entrance.

3.3.1 Storage of Survey Data

Following the completion of the gate survey, the survey forms were collated, and an ACCESS Database storing all of the information was created. This database comprises a table of 32 fields. It was created as a means of preserving the integrity of the data and to allow improved speed of survey data retrieval. Database storage also allows for data manipulation through Structured Query Language (SQL). Once the data had been entered into the database, a number of SQL queries were run on the database in order to ascertain basic survey information such as the response rate. Although SQL is useful for data manipulation, it was also necessary to analyse the survey data using statistical software. SPSS (Statistical Package for the Social Sciences) is a widely used tool that allows for data collection, data access and management, analysis, reporting and deployment. It allows the user to score and analyse quantitative data very quickly. Use of SPSS to analyse the survey data involved exporting the data from the original ACCESS database into SPSS. 38 variables (used to define the categories of data collected) were then defined. Variables in SPSS were used to define pieces of data such as the type of goods delivered, vehicle used, delivery company name, the origin of the delivery trip, type of packaging used for deliveries, arrival time, dwell time and departure time.

3.3.2 Analysis of the Pilot Survey

Specific areas of interest for statistical analysis included:

- Response rate
- Number of deliveries
- Dwell times
- Overview of goods delivered to the campus
- Breakdown of packaging used
- Origins of deliveries (and destinations) (by Dublin code and by DTO zone)
- Breakdown of vehicle types
- Correlations between certain key variables
- Companies making multiple deliveries in the same day

3.3.2.1 Response Rate

Analysis of the survey data produced a number of interesting results. The response rate achieved was 82%. This is considered to be highly satisfactory. The high response rate is attributable to the fact that vehicles must stop at a barrier to obtain clearance from to the campus. This provided an ideal opportunity to carry out the survey.

3.3.2.2 Number of Deliveries

Over the course of the week of the survey, TCD received 687 commercial visits. Of this total, 362 trips to the campus were for the purpose of delivering goods while the remainder are mainly attributable to the provision of services to the college and waste management. The breakdown in trip reasons can be seen in Table 3.1 below.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Delivering Goods	362	52.7	64.3	64.3
	Providing Service	162	23.6	28.8	93.1
	Waste Management	10	1.5	1.8	94.8
	Other	29	4.2	5.2	100.0
	Total	563	82.0	100.0	
Missing	System	124	18.0		
Total		687	100.0		

Table 3.1: Breakdown of Commercial Trips to the TCD Campus

As the survey was carried out from 07:00 to 19:00, this allows trips to be assessed across three distinct time periods – 07:00-11:00, 11:00-15:00 and 15:00 to 19:00. The frequency of deliveries in each time period for each day of the week can be seen in Figure 3.1 below. The time period from 11.00–15.00 emerged as the busiest time period with an average of 38 deliveries being made each day during that time. Thursday and Monday emerged as the busiest days for deliveries to the college with 106 and 91 deliveries respectively. Particularly high levels of deliveries are made between 11:00 and 15:00 on two days, Monday and Thursday, where on average the number of deliveries made increases by 133% compared with the same period on the other days. This is an interesting finding and highlights the variability that can exist in delivery trends. The morning period is the second busiest period with on average 28 deliveries made each day during that period. Delivery frequency declines considerably to an average of 8 in the late afternoon (15:00-19:00).

3.3.2.3 Average Dwell Times for Deliveries

Figure 3.2 below displays the average dwell time per time period for deliveries and it can be observed that mean dwell time was greater during the 7am to 11am period than for the other periods. Overall mean dwell time for deliveries was 23 minutes. Dwell time for commercial service visits on the other hand was 99 minutes.

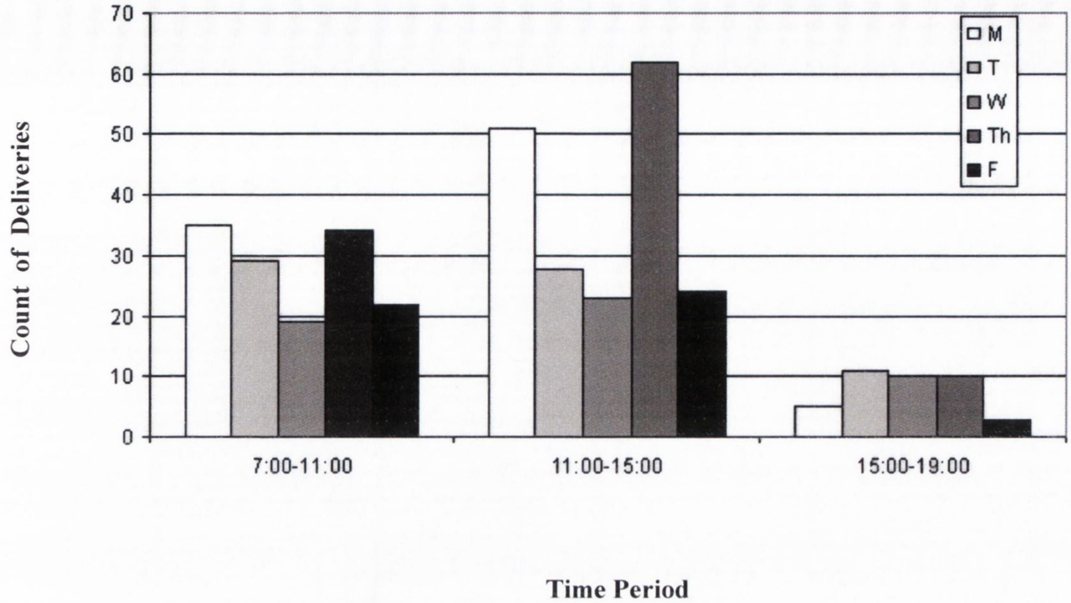


Figure 3.1: Frequency of Deliveries by Time of Day for TCD Survey

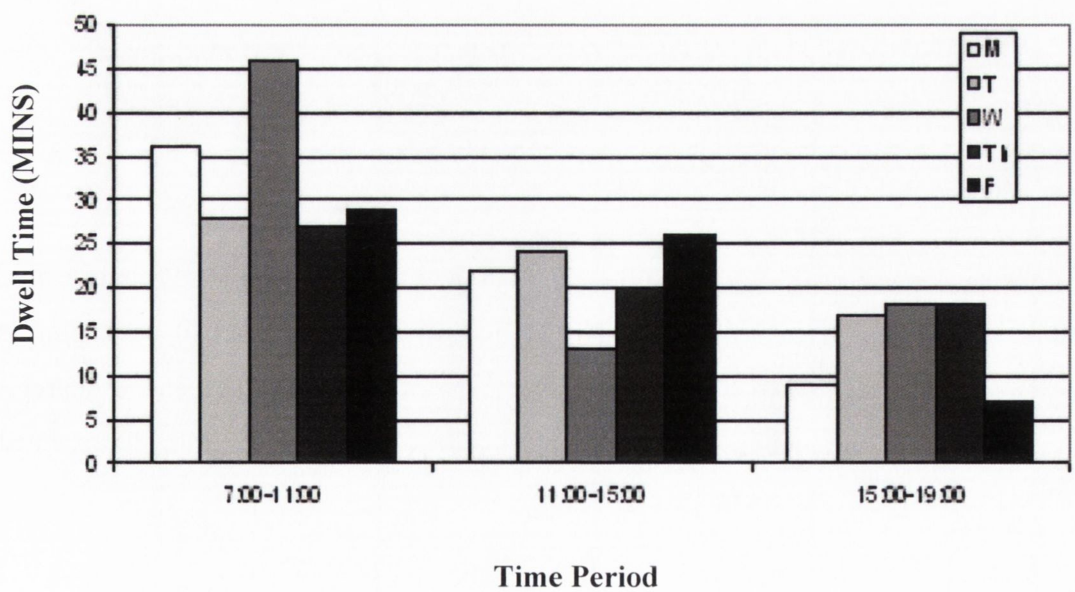


Figure 3.2: Mean Dwell Times by Time of Day for TCD Survey

3.3.2.4 Overview of Goods Delivered to TCD

The types of goods delivered to TCD generally fall into one of seven categories: catering supplies/beverages, laboratory supplies, stationery, construction materials, electrical goods, courier parcels and miscellaneous. The breakdown of the seven categories is provided in Table 3.2 below. Laboratory supplies, catering supplies and stationary are the dominant types of goods delivered to TCD representing 20%, 18% and 17% of the total. Courier parcels and electrical goods account for 19% and 10% of total deliveries respectively. Finally, delivery of construction materials represents 9% of the total. This is attributable to the building work ongoing in various parts of the campus.

		Frequency	Percent
Valid	Catering Supplies/Beverages	64	17.5
	Lab Supplies	72	19.7
	Stationary/Books	61	16.7
	Construction Materials	33	9.0
	Electrical Goods	36	9.9
	Courier Parcels	69	18.9
	Other	28	7.7
	Total	363	99.5
	Missing	2	.5
	Total	365	100.0

Table 3.2: Breakdown of Types of Goods Delivered to TCD Campus

3.3.2.5 Packaging Used in Deliveries

Nine forms of packaging were observed for goods delivered- box, parcel, tray, bag, pallet, drum, letter, carton and loose packaging. The breakdown between types of packaging is viewed in Figure 3.3. A box was the most common type of packaging used (54%). Parcels and loose packaging both accounted for 16 % each of deliveries, while carton represented the smallest proportion with just 1%.

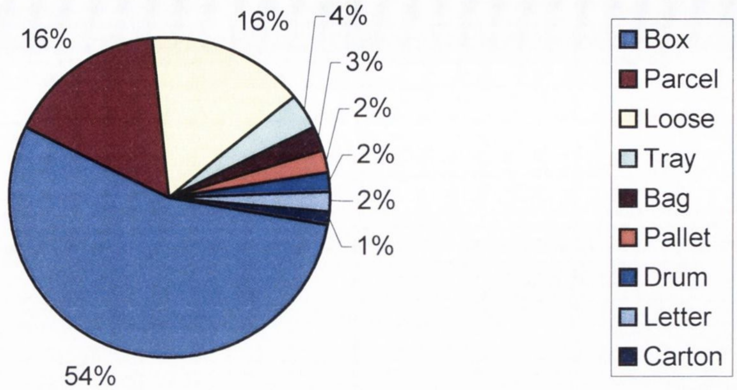


Figure 3.3: Pie Chart Illustrating Frequencies of Types of Packaging Used in TCD Survey

3.3.2.6 Relationships Between Key Variables

Further statistical analysis of packaging involved a correlation exercise. The purpose of this exercise was to measure the relationship between the seven categories of goods and packaging used. The hypothesis tested was that there is a correlation between types of packaging and types of goods. This has relevance in terms of how the goods are transported and delivered. Measures of correlation indicate both the strength and the direction of the relationship between a pair of variables (Bryman and Cramer, 2001). In order to estimate the strength of a relationship, a correlation coefficient is calculated. The most common measure of correlation is "Pearson's Product Moment Correlation Coefficient", also known as Pearson's *r*. Using this measure, a correlation coefficient of -0.126 (indicated in Table 3.3 below) was calculated.

		Category of Goods	Packaging
Category of Goods	Pearson Correlation	1.000	-.126**
	Sig. (2-tailed)	.	.018
	N	363.000	355
Packaging	Pearson Correlation	-.126**	1.000
	Sig. (2-tailed)	.018	.
	N	355	357

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3.3: Correlation Between Type of Good and Packaging

Cohen and Holliday (1982) suggest that a coefficient of 0.19 or below represent a very low correlation. Therefore the null hypothesis (indicating no relationship between the variables) is accepted. This finding highlights the fact that assumptions regarding this relationship are poor indicating that there are high levels of variability across the various categories of goods with regard to types of packaging used.

3.3.2.7 Delivery Origins

Another aspect of the gate survey data of interest is the origin of each delivery. Drivers of delivery vehicles were asked where their delivery trips had started that day and the location of their last delivery drop before visiting TCD. New variables were created in SPSS categorising both types of origin locations according to the Dublin Transportation Office (DTO) coarse zone system. This system has 21 zones, which are aggregated from the 66 zones used in the Dublin Transportation Model, developed and used by the Dublin Transportation Office, the primary transport planning authority in for the Greater Dublin Area. This zoning system was applied in order to provide a structured approach for the classification of areas. Tables 3.4 and 3.5 below provide information regarding the origins of deliveries. Table 3.4 details the zones where delivery trips began at the start of the day Table 3.5 below illustrates the zones visited immediately prior to the TCD delivery drop. Table 3.4, shows that Zone 1 (city centre/within the canal ring) is the source of the greatest proportion of the origins of deliveries (22%). In other words just over one fifth of suppliers are located in the city centre. Zones 6 (includes areas such as Inchicore, Crumlin, Kimmage, Walkinstown and Cherry Orchard.) and 12 (accounts for areas such as Ballyboden, Firhouse, Clondalkin, Ballymount and Tallaght) account for almost 16% and 13% of delivery origins respectively. A number of industrial estates are present in Zones 6 and 12. This may help to explain the popularity of the zones as delivery origins. With regard to zones visited prior to TCD, in approximately 47% of cases, Zone 1 (city centre/within the canal ring) was the last zone visited before delivering to TCD. This suggests that TCD is on regular city centre delivery routes for particular companies. Zones 6 and 14 each accounted for 11% of deliveries immediately prior to TCD. Zone 14 covers areas such as Dun Laoghaire, Dalkey, Blackrock, Stillorgan, Ballinteer, Clonskeagh and Dundrum.

Zone Area	Zone number	Frequency	Percent
City centre (Central Business District)	1	81	22.2%
Dublin Port area	2	12	3.3%
North east city	3	7	1.9%
North west city	4	28	7.7%
South east city	5	5	1.4%
South west city	6	57	15.6%
Fingal west	7	0	0%
Fingal east	8	24	6.6%
Fingal north west	9	0	0.0%
Fingal north east	10	1	0.3%
South Dublin (Lucan, Clondalkin)	11	0	0.0%
South Dublin (Tallaght)	12	48	13.2%
South Dublin (Saggart, Rathcoole)	13	3	0.8%
Dun Laoghaire/Rathdown north	14	38	10.4%
Dun Laoghaire/Rathdown south	15	3	0.8%
Meath	16	6	1.6%
Kildare	17	5	1.4%
West Wicklow	18	0	0.0%
East Wicklow	19	9	2.5%
Louth	20	6	1.6%
Externals	21	9	2.5%
Total		**365**	**100.0%**

Table 3.4: DTO Coarse Zone System: Origin of Deliveries (Where Delivery Rounds Started)

Zone Area	Zone number	Frequency	Percent
City centre (Central Business District)	1	171	46.8%
Dublin Port area	2	8	2.2%
North east city	3	2	0.5%
North west city	4	22	6.0%
South east city	5	5	1.4%
South west city	6	40	11.0%
Fingal west	7	12	3.3%
Fingal east	8	18	4.9%
Fingal north west	9	0	0.0%
Fingal north east	10	1	0.3%
South Dublin (Lucan, Clondalkin)	11	0	0.0%
South Dublin (Tallaght)	12	21	5.8%
South Dublin (Saggart, Rathcoole)	13	2	0.5%
Dun Laoghaire/Rathdown north	14	40	11.0%
Dun Laoghaire/Rathdown south	15	1	0.3%
Meath	16	3	0.8%
Kildare	17	2	0.5%
West Wicklow	18	0	0.0%
East Wicklow	19	5	1.4%
Louth	20	5	1.4%
Externals	21	7	1.9%
Total		**365**	**100.0%**

Table 3.5: DTO Coarse Zone System: Origin of Deliveries Immediately Prior to TCD

Having analysed the proportion of deliveries originating in the various DTO zones, a statistical correlation exercise was then carried out. The purpose of this exercise was to test the hypothesis that if the supplier's base is in zone 1, then the stop before TCD is more likely to be in zone 1. Using the Pearson's measure, a correlation coefficient of 0.458 (indicated in Table 3.6 below) was calculated. This figure constitutes a significant correlation in SPSS and therefore the null hypothesis is rejected. Cohen and Holliday (1982) suggest that a correlation coefficient in the range of 0.40 and 0.69 is considered modest. This modest correlation suggests that for suppliers located in the city centre, delivery routes are focused primarily in the city centre.

		Zone at Start of Trip	Zone Prior to TCD
Zone at Start of Trip	Pearson Correlation	1.000	.458**
	Sig. (2-tailed)		.003
	N	364.000	364
Zone Prior to TCD	Pearson Correlation	.458**	1.000
	Sig. (2-tailed)	.003	
	N	364	365.000

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3.6: Correlation Between DTO Zone at Start and DTO Zone Visited Prior to TCD

3.3.2.8 Types of Vehicles Used for Deliveries to TCD

A breakdown of vehicle types revealed that 69% of deliveries were made using vans. Trucks accounted for 17% of the total while car and motorcycle deliveries constituted 11% and 3% respectively. In relation to service trips to the campus, vans again were used in the majority of cases - 62%. The predominance of vans as delivery vehicles in the survey was duly noted and therefore constituted a trend to be aware of during the wider survey.

3.3.2.9 Multiple Deliveries to the Campus

One further trend observed in the data from the survey, and of particular interest, was that certain companies made multiple deliveries on the same day. This trend reflects a demand for 'just in time' products and also suggests that there is a lack of a co-ordinated delivery system on the part of the supplier. From the survey data, it was ascertained that over the course of the week of the survey, 13 companies made multiple deliveries on the same day.

In total 18 incidences of multiple deliveries by the same company on the same day were uncovered. Ten of these thirteen companies were courier companies. Overall, the pilot study and its subsequent analysis were useful exercises in highlighting important issues to be aware of during the survey of city centre businesses. The pilot survey also constituted an interesting case study of the nature of deliveries to a city centre campus environment.

3.4 OVERALL CITY CENTRE DELIVERY SURVEY

3.4.1 Design of the Survey Form

Following completion of the TCD delivery survey, the next step was to design an appropriate survey form for the wider survey. Due to the precise nature of the data requirements, especially in relation to the quantities involved, it was decided to request self-completion delivery logs for the businesses surveyed. It was considered that a written report of a business's deliveries would provide a more accurate reflection of delivery patterns than a face-to-face interview. However, having analysed the data requirements from the survey, it became clear that completing the survey form was likely to be a rather onerous task for participants. Therefore, it was important to construct the form in a manner that would minimise the burden as much as possible. The structure of a number of other similar questionnaires was examined including (Allen et. al, 2000) This survey form was of particular interest because it was used in a research project carried out by the Transport Studies Group, Westminster and funded by the EPSRC as part of the Sustainable Cities Programme. As can be seen from Appendix A, the form is designed in a diary format with columns allocated for nine categories of delivery information:

- Time of delivery arrival
- Time of delivery departure
- Type of goods
- How packaged
- Quantity of packages
- Type of delivery vehicle
- Who supplied the goods
- Location of supplier
- Where loading/unloading takes place
- Vehicle Type

The format of the survey form ensured that respondents were only required to provide short answers for each of the nine categories. For example, in the categories for time of delivery arrival and departure, respondents simply write in the appropriate times. This information allows calculations to be made regarding dwell time of a delivery. In relation to the category for "Type of Vehicle Used", four options were highlighted for respondents- truck, van, car and motorbike.

Ideally, it would be desirable to request businesses to complete the delivery diaries for an entire week. Unfortunately this would demand even greater effort on the part of respondents. The Dublin City Centre Business Association, which has considerable experience with surveying its members emphasised the high levels of survey fatigue currently present amongst city centre businesses. Conscious of this fact, it was decided to use the survey forms to ascertain a "typical" delivery day for each business surveyed, rather than requesting a full week's delivery information. In order to gauge delivery patterns for a typical day, respondents were requested to answer three additional questions appended to the survey form. These questions related to whether the number of deliveries received was typical for an average day. If the day's deliveries were not typical, respondents were asked to quantify within a certain range, by how much the deliveries were not typical. In other words, the number of deliveries more or less than on a typical day was ascertained.

The section of the survey dealing with loading facility information provides useful data on two levels, each of which relate to traffic management. Firstly, results provide statistics regarding the percentage of deliveries in the survey using loading bays or on-street parking. Secondly, since the time of delivery arrival and departure is captured in the survey, it is possible to provide a time profile for deliveries to city centre organisations surveyed.

3.4.2 Postal Surveys

Having designed the survey form and carried out the pilot study in TCD, the next step was to decide on a method of canvassing businesses to complete the survey. From initial consultations with trade associations, it became clear that the DCCBA represents a wide range of business sectors in the city centre including retail, property, financial, catering and tourism, and other general services. Its members constitute the major commercial interests and retailers in the Dublin City Area. Therefore, it was decided as a starting point in the survey to avail of the association's mailing list of members. This list of 150 includes businesses with multiple outlets. The total number of DCCBA businesses that received the survey was 175.

In order to elicit goodwill from the businesses surveyed, a letter of support from DCCBA Chief Executive was enclosed along with the survey. The letter of support also stated that businesses that participated in the survey would receive a summary of survey results. It was hoped feedback on the current situation regarding deliveries in the city would encourage participation in the survey.In total, 21 survey forms were returned from the DCCBA survey. This figure represents a survey response rate of 12%. This response rate is typical for surveys of this kind.

With membership of over 700, many of which are located in the city centre, the Licensed Vintners Association (LVA) provided an opportunity to survey the delivery patterns of pubs within the city centre. Of the total membership, approximately 25% are located in the Dublin 1 and 2 areas, with 4% and 7% located in Dublin 7 and 8. These areas comprise the core parts of Dublin City Centre. For the purposes of the postal survey, 73 survey forms (approximately 10% of total membership) were posted out to LVA members. Members were selected on the basis of their location in Dublin City Centre. 50 surveys were sent to pub addresses in Dublin 1 and 2 and the remaining 23 were sent to businesses in Dublin 7, 8 and 4 which lie within the canal boundaries. In order to boost response rates, once the surveys had been posted out, follow up telephone calls were made to half of the pubs surveyed to further encourage participation in the survey. Similar to the DCCBA survey, a letter of support from the Chief Executive of the LVA was enclosed and feedback on the overall survey was promised to participants. Following the LVA canvas, 16 responses were received from pubs– 12 from Dublin 1 and 2, two from Dublin 7 and one each from Dublin 4 and 8. This amounted to a response rate of almost 22%, which is again typical for this type of survey.

Next, RGDATA and RAI association members were targeted for the postal survey to allow inclusion of newsagent shops and restaurants in the survey. Disappointingly, response rates for each of these surveys did not exceed 5%, despite letters of support from both associations. Overall in the postal survey, 500 businesses received delivery survey forms. The aggregated response rate from these businesses was approximately 10%.

3.4.3 Street Survey Approach

In light of the response rate to the postal surveys, it was decided to take a more hands-on approach to distributing the surveys amongst city centre businesses in order to improve survey response. This approach involved a focus on predetermined streets in Dublin 1 and 2, listed below and highlighted in Figure 3.4.

- Dawson Street
- Nassau Street
- Grafton Street
- Suffolk Street
- Dame Street
- Kildare Street
- Westmoreland Street
- Aston Quay
- Wellington Quay
- Ormond Quay
- Bachelors Walk
- Middle/Lower Abbey Street
- Henry Street

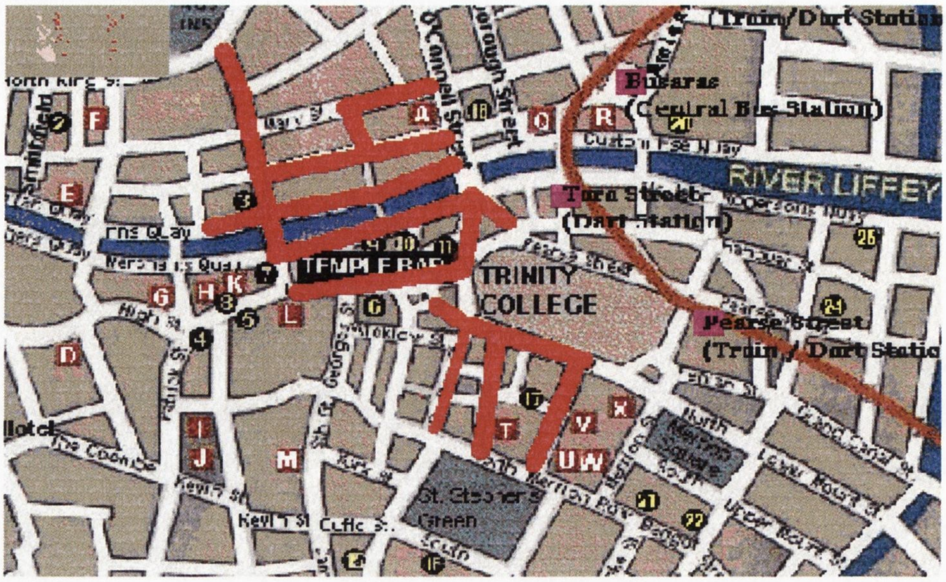


Figure 3.4: Map Highlighting Streets Surveyed

Survey forms were personally distributed to business premises along these streets. Visits to businesses were made and delivery managers and shop personnel were briefed regarding the purpose of the survey, its potential relevance to city centre businesses. The immediacy of the situation and the assurance that the survey would not take too long encouraged a positive response from businesses. In a number of cases, it was necessary to call into locations several times to obtain the completed survey form.

This approach was also helpful from the perspective that useful feedback and comments made by personnel in the shops surveyed were noted along with the data that was collected. Comments made related to companies' reactions to the restrictions currently in place for delivery times. Also, a number of comments focused on the amount of loading-bays available in the city. Numerous shops on Nassau Street pointed to the fact that deliveries are often forced to park on-street due to the fact that loading bays are often occupied. Furthermore, it was discovered that deliveries to pharmacies are hampered to an even greater extent than other businesses when there is no loading bay available and delivery vehicles are forced to park a distance away from the premises. This is because of the high security risk involved in transporting pharmaceutical goods.

In terms of public entities, five government departments were surveyed. The government departments were: Department of the Environment, Heritage and Local Government, Department of Agriculture and Food, Department of Education and Science, Department of Health and Children and the Houses of the Oireachtas. Due to the high levels of co-operation in the public sector departments, comprehensive delivery diaries for a week were obtained.

It is considered that the contacts made in the various trade associations proved to be helpful in forging goodwill among businesses towards the survey. Letters of support from the trade associations provided enhanced credibility to the survey, especially for the street survey approach. This approach, although time consuming, (sometimes three or four visits to businesses are required) proved itself to be the most effective means of encouraging participation in the survey.

3.4.4 Quality of Feedback From the Surveys

In general, returned survey forms from private companies provide good quality delivery information. Out of all the surveys returned, only three were completely void- these forms had not been completed at all. In a very small number of cases, the name of the supplier was provided but not the supplier's address. This was easily resolved using the telephone directory and double-checking with the business once the address was found. In other cases, the individual completing the survey form was absent for either delivery arrival or departure and consequently was unable to fill in both times. Once again, this was generally resolved by contacting the business in question to further clarify delivery times. Contact details of the author were stated on the delivery form itself. In four cases, telephone calls were received from survey participants with queries regarding aspects of the survey. These queries were quickly resolved. Otherwise, survey forms were completed in a satisfactory manner and contain the required delivery information.

3.5 RESULTS OF THE OVERALL BUSINESS SURVEY

3.5.1 Frequency of Deliveries

In total the survey captured 906 individual deliveries from 125 organisations. Businesses were categorised into 12 distinct categories. The breakdown of the number of deliveries to each category can be viewed below in Table 3.7. Deliveries to retail organisations comprised 20% of all deliveries. Restaurant/food retail related deliveries and pub deliveries accounted for approximately 14% each. Deliveries to hotels and department stores accounted for 11% and 9% of total deliveries respectively.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Department Store	80	8.8	8.8	8.8
	Restaurant/Food Retail	127	14.0	14.0	22.8
	Pub	123	13.6	13.6	36.4
	Hotel	95	10.5	10.5	46.9
	Convenience Store	37	4.1	4.1	51.0
	Newsagency	58	6.4	6.4	57.4
	Retail (clothing)	36	4.0	4.0	61.4
	Retail (Other goods)	185	20.4	20.4	81.8
	Financial Instit/Office	68	7.5	7.5	89.3
	pharmacy	41	4.5	4.5	93.8
	Supermarket	26	2.9	2.9	96.7
	Shopping Centre	30	3.3	3.3	100.0
	Total	906	100.0	100.0	

Table 3.7: Breakdown of the Number of Deliveries to each Business Classification

Frequency of deliveries is analysed firstly according to time of day. Figure 3.5 shows the number of deliveries arriving each hour. The busiest period for deliveries occurs between 9am and 12pm. The number of deliveries peaks between 10-11am with 16% of the total arriving during this time. Only 2% of deliveries occurred between 17:00 and 23:00.

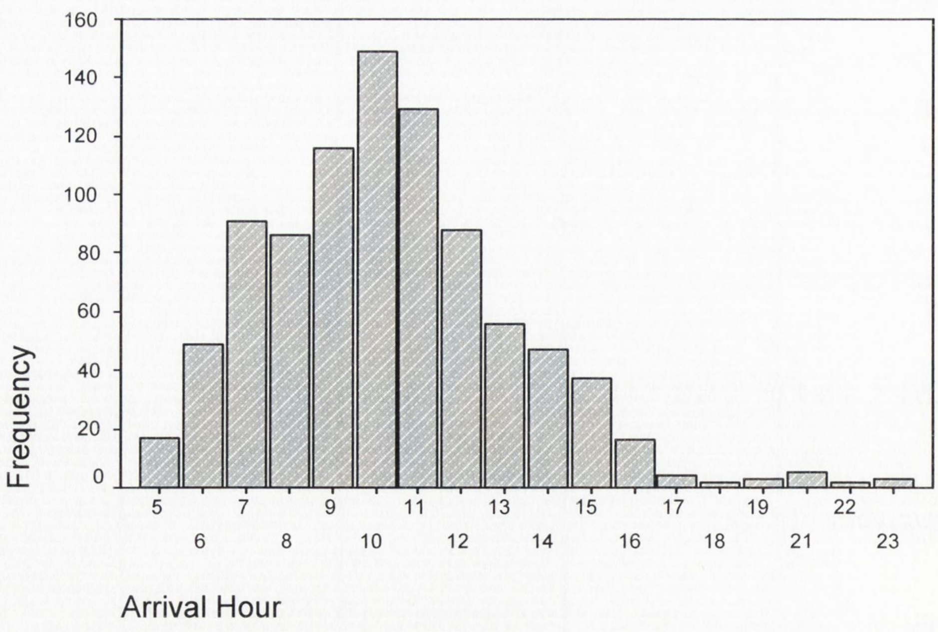


Figure 3.5: Frequency of deliveries arriving each hour

Deliveries were also analysed in terms of the delivery arrival time according to category of good delivered. Table 3.8 below sets out average arrival times for different classes of goods. Food/Catering type goods tend to arrive approximately two hours earlier than other categories of goods. Alcoholic beverages arrive between 10:00 and 11:00 and Electrical goods, clothing, household goods, pharmaceutical products and other miscellaneous goods arrive between 11:00 and 12:00. Stationery and books arrive on average after midday

arrtime

Goods Category	Mean	N
food/catering ...	09:18 o'clock	342
Electrical Goods	11:52 o'clock	29
Clothing/Shoes	11:17 o'clock	80
Household ...	11:39 o'clock	96
Stationary/Books/...	12:20 o'clock	89
pharamaceutical/c...	11:19 o'clock	47
Post/Parcels	12:34 o'clock	23
Miscellaneous retail	11:45 o'clock	67
Alcoholic Bevs	10:43 o'clock	124
Total	10:41 o'clock	897

Table 3.8: Average Arrival Time of Various Goods Categories

3.5.2 Types of Vehicles Used and Average Number of Miles Travelled

With regard to the nature of delivery vehicle usage, it was found that vans were the most prevalent type of vehicle used, accounting for approximately 55% of all deliveries. Trucks accounted for 40% of the total, while cars and motorcycles only accounted for 6%. The number of trucks captured in the survey (354 in total) is a cause for concern from an accessibility perspective and also from an environmental perspective. It highlights the need for more novel delivery solutions for Dublin to minimise the effects of large vehicles on the streets of the city. The average number of miles travelled from supplier to business destination was calculated as 13.65. However, this varies from business to business, for example the average distance in miles for deliveries to pharmaceutical businesses, restaurants and bars was 10.39, 18.45 and 9.39 respectively.

3.5.3 Average Dwell Time for Deliveries

The average dwell time for deliveries was 14 minutes (in the pilot survey the average dwell time was 23 minutes). This varies across different business types, for example deliveries to clothing retail stores were found to have an average dwell time of approximately 26 minutes, department store deliveries had an average dwell time of approximately 16 minutes and offices/financial institutions had an average dwell time of just 7 minutes.

3.5.4 Loading Arrangements for Deliveries

Loading arrangements for deliveries are a further area of interest during the statistical evaluation. 49% of deliveries used on-street parking for unloading goods. Dedicated loading bays (loading facilities operated by the company receiving the delivery) were used for 39% of deliveries, while shared loading bays (loading facilities designated by the city authorities) were used for the remaining 12% of cases. It was observed that 39% of trucks parked on street for deliveries. This trend has implications for city centre accessibility.

A test was also carried out to evaluate the variation in dwell times for different types of loading arrangements. Table 3.9 below displays average dwell times for different loading arrangements. On-street loading bays and shared loading bays have similar average dwell times with approximately 12 minutes and 13 minutes respectively. Dedicated loading bays have a longer average dwell time of almost 18 minutes.

dwell

loading	Mean	N	Std. Deviation
on-street parking	12.27	431	10.984
shared loading bay	12.77	105	11.796
dedicated loading bay	17.62	333	30.425
other	25.00	5	28.504
Total	14.44	874	20.950

Table 3.9: Average Dwell Times For Different Loading Arrangements

3.5.5 Delivery Origins

In addition to the analysis of deliveries by time of day, deliveries were also analysed according to the geographical area from which they originated. Delivery origin locations were categorised again according to the Dublin Transportation Office (DTO) coarse zone transport modelling system, which contains 21 zones. Table 3.10 shows that the top six delivery generating areas are the south west of the city (zone 6), the city centre (zone 1), outside of Ireland, the north west of the city (zone 4) and outside of the Greater Dublin Area (GDA) (GDA includes the counties of Dublin, Kildare, Louth, Meath and Wicklow). For the purposes of comparison it is useful to note that in the pilot feasibility survey the top six delivery generating zones were Zone 1, Zone 4, Zone 6, Zone 8, Zone 12 and Zone 14. Therefore Zones 1, 6 and 12 are common to both the pilot survey and the overall business survey indicating a strong level of business activity in these are

Zone Area	Zone number	Frequency	Percent
City centre (Central Business District)	1	159	17.5
Dublin Port area	2	8	0.9
North east city	3	15	1.7
North west city	4	62	6.8
South east city	5	10	1.1
South west city	6	185	20.4
Fingal west	7	20	2.2
Fingal east	8	34	3.8
Fingal north west	9	7	0.8
Fingal north east	10	0	0
South Dublin (Lucan, Clondalkin)	11	17	1.9
South Dublin (Tallaght)	12	95	10.5
South Dublin (Saggart, Rathcoole)	13	8	0.9
Dun Laoghaire/Rathdown north	14	44	4.9
Dun Laoghaire/Rathdown south	15	4	0.4
Meath	16	10	1.1
Kildare	17	16	1.8
West Wicklow	18	1	0.1
East Wicklow	19	13	1.4
Louth	20	8	0.9
Externals	21	62	6.7
Outside Ireland		114	12.6
Undefined		14	1.5
Total		**906**	**100**

Table 3.10: DTO Coarse Zone System: Origin of Deliveries

Having analysed the frequency of deliveries from zones, the next step in the survey analysis was to examine whether certain categories of goods could be linked to certain zones. Table 3.11 below shows the proportion of goods originating in the six high delivery-generating zones. Although food/beverages feature strongly in all of the zones, there are a number of instances of other goods categories that are prominent in particular zones. These include:

- Alcohol in zones 1, 6 and 21
- Pharmaceuticals/Cosmetics in zone 12
- Stationery/Books/Newspapers in all six zones
- Household/Hardware Goods in zone 21 and outside Ireland
- Clothing/Shoes in zone 21 and outside Ireland

	Zone 1	Zone 4	Zone 6
Food/Beverages/General Catering Supplies	31%	47%	46%
Electrical Goods	.05%	6%	4%
Clothing/Shoes	6%	5%	4%
Household/Hardware Goods	6%	6%	7%
Stationery/Books/Newspapers	7%	13%	8%
Pharmaceutical Goods/Cosmetics	2.5%	11%	5%
Alcoholic Beverages	28%	5%	19%
Post/Parcels	8%	2%	2%
Miscellaneous Retail	11%	5%	5%
	Zone 12	**Zone 21**	**Outside Ireland**
Food/Beverages/General Catering Supplies	47%	26%	12%
Electrical Goods	0%	0.5%	7%
Clothing/Shoes	2%	18%	31%
Household/Hardware Goods	5%	21%	19%
Stationery/Books/Newspapers	10%	10%	18%
Pharmaceutical Goods/Cosmetics	20%	2%	3%
Alcoholic Beverages	13%	16%	2%
Post/Parcels	0%	0.5%	1%
Miscellaneous Retail	3%	6%	7%

Table 3.11 Breakdown of Types of Goods Originating from High Delivery Generating Zones

3.5.6 Packaging Used In Deliveries

In terms of the packaging used for deliveries, boxes were found to be the most common type of packaging used (53%). In approximately 10% of cases, no packaging was used and the goods were delivered loose. Pallets were used in a further 10% of cases, while parcels, kegs and cartons accounted for 7%, 6% and 6% respectively. Various other forms of packaging were used in the remainder of deliveries. A pie chart illustrating the breakdown of the type of packaging used can be seen below in Figure 3.6.

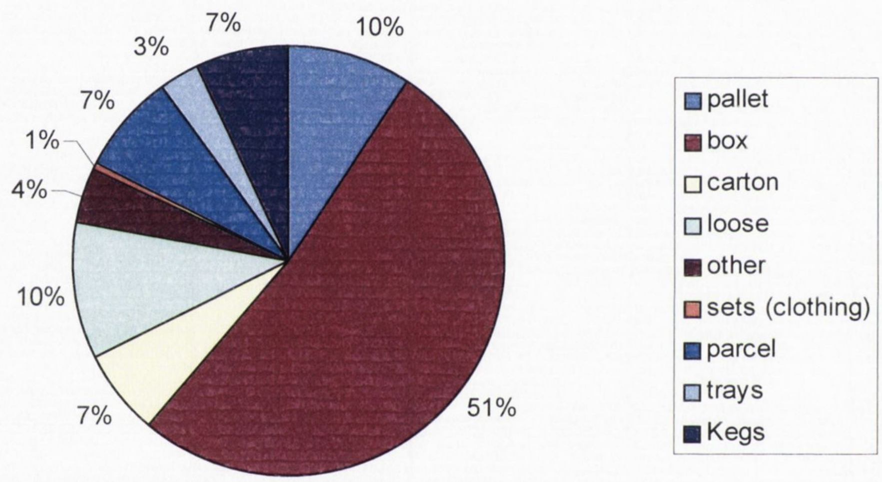


Figure 3.6: Pie Chart Illustrating Frequencies of Types of Packaging Used

Earlier analysis of the packaging used in the pilot survey indicated a correlation coefficient of –0.126 between the type of packaging and the type of goods. This coefficient indicated a very weak relationship between the two variables. When the same correlation exercise was carried out for the overall survey (again using Pearson's Correlation Coefficient as a measurement), a correlation coefficient of 0.224 was obtained. Although still a relatively low figure, it points to a very mild relationship between the variables. The coefficient of determination (COD) is an indication of how far variation in one variable is accounted for by the other variable. In the case of the overall survey, a coefficient of determination of 5% was obtained. In the pilot survey the COD was only 1.5%. The relevancy of the packaging used lies in the consolidation opportunities possible and the choice of vehicles used to transport the goods from the centre to the city centre. Materials handling techniques such as shrink-wrapping and palletization have the potential to improve delivery operations because goods can be consolidated into larger shipping units (Ogden, 1992).

3.5.7 Relationships Between Key Variables

In order to establish if deliveries to certain types of businesses occur at particular times, another correlation exercise was carried out examining the relationship between delivery arrival times and categories of business. It was found that only a very low correlation of 0.104 exists between the two variables. This suggests that at best, only a mild relationship exists between the arrival time of delivery vehicles and the type of businesses that they deliver to at that particular time. In other words, in general the category of business concerned does not appear to dictate the arrival times of deliveries to any significant extent. However upon further analysis of the relationships between arrival time and business category for various streets, some interesting findings were noted. Firstly, a modest correlation of 0.335 was found between arrival time and business categories for deliveries to Ormond Quay, Wellington Quay, Bachelor's Walk and Aston Quay (all located along the quays o Dublin's main River, the Liffey in the city centre). Secondly, on the south of the city (Dame Street, Nassau Street, Dawson Street and Kildare Street) a correlation of 0.280 was found. These findings suggest that correlations are more likely to be found at a localised street level than throughout the city centre. This highlights the variable nature of delivery patterns to Dublin City Centre. It also emphasises the influence that the location of a business on a particular street can have on delivery times. This is something that is reinforced by anecdotal evidence from discussions with suppliers. One particular food and groceries supplier highlighted the fact that certain delivery runs were determined to a large extent by the timing of city centre deliveries, which occurred at a particular time of the day.

Another area of interest for statistical evaluation is the relationship between the delivery arrival time and category of good delivered. A correlation figure of 0.249 was found to exist between the two variables. This mild correlation may help to explain to a certain extent peak delivery hours for certain type of goods. The greatest proportion of food deliveries (over 19%) arrived between 7:00 and 8:00. Furthermore, the greatest proportion of post and parcel arrived between 10:00 and 11:00 and between 11:00 and 12:00 (17% in each case). Peak delivery hour for household goods/hardware occurred between 11:00 and 12:00 when 17% of the total of goods for the category arrived.

3.6 DISCUSSION

Both the pilot survey and the overall business survey proved valuable in terms of providing qualitative and quantitative information on current trends of urban freight distribution in Dublin City Centre. The pilot survey of deliveries to Trinity College Dublin was useful as a trial run of the later survey. It also served to highlight the extent and nature of deliveries to a large and essentially non-commercial environment.

The main obstacle of the overall city centre survey proved to be the low response rate inherent in surveys of this kind. Postal surveys were helpful to an extent, however it was found that personally delivering survey forms to businesses and collecting them was the most effective survey approach. Although time consuming, this approach helped to ensure direct feedback on various freight issues from the businesses concerned. Common anecdotes heard from the businesses included issues such as the illegal occupancy of loading bays.

Analysis regarding high delivery generating zones identified the south west of the city, the north west of the city, South Dublin and the city centre as areas that generate high numbers of deliveries. Furthermore, a significant amount of deliveries were found to originate outside of the country (almost 13%). The category of food and beverages featured prominently in all of the high delivery generating zones, emphasising the importance of the role of these goods in the general commercial life of the city. Another issue of general interest highlighted in the analysis of survey data was the use of specialised loading bays for deliveries. From the data, it was observed that 39% of deliveries made by trucks parked on-street. Given that the average dwell time for trucks was found to be greater than 22 minutes, (compared to approximately 10 minutes for vans and 9 minutes for cars) this clearly has implications for city centre accessibility both for pedestrians and for traffic in general.

Overall, the organisational survey described in this chapter:

1. represents the first substantive piece of primary research on urban freight in the city centre area;
2. addresses the gap in knowledge regarding deliveries to the city centre, particularly at a micro-level

3. provides data for this thesis and an input into the scenarios developed in Chapter 6
4. offers a basis for future urban freight research and planning by local authorities.

CHAPTER 4: HGV MANAGEMENT STRATEGY: A COMPREHENSIVE ASSESSMENT

4.1 INTRODUCTION

The issue of managing freight traffic in an urban centre presents a number of challenges for local authorities in terms of balancing economic and social objectives. Freight vehicles in urban areas generate high societal costs by producing pollution and noise (Taniguchi et al, 2003). An OECD report detailing challenges to urban goods transport (OECD, 2003) points to the fact that although trucks account for only 10 percent of all transport operations in urban areas, they produce over 40 percent of the pollution and noise caused by local traffic. It is within this context of minimising the impacts of HGVs on the streets of this city centre that the Dublin Port Tunnel (DPT) and associated HGV Management Strategy were developed. This two-tiered approach represents a particularly innovative initiative for managing HGVs in an urban context. The DPT represents the infrastructure implemented to entice HGVs from urban streets into a direct motorway connection to and from Dublin Port. The HGV Management Strategy represents the control mechanism used to optimise the usage of the DPT while simultaneously managing how deliveries to the city centre using large HGVs are made.

This chapter describes the HGV Management Strategy, provides a comprehensive statistical analysis of the data obtained from the permit system, assesses the implications of the two-tiered approach on the affected cordon area (both for HGVs and for non-HGVs), and analyses the long-term viability of the Strategy from a cost perspective. The chapter outlines in detail how data from a number of sources was collated in order to firstly, provide a statistical picture of the HGV Management Strategy and secondly, provide a traffic context to these statistical results and findings.

4.2 MANAGING HGVS IN DUBLIN

HGVs are managed in Dublin via the Dublin Port Tunnel and the HGV Management Strategy. The Permit System is a key part of the Strategy.

4.2.1 Dublin Port Tunnel

The Dublin Port Tunnel (DPT) is the largest and most complicated piece of transport infrastructure ever constructed in Ireland and took over five years to complete. The chief purpose of the DPT is to remove as far as possible, port-related Heavy Goods Vehicles (HGVs) from the heart of the city centre by providing a direct link between Dublin Port and the national road network via the M50 (C-Ring motorway). The need to improve access to Dublin Port became more vital as the tonnage processed through the port increased on a annual basis. In 1994, total tonnage of Dublin Port was 9.5 tonnes. In 2006, this figure had risen to 29 million tonnes (Finnegan, O'Brien, Bolger, 2008) reflecting the increasing importance of the port as a focal point for national freight.

The DPT consists of two separate tunnels each containing a two-lane motorway quality road that allows access to the M50 from Dublin Port in approximately six minutes. The provision of the tunnel was expected to dramatically reduce the number of HGVs visible on the city's street network. However, it was recognised at an early stage that the impact of the DPT was dependent on the fact that HGVs will only use the tunnel if it provides a quicker, more direct route between the port and the destination. As a result, the HGV Management Strategy was developed by Dublin City Council in order to ensure optimal use of the DPT by large goods vehicles. The strategy was also driven by a need to clarify procedures for situations where HGV trips either do not use the tunnel (city centre deliveries), or cannot use the tunnel (overheight vehicles). The tunnel was constructed with a physical height clearance of 4.9 metres but operates at a limit of 4.65 metres to protect against loose loads or flapping tarpaulins. The tunnel height has been the subject of much media discussion, largely due to the fact that it does not accommodate super-cube trucks. However, the tunnel height is firmly in line with European tunnels, where heights generally range from 4.3 metres to 4.75 metres.

The DPT coupled with the HGV Management Strategy represents an innovative approach by a local authority to manage the on-street impact of HGVs in the city centre while simultaneously improving infrastructure for the haulage industry in general.

4.2.2 HGV Management Strategy

The concept of a HGV Management Strategy for Dublin City was originally proposed as part of the Dublin Transportation Initiative (DTI). The DTI was the integrated transport strategy for the Greater Dublin Area, which was adopted as Government Policy in 1994. The DTI report (DTI, 1994) recommended the construction of a tunnel link from the C-Ring motorway to Dublin Port and also the implementation of a set of HGV restrictions to ensure maximum use of the DPT by HGV traffic. Prior to the opening of the DPT, a limited range of HGV access restrictions were implemented by Dublin City Council and consisted of three tonne limits and access restrictions on various roads in the city. However, in general, HGVs had unrestricted access to the main roads within the city, particularly within the city centre. As a result, there were repercussions in terms of the environment, traffic conditions and quality of life for those living and working in the City Centre area. There is a direct relationship between the percentage of HGVs within a given traffic stream and the level of particulates (PM10) measured at the street level. Furthermore, during a two and half year period between October 2003 and April 2006, it was estimated by An Garda Siochana (Irish Police Force) that 16 fatal traffic accidents occurred in the City Centre involving HGVs, resulting in 19 fatalities (Finnegan, et al., 2007). The process of implementing the HGV Management Strategy commenced with a number of evaluation documents. A draft report on the strategy was prepared in 2004. (Delcan, 2004). This report was subject to public consultation and as a result the following recommendations were adopted by the full City Council in 2004:

- the HGV Management Strategy should be based on a cordon area with vehicles over a certain axle count excluded. A map of the affected cordon area can be seen below in Figure 4.1
- the hours of operation should be 07:00-19:00, Monday to Sunday
- the excluded vehicles should be those with five or more axles, this restriction to be extended to 4 axles on phased basis
- a restricted permit scheme should be introduced for certain delivery types within the cordon area
- dialogue should commence with the Department of Transport regarding necessary legislation

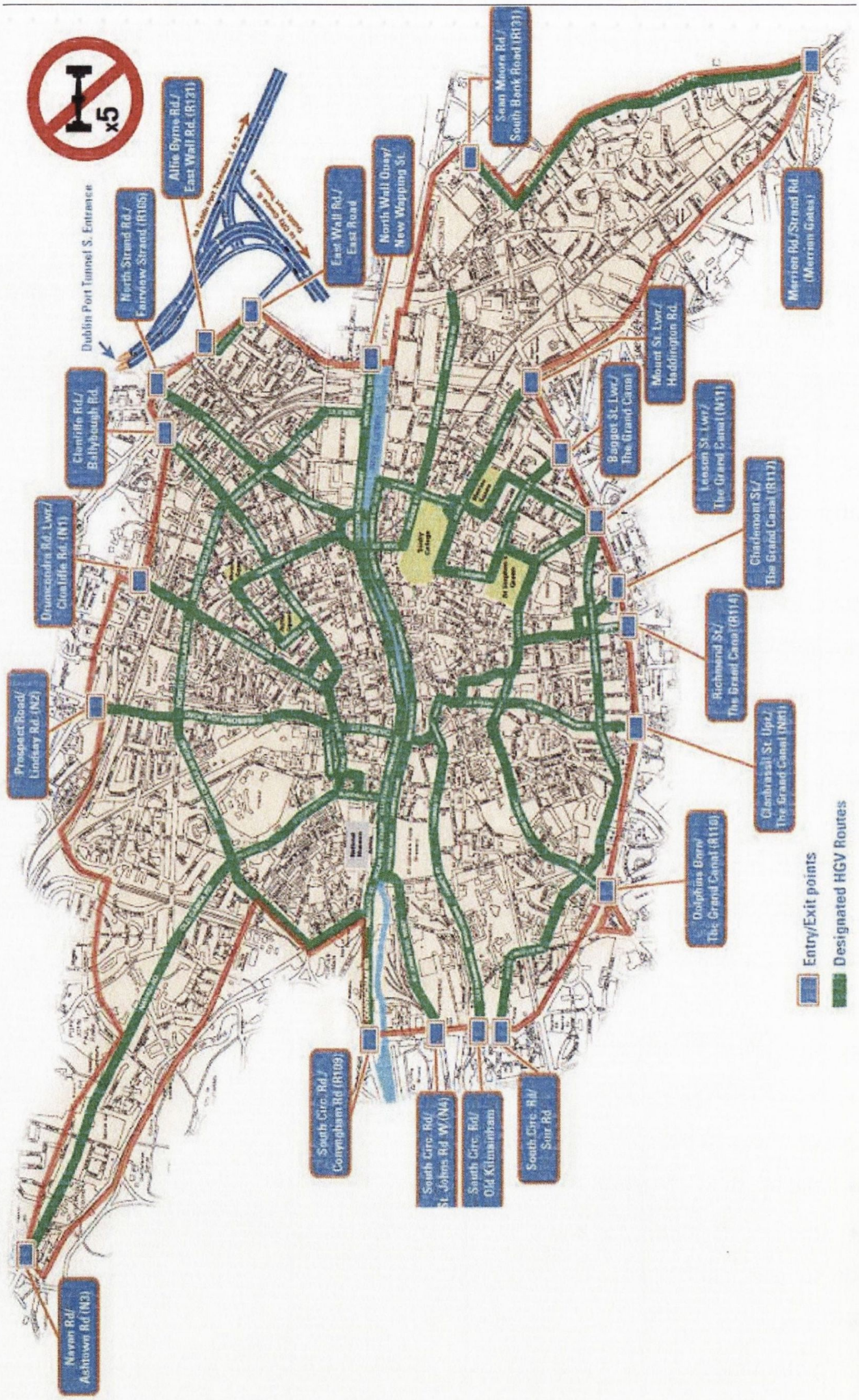


Figure 4.1: HGV Cordon Area

An important element of the HGV Management Strategy is the use of an axle number ban rather than a weight or environmental rating. This was decided upon for two key reasons:

1. Difficulties associated with the enforcement of weight based schemes
2. The visual advantages of the scheme; it is very clear to both public and enforcement agencies if a truck is included or excluded from the ban.

The 5 + axle was chosen as over 65% of HGVs using the port fell into this category (Dublin City Council, 2006). The objectives of the HGV Management Strategy as outlined in a report to councillors (Dublin City Council, 2006) were:

- to maximise the use of the DPT and minimise the use of the city streets by HGVs travelling to/from Dublin Port
- to mimimise the conflicts between delivery and service requirements of businesses and the needs of all other road users
- to manage for a limited period on the city's streets, the small number of over-height HGVs unable to use the DPT
- to manage diverted HGVs under partial or full DPT closure conditions
- to operate a rebate scheme for hauliers forced to use the East Link Toll Bridge

The need for a cordon is based on the fact that the tunnel is a North-South link to the port which significantly benefits any traffic using the north West quadrant approaches to the city (approximately 53% of all port traffic), however approaches to the port from the West and particularly the South would not experience a shorter journey time using the Dublin Port Tunnel and in fact have their journeys lengthened. (Finnegan et al, 2008). Another important consideration was the presence of a toll bridge in the centre of the Dublin ring motorway which meant that trucks that previously could access the Port without using this facility would now be forced to do so or to change to night-time access or make extensive diversions.

Having produced a number of reports on the HGV Strategy and carried out a full public consultation process, Dublin City Council recognised that even if HGV utilisation of the DPT is optimised, there would still be a need to manage residual HGV traffic. This included those vehicles undertaking deliveries in the cordon area and also for a limited period certain over height vehicles that cannot be accommodated by the DPT. A significant number of premises within the city centre use 5/5+ axle vehicles to load or unload within the cordon area and could not be expected to suddenly change to night-time operation or move to other types of vehicles. This meant that some form of permit system was required to facilitate these commercial activities while at the same time ensuring that the system was not open to misuse.

The HGV Strategy as agreed by the City Council in April 2006 put in place a closed cordon around both the north and south port areas. This has the impact that hauliers moving between the two parts of the port would have to pay a toll during the hours of operation of the HGV strategy, as there would be no alternative route available to them. The Eastlink toll rebate scheme was therefore introduced to mitigate the financial impacts of this additional charge for hauliers. The scheme operates as a refund system where an affected haulier pays the toll as normal and is then entitled to claim a rebate on this toll upon the production of evidence of the time and date of the bridge crossing and the type of vehicle used. As part of this scheme, the current owners of the toll, National Toll Roads (NTR) provide a special report for hauliers of their usage of the Eastlink toll facility during cordon hours. This report is then presented to Dublin City Council as evidence of the trip. The scheme requires companies wishing to claim a rebate to register and provide a tax clearance certificate as well as company details. In total from May 2007 to September 2009, €1,567,405 has been paid out in toll rebates by the Council.

4.2.3 HGV Permit System

The permit system forms the cornerstone of the overall HGV Management Strategy and was introduced to cater for the residual HGV traffic unable to use the DPT. As a general principle, the strategy prohibits 5 axle vehicles or greater from entering the city cordon between 07:00-19:00 daily. Any vehicle with five or more axles seeking to enter the city cordon within these hours must apply for a permit.

A number of operational and technical issues were assessed during the preliminary design stage of the permit system. Originally a yearly or monthly permit was considered where vehicles would be issued with permit discs and applications would be made in advance either by post or in person. However, this did not meet the requirements of the haulage industry, who were extensively consulted about the type and operation of the permit scheme. Following consultations, it was decided that the permit scheme should have the following features:

- 24 hour availability to enable foreign operators to pre-book permits
- electronic permit scheme requiring no paperwork
- multi lingual
- complete on line transaction
- enforceability

90% of Irelands GDP is exported and Dublin Port handles 42% of this trade (Finnegan, O'Brien, Traynor, 2007). Consequently, this means that the port has a large number of non-national HGVs entering Dublin via ferries from the U.K. or the Continent. Therefore, it was vital that this trade could be accommodated, as it was impractical to have foreign trucks arriving in Dublin Port and then waiting to receive a paper permit. The solution to this scenario was to design and implement an online permit scheme, which is:

- multi-lingual
- a complete payment portal
- allows a complete transaction to take place on line.

Another key factor in the development of this scheme was the concept of encouraging the premises within the cordon area to reduce their usage of the large HGVs and move to alternative and sustainable means of delivery. This could only be done if very accurate information were kept on the delivery pattern within the city and if at some point premises could be forced to reduce their usage if this was not happening in a voluntary fashion. Another item was the enforcement of the system and ensuring that bogus delivery permits were not being applied for in order to avoid using the tunnel. The system was therefore designed to be a two-part process:

1. A premises must register with the City Council to use 5+ axle vehicles.
2. A haulier could only deliver to a premises that had previously registered its details with the City Council

The system was implemented in a number of key phases. The first stage was introduced in February 2007 and required applicants to submit the following information online if they wished to make a delivery within the cordon area using a 5+ axle vehicle:

- details of the 5+ axle vehicle
- details of the company applying for the permit
- date for which the permit applies
- address of the destination premises
- details of the journey in terms of the designated cordon entry and exit points used

Having entered this information, applicants received an electronic load/unload permit. Initially there was no charge for these permits as this preliminary stage was essentially a familiarisation process. This stage also involved the provision of permits for 5+ axle vehicles unable to use the DPT under the terms of the Tunnel bye-laws. These permits are known as transit permits and allow the vehicles to enter the cordon area along one specific route only. There is no charge for transit permits, however this route allows no access to the main city centre area.

The second phase in the permit system was implemented in April 2007 and mandated companies operating businesses inside the cordon and requiring deliveries using five plus axle vehicles during cordon hours to register premises details. From 18th April, permits were only issued to applicants for postal addresses within the cordon that had been registered using the online registration system. Companies registering are also required to submit a mitigation plan detailing the following information:

- an explanation why 5+ axle vehicles are required
- number of trips made by 5+ axle HGVs per month within cordon time period
- proposals regarding how to reduce this number on an annual basis
- timescale identifying when the company will no longer require permits
- if the company feel they cannot eliminate the use of these vehicles completely by 2012, a detailed justification for still requiring their use is required
- Update and report progress achieving these reductions annually.

The final phase of the permit system was introduced on 1st May 2007 when a charge of €5 was introduced for each load/unload permit. This charge was originally €10 but was instead implemented on a sliding scale being initially €5 rising by euro increments to €10 euros in 2012. The current charge for 2009 is €7.

Applicants for both load/unload permits and transit permits receive details of the permit on-screen. HGVs are confined to designated roads within the cordon consisting of the main roads into the city centre. A five plus axle vehicle may use any designated road in order to transit to the nearest point to the load/unload stop. Only at this point is the vehicle allowed to deviate from a designated road to access the address on the permit. Deliveries by 5+ axle vehicles to unregistered premises must be made between 19:00-07:00.

An Garda Siochana (Irish Police Force) is the enforcing body for the permit system. They have direct access to the permit system database and can easily check whether a vehicle has a valid permit to enter the cordon without the necessity to mount any checkpoints. If an applicant is found in breach of the terms of the permit scheme, they are liable for fines of up to €800 for the first offence, €1500 for the second offence within twelve months and €1500 and possible imprisonment for third offence. Breaches of the scheme cover situations where a five plus axle vehicle is found in a location that is inconsistent with the destination address submitted on the permit. It is important to note the any fine incurred relates to the driver of the vehicle. The haulage organisation or the company receiving the goods are not liable for fines due to breaches of the cordon. To date, An Garda Siochana have over 150 truck drivers recorded for violations of the cordon. Dublin City Council uses two systems to keep a check on the numbers of five plus axle vehicles within the cordon area, namely a set of axle counters located at key points in the city, and also an Automatic Number Plate Recognition (ANPR) system which is linked to the axle counters. Data from the axle counters is dealt with in Section 4.5.3. A fundamental aim of the Strategy is to reduce the number of permits issued over time to an absolute minimum. However it is also acknowledged that this will take some time to achieve and 2012 was originally set as a target date when five plus axle vehicles are to be reduced to a minimum.

4.3 ACQUIRING DATA FROM THE PERMIT SYSTEM

Data from the HGV Permit System is stored in an Oracle Relational Database comprising of 41 tables. This database is constantly updated with each new permit application or organisation registration. Tables in the database contain both new data collected as part of the Permit System and pre-existing data pertaining to organisations, such as geographical location and the company's registration number.

In order to facilitate flexibility in relation to data analysis, all tables from the HGV Permit System (from May 2007- May 2009) were copied into individual text files. This was done using SQL+ syntax commands. In total, 21 key tables for analysis were identified and an Access Database was established using the original Oracle Database as a template. In order to ensure data integrity, relationships between tables were established in the same manner as the original database and each table was given a primary key (unique identifier). Referential integrity is important as it ensures that the database contains valid and usable data and records by preserving the connections between related tables. Without it, the relationships could quickly become meaningless, and results returned via SQL queries on the data would return unreliable results. An entity relationship diagram was established in order to implement the relationships between the various tables in the new Access database. Figure 4.2 below illustrates the relationships between the various tables.

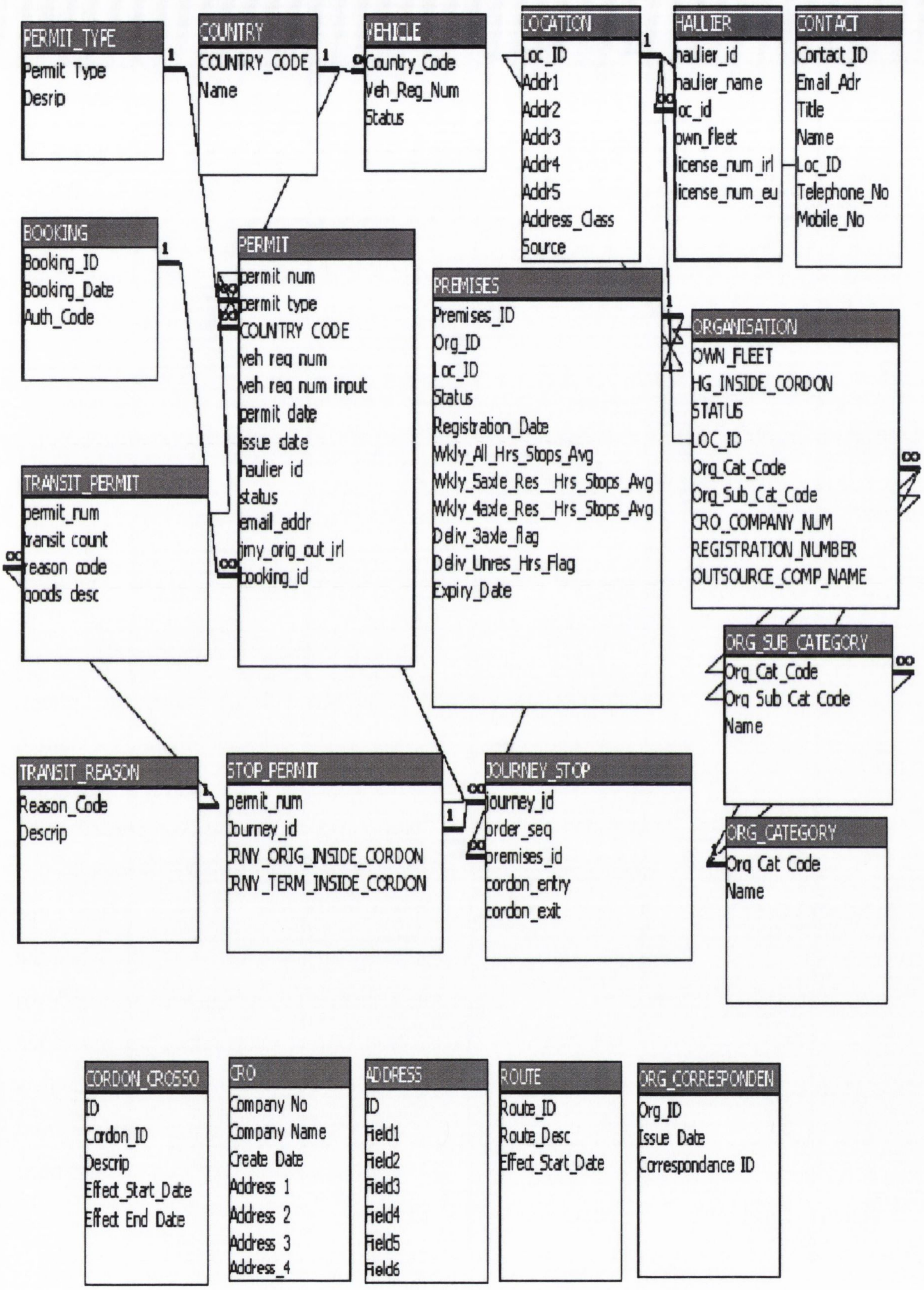


Figure 4.2: HGV Access Relational Database Entity Relationship Diagram

The critical tables for analysis are Organisation, Premises, Permit, Journey_Stop, Stop_Permit and Transit_Permit. Remaining tables in the database provide additional background information regarding the actual permits (Permit_Type, Vehicle, Booking, Country), the organisations (Organisation Subcategory, Organisation Category, Location) and the premises receiving deliveries (location). There are also two tables that are populated from external sources- CRO Table and Location Table. The CRO table (Companies Registration Table) provides a crosscheck of organisations in the permit system with a centralised repository of public statutory information on Irish companies and business names. The Location Table is populated by a nationally recognised database, the GeoDirectory. The GeoDirectory is a comprehensive database of buildings in the Republic of Ireland. It assigns each property a unique, verified address together with a precise Geocode and is maintained by An Post, the national postal company.

In order to ensure compliance with the permit system, organisations expecting to receive deliveries using vehicles with five or more axles must register their head office and maintain a list of premises used for deliveries within the HGV cordon. To ensure that the organisation is a legitimate entity, a Company Registration Number (CRO Number) must be submitted via the online system. The address of the organisation headquarters is selected from a dropdown box containing all entries in the Location Table. Addresses not available for selection from the dropdown box must be manually entered in the system. These organisations are classified as "pending" until verified by Dublin City Council. Having registered the organisation, a list of the associated premises receiving deliveries using vehicles with five or more axles within the cordon area must also be recorded in the system. The address of each premises associated with an organisation is crosschecked with the details in the Location Table. Organisations wishing to record the address must select from a dropdown box containing all entries in the Location Table. Again, when the required address of a particular premises cannot be found on the system via the dropdown box, an address is manually added by the user and is classified as "pending" until verified by Dublin City Council. Following investigation, if a pending address is verified, it is then added to entries listed in the Location Table. A valid premises address is vital because an organisation can only apply for a permit in respect of a premises that has been previously registered on the system and is fully verified.

4.3.1 Data Anomaly Issues

During the data acquisition and preparation phases, a number of anomalies in the data became apparent.

There are 586 organisations registered in the system, however just 129 of these organisations have assigned premises. This may be attributable to an initial flurry of organisations registering in the first year of operation of the system. 480 organisations registered in 2007 with 84 and 22 respectively registering in 2008 and 2009 respectively. Organisations registering in the first year may have done so as a precautionary step for potential future deliveries using five plus axle vehicles. This anomaly does not impact on the assessment of the database as permits must be associated with registered premises, thereby ensuring that analysis is based on the 129 organisations with assigned premises.

Another particular source of difficulty during the process of cleaning the data from the permit system in preparation for its subsequent analysis was the issue of pending organisations and pending premises location addresses. There are 635 entries in the Premises Table. According to the Entity Relationship Diagram, each premises should be associated with a particular organisation. However, in total only 229 premises have corresponding organisational details. Following a thorough investigation of the data, it has been ascertained that this is attributable to the fact that although pending organisations have been verified, the details associated with these organisations have not been subsequently entered into the Dublin City Council Oracle Database. This means that inferences made about organisations (and organisation types) associated with various premises during the analysis of the data are based on a subset representing over one third of the Premises Table. This proportion is sufficient to provide a representative sample of the overall data. The issue of pending premises addresses (as outlined in Section 4.3) also has implications for the consistency of the database. In total, from the Premises Table consisting of 635 distinct premises entries, 533 have address details. The remaining 102 entries are accounted for by the fact that details of premises addresses, which were originally classified as pending in the system and were verified were not subsequently entered into the Oracle Database. Since 84% of the premises have associated address details in the database, this particular anomaly does not cause undue concern for data analysis.

4.4 ANALYSING THE HGV PERMIT SYSTEM: MEASURES OF ACTIVITY

In order to examine the relationships between various tables in the database, a large number of SQL queries were run. The output from these queries was then imported into SPSS using the Access Database as an ODBC data source. Open Database Connectivity is an interface that makes it possible for applications such as SPSS to access data from a database management system.

4.4.1 Permits

In total, over the period May 2007- May 2009, 94,015 permits were issued. This total is comprised of 85% (80192) stop permits and 15% (13823) transit permits. Figure 4.3 below illustrates the number of stop and transit permits each month from the beginning of the permit scheme in May 2007 up to the end of May 2009. In 2007 (for eight months in total), the average number of stop and transit permits issued per month was 3811 and 724 respectively. In 2008, the average number of stop and transit permits had dropped to 3662 and 531. This trend of decreasing permit numbers continued into 2009 where the first five months of the year demonstrated a further drop in the number of permits issued with an average of 2428 stop permits and 331 transit permits issued per month

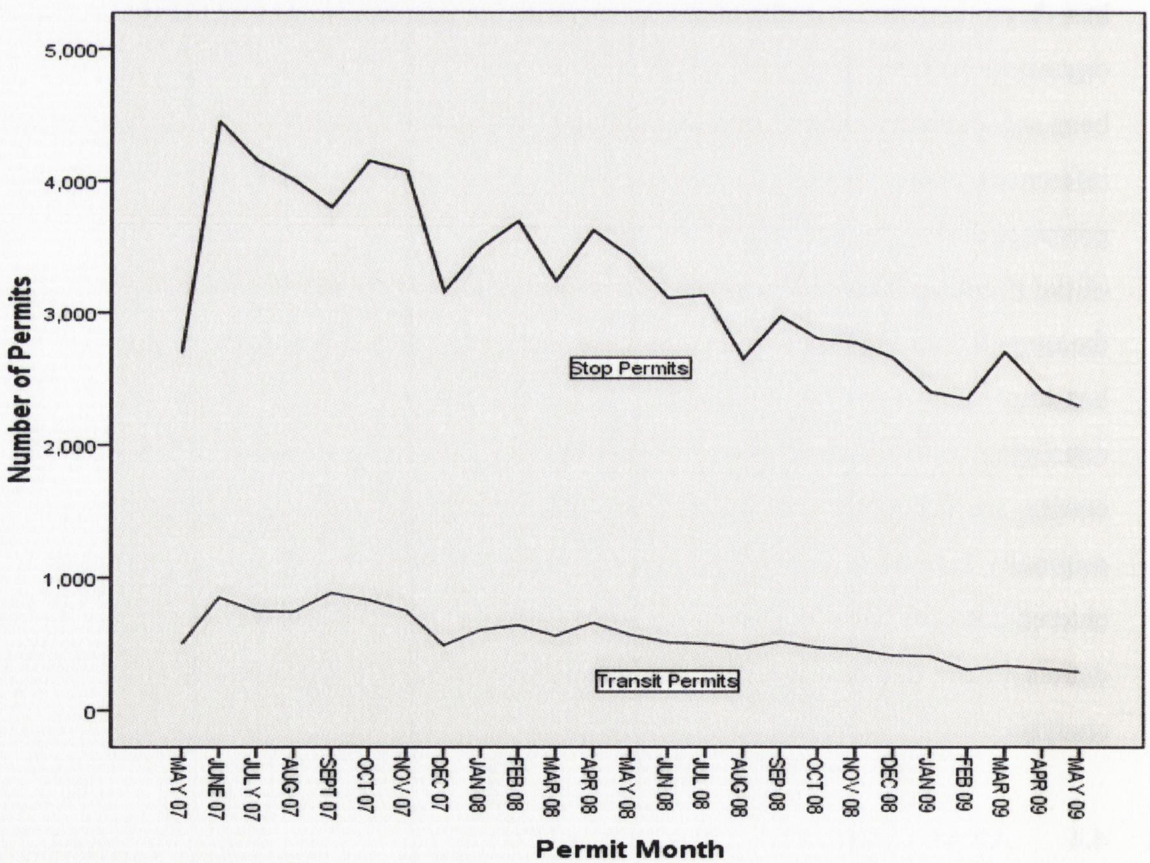


Figure 4.3: Frequency of Stop and Transit Permits from May 2007 to May 2009

There is a relatively even distribution of permits across days of the week as displayed by Table 4.1 below. Tuesday, Wednesday and Thursday are the busiest days for permits and account for approximately 55% of the overall total. Just over 11% of permits are issued for Saturday and Sunday

PERMIT DAY OF WEEK

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SUN	3323	3.5	3.5	3.5
	MON	15477	16.5	16.5	20.0
	TUE	16869	17.9	17.9	37.9
	WED	17603	18.7	18.7	56.7
	THU	16890	18.0	18.0	74.6
	FRI	16559	17.6	17.6	92.2
	SAT	7294	7.8	7.8	100.0
	Total	94015	100.0	100.0	

Table 4.1: Frequency of Permits by Day of Week

13% of permits are issued (15,988) for journeys that originate outside of Ireland, while the remaining 87% of permits (78027) are related to journeys that originate within the country. This statistic is entirely consistent with the classification of the origins of vehicles. Table 4.2 below demonstrates that 87% of vehicles used for permits are registered in Ireland. Approximately 10% are registered in the UK with the remaining 3% of vehicles registered to the Netherlands, Germany, Poland, Hungary, Iceland and Italy.

COUNTRY_CODE		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	AD	1	.0	.0	.0
	AL	5	.0	.0	.0
	AT	101	.1	.1	.1
	BE	31	.0	.0	.1
	BG	5	.0	.0	.2
	BY	2	.0	.0	.2
	CH	1	.0	.0	.2
	CY	2	.0	.0	.2
	CZ	9	.0	.0	.2
	DE	249	.3	.3	.4
	DK	21	.0	.0	.5
	EE	1	.0	.0	.5
	ES	5	.0	.0	.5
	FI	1	.0	.0	.5
	FR	5	.0	.0	.5
	GE	1	.0	.0	.5
	GR	1	.0	.0	.5
	HR	2	.0	.0	.5
	HU	125	.1	.1	.6
	IE	81933	87.1	87.1	87.8
	IS	144	.2	.2	87.9
	IT	182	.2	.2	88.1
	LI	3	.0	.0	88.1
	LT	11	.0	.0	88.1
	LV	4	.0	.0	88.1
	MN	1	.0	.0	88.1
	NL	1545	1.6	1.6	89.8
	OT	3	.0	.0	89.8
	PL	423	.4	.4	90.2
	RO	5	.0	.0	90.2
	SE	3	.0	.0	90.2
	SI	40	.0	.0	90.3
	SK	40	.0	.0	90.3
	TR	2	.0	.0	90.3
	UA	9	.0	.0	90.3
	UK	9098	9.7	9.7	100.0
	VA	1	.0	.0	100.0
	Total	94015	100.0	100.0	

Statistics

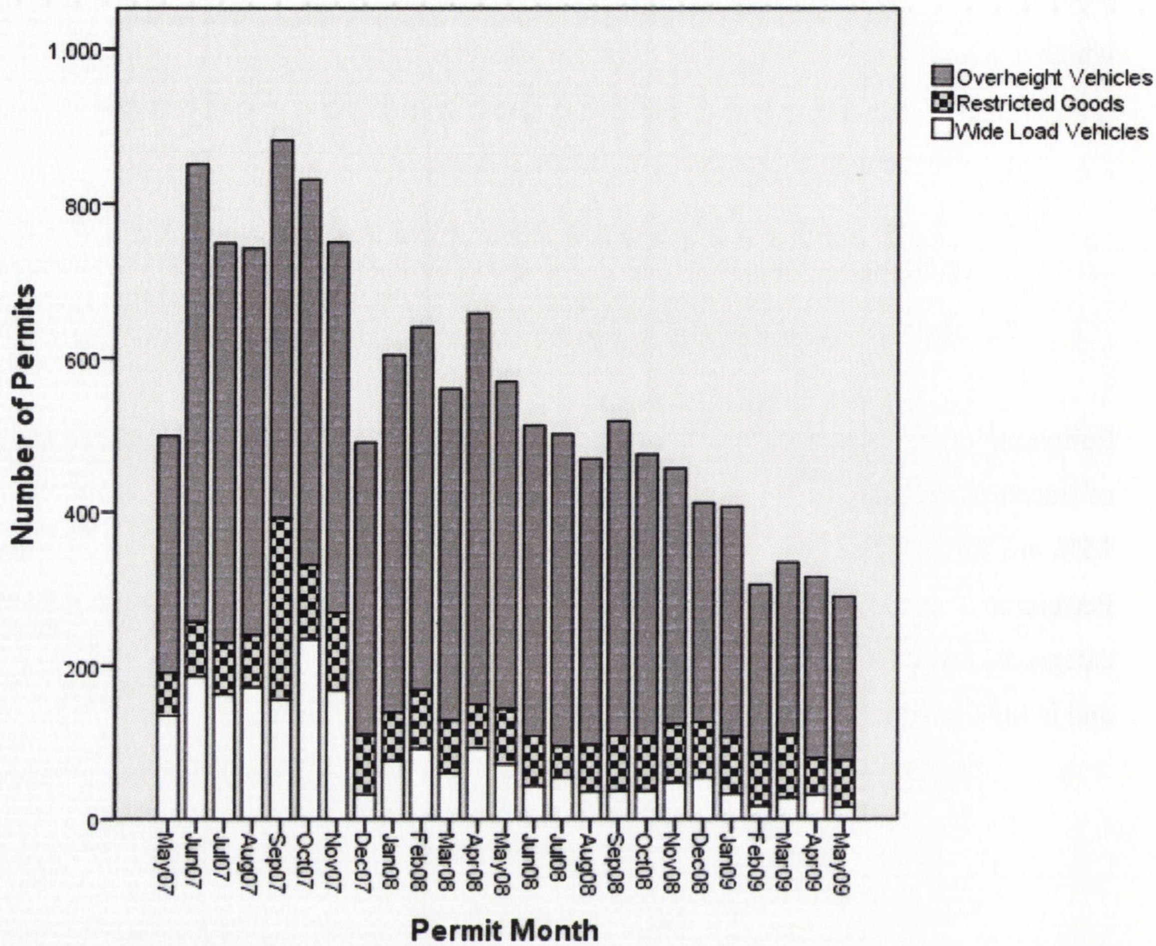
Table 4.2: Breakdown of Permits by Country

4.4.2 Transit Permits

The permit regulations allow for the provision of a transit permit, which can be applied for by vehicles that are banned from using the Dublin Port Tunnel (DPT) under the tunnel bye-laws. A vehicle that is issued with a permit under this regulation can only enter and exit the HGV cordon area at one point only (East Wall Road). A transit permit does not entitle a vehicle to be anywhere else within the cordon area. There are three situations for which a vehicle may not use the DPT. These are:

1. The vehicle is too high to fit in the tunnel
2. The vehicle class is prohibited from the tunnel, i.e. certain types of tankers, or the transport of certain types of restricted goods
3. The vehicle is too wide for the tunnel.

Following an assessment of the transit permits in the system, it was established that 71% of transit permits are for over-height vehicles, 14% are in respect of restricted goods and 15% are for vehicles that are too wide for the tunnel. Restricted goods include Liquid Petroleum Gas, Hydrogen and Hazardous Waste. This breakdown between the three categories has remained relatively consistent over the course of the permit system to date and is illustrated in Figure 4.4 below.



Figures 4.4: Reason for Transit Permits Viewed on a Monthly Basis

4.4.3 Advance Planning of Permits

Information captured as part of the permit application system includes the date of application and the actual usage date. Comparison of the permit date with the application date for each case provides a clear indication of the level of advance planning currently required for stop permits and transit permits. Figure 4.5 below illustrates the application patterns for stop and transit permits. Almost 40% of permits are obtained on the day of use (for both stop and transit permits). Approximately 48% of stop permits are obtained in the day prior to usage. This figure drops to 25% for transit permits. A further 11% of stop permits are obtained between two and four days before the permit is used. Transit permits have a more spread out distribution pattern with 16% of permits obtained between two and four days before the permit is used, and a further 11% obtained five to seven days prior to usage. These statistics indicate that a greater level of planning is possible for transit permits than stop permits. Approximately 35% of transit permits are obtained at least two days in advance. Just 12% of stop permits on the other hand are obtained at least two days in advance.

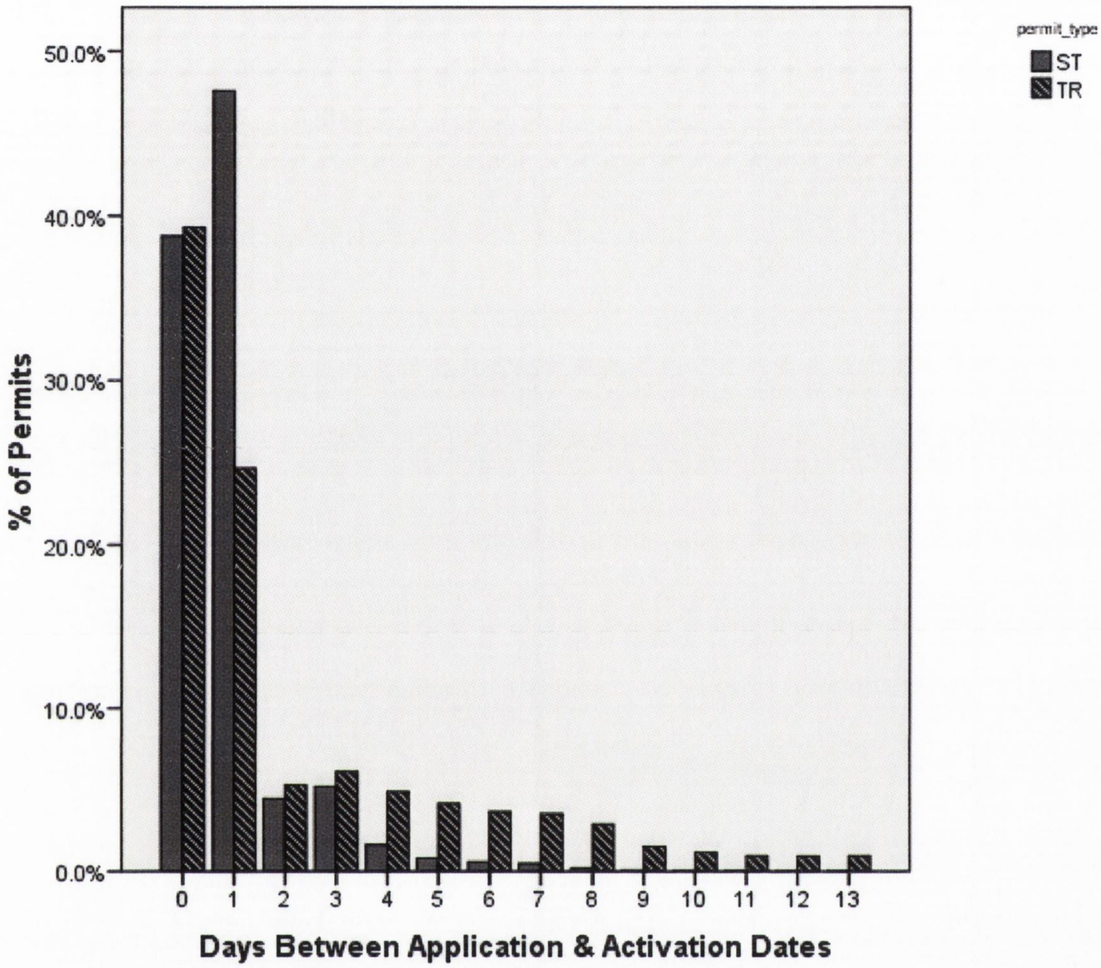


Figure 4.5: Advance Planning of Permit

4.4.4 Vehicles

In total there are 11,540 vehicles registered in the permit system. Approximately 74% (8524) of these vehicles are Irish registered. 17% are UK registered vehicles with the remaining 9% of vehicles registered in other European Union countries such as Italy, Poland, the Netherlands and Germany.

4.4.5 Estimated Age of the Permit System HGV Fleet

In order to assess the age profile of vehicles in the HGV Permit System, an analysis was carried out on the registration plates of Irish registered vehicles. The first two digits of Irish vehicle registration plates represent the year the vehicle in question was registered.

In most cases, this is also the purchase year of the vehicle and is a therefore a good proxy for the age of the vehicle. The first two digits were extracted from vehicles registered for permits and the breakdown was then analysed. Figure 4.6 below illustrates the percentage of permit vehicles registered each year from 2000 to 2008 and prior to 2000. In general the age profile of five/five plus axle vehicles entering the cordon area is relatively young with 85% of vehicles aged 9 years or less. 15% of vehicles are greater than 9 years old, being registered prior to 2000.

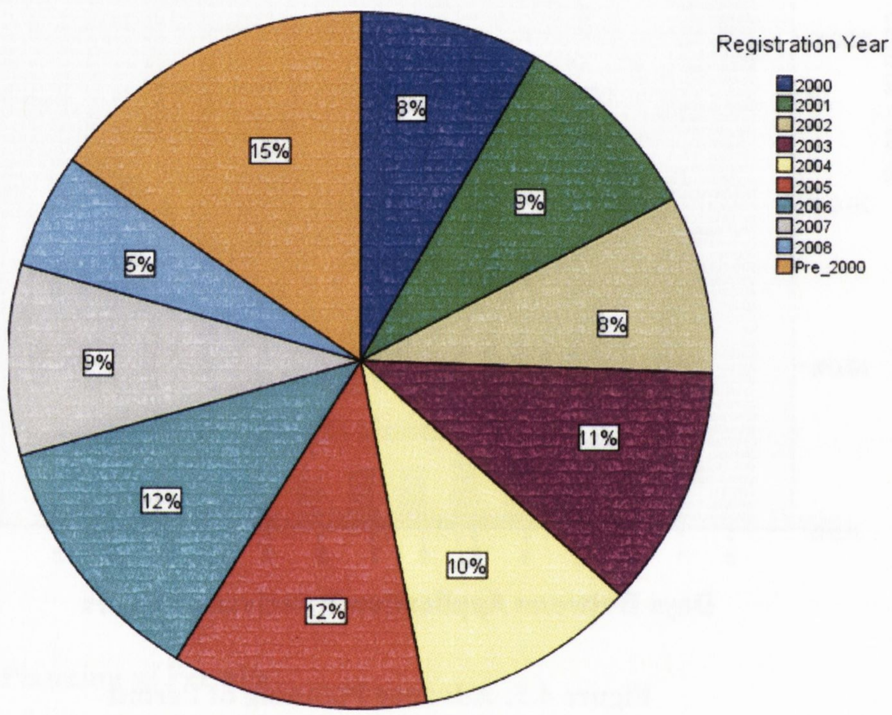


Figure 4.6: Percentage of Irish Vehicles Registered Each Year

4.4.6 Organisations: All Organisations Registered on the System

The total number of organisations registered in the permit system is 586. However, not all of these organisations have an associated list of premises receiving deliveries. This is attributable to the initial rush by organisations in the first year of operation of the system to register. In 2007, 480 organisations registered their details. In 2008, 84 organisations had registered and in the first five months of 2009, just 22 had registered.

Registered organisations are classified by type into categories and sub-categories. Tables 4.3 and 4.4 below provide details of the breakdown of organisations by categories and sub-categories respectively. Approximately 30% of organisation categories details and 46% of organisation sub-categories details are missing. However in overall terms, 52% of organisations registered are commercial companies. The remaining 28% are categorised as charities, government bodies, semi-state bodies and "other" non-specific organisations. A further breakdown of the type of organisations involved is given by the sub-category information provided at the time of organisation registration. Although 46% of sub-category detail is missing from the dataset, a pattern of dominant types of commercial organisation emerges. Organisations concerned with construction comprise approximately 20% of the total. Retail and wholesale type organisations account for 9% and 8% respectively, while the service industry accounts for 4%.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	177	30.2	30.2	30.2
	Charity	12	2.0	2.0	32.3
	Comericial Company	307	52.4	52.4	84.6
	Gov Body	12	2.0	2.0	86.7
	Other	69	11.8	11.8	98.5
	Semi-state	9	1.5	1.5	100.0
	Total	586	100.0	100.0	

Table 4.3: Breakdown of Organisations by Categories

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	267	45.6	45.6	45.6
	Construction	115	19.6	19.6	65.2
	Central Gov	5	.9	.9	66.0
	Financial Bus.	12	2.0	2.0	68.1
	Haulier	11	1.9	1.9	70.0
	Health Service	3	.5	.5	70.5
	Loval Gov	3	.5	.5	71.0
	Other	45	7.7	7.7	78.7
	Retail	52	8.9	8.9	87.5
	Service Industry	25	4.3	4.3	91.8
	Tech. Services	2	.3	.3	92.2
	Wholesale	46	7.8	7.8	100.0
	Total	586	100.0	100.0	

Table 4.4: Breakdown of Organisations by Sub-Categories

In terms of the location of the organisations, it was observed from the data that 480 of the overall total have headquarters located within the canal cordon boundaries. Just 106 organisations are located outside the canal cordon. This points to a trend of relatively concentrated organisations within the Dublin City Area generating deliveries that require vehicles with five or more axles.

Examination of the data also points to the fact that 88% of organisations (514) do not operate their own fleet for deliveries. Just 72 organisations registered have their own fleet. This reflects the general dispersed nature of the haulage industry where a large number of companies are involved in the daily transport of goods in the city.

4.4.7 Organisations: Organisations with Registered Premises

As highlighted in Section 4.3.1, although there are 586 registered organisations, 129 of these organisations have registered premises for deliveries by vehicles affected by the HGV ban. This is attributable to the initial rush in the opening months of the system by organisations to register to cater for future deliveries, which have not materialised. It is also attributable to the "pending" organisations issue described in Section 4.3, which has resulted in organisational details not being manually entered into the database once an organisation has been verified.

Having provided details of the overall organisations entered into the system, it is also worth noting the characteristics of organisations with associated registered premises. Tables 4.5 and 4.6 below provide the breakdown of organisations by category and sub-category respectively. In terms of broad categories, commercial companies account for the vast majority of organisations with almost 87% of the total. The remaining 13% is accounted for by non-specific classification "other" and semi-state and charity related organisations to a lesser extent. The sub-category classification provides more refined information regarding the dominant types of organisation. Similar to the overall organisation situation (586 in total), construction, wholesale and retail concerned organisations are again dominant although in more pronounced proportions. Approximately 23% of organisations are retail related. As expected, construction companies constitute a sizeable overall proportion with 21% of the total. Wholesale companies also account for 21% of the total. Missing values and the non-specific sub-category "other" account for 13% each. Hauliers and the service industry account for 4% and 3% of the total respectively.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Charity	1	.8	.8	.8
	Commercial Company	112	86.8	86.8	87.6
	Other	12	9.3	9.3	96.9
	Semi-State	4	3.1	3.1	100.0
	Total	129	100.0	100.0	

Table 4.5: Breakdown of Organisations (with registered premises) by Categories

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	17	13.2	13.2	13.2
	Construction	27	20.9	20.9	34.1
	Financial Business	2	1.6	1.6	35.7
	Haulier	5	3.9	3.9	39.5
	O	17	13.2	13.2	52.7
	Retail	30	23.3	23.3	76.0
	Service Industry	4	3.1	3.1	79.1
	Wholesale	27	20.9	20.9	100.0
	Total	129	100.0	100.0	

Table 4.6: Breakdown of Organisations (with registered premises) by Sub-Categories

Vehicles can make up to five transits through the cordon on single transit permit. A transit constitutes one traverse through the cordon. Therefore a return journey requires two transits. Table 4.7 below indicates the number of transits per permit. 38% of transit permits have two traverses through the cordon, 29% have a single traverse and just 4% have three traverses per permit. Approximately 16% and 15% of transit permits have four and five transits through the cordon area respectively.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	3934	28.5	28.5	28.5
	2	5189	37.5	37.5	66.0
	3	501	3.6	3.6	69.6
	4	2150	15.6	15.6	85.2
	5	2049	14.8	14.8	100.0
	Total	13823	100.0	100.0	

Table 4.7: Count of the Number of Transits Per Permit

4.4.8 Organisations with Significant Requirements for Permits

Table 4.8 below displays the most prolific users of the permit system. The top twenty organisations listed in the table account for 66% of the total number of permits issued. The highest single user of the system is Diageo, taking into account two delivery premises, located on Victoria Quay and at St James' Gate. Total Produce, a fruit and vegetable wholesale organisation, has the second highest number of permits overall with a total of 8939. Marks and Spencers also features prominently on the list in third place, on the basis of deliveries to its Mary Street and Grafton Street Premises. Another high street store, Tesco also features on the list in 18^{th} place with 724 permits over the evaluation period (May 2007-May 2009). Construction companies feature prominently on the list of high permit generating organisations.

	Organisation	Delivery Address	Number of Permits
1	Diageo Ireland	Victoria Quay & James' Gate	19948
2	Total Produce	Beresford Street	8939
3	Marks and Spencer	Mary Street & Grafton Street	3464
4	Readymix	East Wall Road	3060
5	Sam Dennigan & Co	Halston Street	1702
6	Keelings Wholesale	Little Green Street	1650
7	Blenders Ltd	New Market Industrial Est.	1580
8	Sitreas Construction Mgt	North Wall Quay	1393
9	P Elliot & Co	James Walk	1353
10	JJ Rhatigan	Heuston South Quarter	1344
11	Begley Bros Ltd	Arran Street East	1006
12	Missing	Missing	974
13	L Connaughton & Sons Ltd	Grand Canal Quay	959
14	LW Flowers	St Michans Street	945
15	KN Networks	City Wide Operation	891
16	Michael McNamara & Co	Landsdowne RFC, Ballsbridge	839
17	Chadwicks	Thomas Street	819
18	Tesco	Prussia Street	724
19	John Sisk and Sons Ltd	Church Street	681
20	Pierce Contracting Ltd	Misery Hill	681
		Total	52952
		Overall Total of Permits	80192
		% of Total	66%

Table 4.8: Top 20 Users of the Permit System

Figures 4.7 and 4.8 below illustrate the pattern of permits for two distinct users of the permit system. Figure 4.7 illustrates how the various phases of a construction project are reflected in the demand for permits over a twenty-one week period. The construction project in question was the redevelopment of a football stadium within the cordon area (Landsdowne Road) and the peak in the graph coincides with the period during construction when pre-cast concrete units were being delivered to the site.

Figure 4.8 below illustrates the pattern of permits required for Diageo Ireland, over the first two months of operation of the permit system. The graph illustrates the frequent use of the permit system by the company. It reflects the consistent and repeatable nature of the requirements for permits which a company like Diageo has.

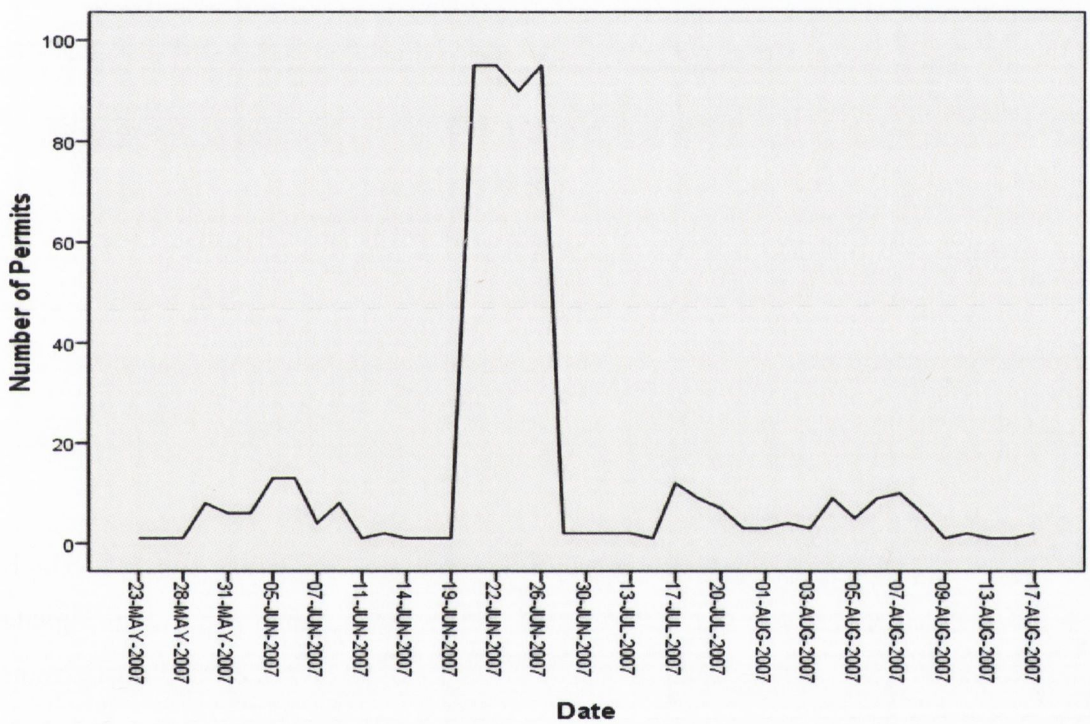


Figure 4.7: Graph Illustrating Pattern of Permits Required for a Construction Site

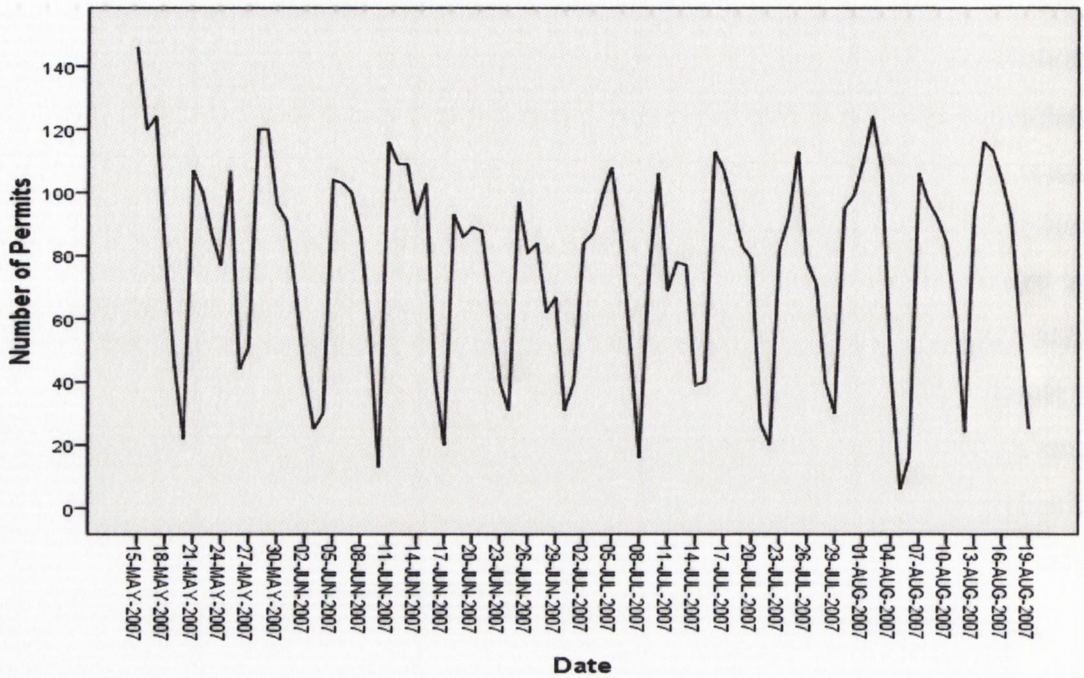


Figure 4.8: Graph Illustrating Pattern of Permits for a Regular User

4.4.9 Journey Analysis

4.4.9.1 Cordon Entry and Exit Points

One of the fundamental principles of the HGV permit system is that affected vehicles (those with five or more axles) must enter and exit the cordon area using 21 designated crossing points. These cordon points are the primary inbound and outbound traffic routes for the city centre. In the original design of the Oracle HGV database, each permit has a corresponding journey identification number. In turn, each journey identification number is associated with an order sequence number. This number refers to the sequence of stops during a particular journey. The maximum number of stops per permit is five. In the design, the cordon entry and exit points are linked to each journey. The database has a total of approximately 160,000 journeys, which are related to the 80,000 stop permits in the system.

Tables 4.9 and 4.10 below demonstrate the frequency of vehicles from the permit system passing through each of the 21 points. The ten most frequently used cordon entry and exit points are common to both tables. There is a clear concentration of vehicles passing through five particular cordon points for both entries and exits. The top five trip generating cordon points comprise 61% and 57% of the overall totals for entry and exit points respectively. North Wall Quay in the city centre, north of the River Liffey is the location with the highest proportion of trips recorded on the permit system with 26% (41480) for cordon entries and 21% (33,535) for cordon exits. South Circular Road at St. John's Road is the second most popular cordon crossing point with entries and exits comprising 13% (20,644) and 14% (22334) of respectively of the overall total. This point is located in the west of the city.

Other prominent cordon points are North Strand Road (10% of both cordon entries and exits), Navan Road (6% of entries and 7% of exits) and East Wall Road (7% of entries and 6% of exits). Missing values represent 14% of cordon entries and 18% of cordon exits. This is due to the fact that cordon entry and exit specification fields are not obligatory in the permit system. However the vast majority of permits contain entry and exit details.

There are thirteen crossing points on the south of the city (south of the River Liffey) and eight on the north side. However, 70% of journeys enter the cordon through north side entry points in comparison to just 30% entering through south side points. This breakdown is also reflected in cordon exits with 69% of journeys exiting the cordon through north side points in comparison to 31% exiting through south side points.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Sean Moore Rd	3638	2.3	2.6	2.6
	Merrion Rd	2162	1.3	1.6	4.2
	Mount St	1180	.7	.9	5.1
	Baggot St	709	.4	.5	5.6
	Leeson St Lwr	1150	.7	.8	6.4
	Charlemont St	174	.1	.1	6.5
	Richmond St	132	.1	.1	6.6
	Clanbrassil St	459	.3	.3	7.0
	Dolphins Barn	6247	3.9	4.5	11.5
	SCR @ Suir Rd	1794	1.1	1.3	12.8
	SCR @ Old Kilmainham	1581	1.0	1.1	14.0
	SCR @ St Johns Rd West	20644	12.9	15.0	29.0
	SCR @ Conyngham Rd	1748	1.1	1.3	30.2
	Navan Rd	9759	6.1	7.1	37.3
	Prospect Rd	7349	4.6	5.3	42.7
	Drumcondra Rd Lwr	7776	4.8	5.6	48.3
	Clonliffe Rd	305	.2	.2	48.5
	North Strand Rd	15481	9.6	11.2	59.8
	Alfie Byrne Rd	3400	2.1	2.5	62.3
	East Wall Rd	10475	6.5	7.6	69.9
	North Wall Quay	41480	25.9	30.1	100.0
	Total	137643	85.8	100.0	
Missing	System	22805	14.2		
Total		160448	100.0		

Table 4.9: Breakdown of Cordon Entry Points

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Sean Moore Rd	3509	2.2	2.7	2.7
	Merrion Rd	2509	1.6	1.9	4.6
	Mount St	1243	.8	.9	5.5
	Baggot St	409	.3	.3	5.8
	Leeson St Lwr	731	.5	.6	6.4
	Charlemont St	74	.0	.1	6.4
	Richmond St	115	.1	.1	6.5
	Clanbrassil St	355	.2	.3	6.8
	Dolphins Barn	5294	3.3	4.0	10.8
	SCR @ Suir Rd	1897	1.2	1.4	12.3
	SCR @ Old Kilmainham	1598	1.0	1.2	13.5
	SCR @ St Johns Rd West	22334	13.9	17.0	30.4
	SCR @ Conyngham Rd	1381	.9	1.0	31.5
	Navan Rd	10677	6.7	8.1	39.6
	Prospect Rd	8877	5.5	6.7	46.4
	Drumcondra Rd Lwr	9065	5.6	6.9	53.2
	Clonliffe Rd	247	.2	.2	53.4
	North Strand Rd	15701	9.8	11.9	65.4
	Alfie Byrne Rd	2568	1.6	2.0	67.3
	East Wall Rd	9491	5.9	7.2	74.5
	North Wall Quay	33535	20.9	25.5	100.0
	Total	131610	82.0	100.0	
Missing	System	28838	18.0		
Total		160448	100.0		

Table 4.10: Breakdown of Cordon Exit Points

4.4.9.2 Number of Stops Per Permit

Each stop permit allows the user to make up to five delivery stops (and five sets of cordon crossovers if necessary). One key area of interest is intensity of deliveries per permit for large five plus axle HGVs in the cordon area. Table 4.11 below illustrates that permits involving a delivery to one premises are the most common form of stop permit, comprising 61% of the overall total. Permits with 5 stops constitute almost 20% of the total and permits with 2, 3 and 4 stops represent 12%, 5% and 2% of the total respectively.

During the process of permit application, organisations must indicate whether the journey for a permit originates and terminates inside the HGV cordon area. Journeys for an overwhelming majority of permits originate and terminate outside the area- 97% and 89% respectively as can be viewed in Tables 4.12 and 4.13 below.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	47853	61.4	61.4	61.4
	2	9455	12.1	12.1	73.5
	3	3904	5.0	5.0	78.5
	4	1501	1.9	1.9	80.5
	5	15231	19.5	19.5	100.0
	Total	77944	100.0	100.0	

Table 4.11: Number of Delivery Stops per Permit

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	N	77814	97.0	97.0	97.0
	Y	2439	3.0	3.0	100.0
	Total	80253	100.0	100.0	

Table 4.12: Journeys Originating Inside the HGV Cordon

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	N	71705	89.3	89.3	89.3
	Y	8548	10.7	10.7	100.0
	Total	80253	100.0	100.0	

Table 4.13: Journeys Terminating Inside the HGV Cordon

4.4.9.3 Identification of Journey Delivery Patterns in the Permit System

A further area of interest in the permit system database for analysis is the extent to which there is a consistent set of trips occurring with a destination inside the canal cordon boundary. Essentially, this requires an examination of the frequency of a unique combination of a particular cordon entry point, particular destination (stop for delivery) and a particular cordon exit point. In total, there are 160,466 journeys recorded in the permit system representing 80,192 stop permits. There are 7909 variations of journey patterns within this overall journey total. Table 4.14 below indicates that 53% of journey patterns occur just once over the appraisal period (May 2007 to May 2009). This type of journey is more difficult to predict. 44% of journey types have reoccurred between 2 and 50 times. 3% of journey types occur more often than 50 times over the two-year period.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 Jrny	4173	52.8	52.8	52.8
	2-50 Jrnys	3469	43.9	43.9	96.6
	51-100 Jrnys	112	1.4	1.4	98.0
	101-500 Jrnys	120	1.5	1.5	99.6
	501-1000 Jrnys	18	.2	.2	99.8
	1001-5000 Jrnys	14	.2	.2	100.0
	5001-10000 Jrnys	1	.0	.0	100.0
	> 10000 Jrnys	2	.0	.0	100.0
	Total	7909	100.0	100.0	

Table 4.14: Frequency of Repetition of Journey Types

In total, the top twenty journey patterns account for 56% of the total number of journeys in the system (89,605). The top fifty journey patterns account for 65% of total journeys (104,592). Table 4.15 below outlines the twenty most prevalent journey patterns amongst all of the 160,466 journeys in the system. These patterns take into account the cordon entry point, the delivery premises and the cordon exit point of the journey. It is clear from Table 4.15 that as the organisation that receives the greatest number of permits, Diageo Ireland dominates the journey patterns for permits. The organisation features in six of the twenty journey types. Delivery locations for Diageo Ireland are on Victoria Quay and at St James Gate. There are five sets of cordon entry and exit points used for deliveries to Victoria Quay. These are North Wall Quay at New Wapping Street, South Circular Road at St John's Road West, Drumcondra Road Lower at Clonliffe Road, East Wall Road at East Road and Navan Road at Ashtown Road. Deliveries for the Diageo Premises at St James Gate use Dolphins Barn at the Grand Canal for both entries and exits.

Seven journey patterns are related to the delivery of construction materials into the cordon area. Delivery addresses included, East Wall Road, Smithfield, Heuston South Quarter, Rialto and North Wall Quay. The sets of cordon entry and exit points used for these deliveries are North Strand Road at Fairview, Prospect Road at Lyndsay Road, South Circular Road at St John's Road West, Navan Road at Ashtown Road and North Wall Quay at New Wapping Street.

Total Produce, another prominent applicant for permits, features four times on Table 4.15. The delivery address for Total Produce is located in the Smithfield area of city on Beresford Street. There are three distinct delivery pattern types of Total Produce journeys. The first set of journeys destined for Smithfield enter and exit the cordon at South Circular Road at St John's Road West. The second set of journey types enter and exit the cordon at North Wall Quay at New Wapping Street. The third category of journeys use North Wall Quay at New Wapping Street as the cordon entry point and exit at Drumcondra Road Lower at Clonliffe Road.The only retail organisation to feature in Table 4.15 is Marks and Spencers Ltd. Marks and Spencers have two delivery points in the canal cordon- on Mary Street and on Grafton Street. East Wall Road at East Road is used as the entry and exit points for deliveries to both locations.

The importance of identifying dominant delivery journey trends lies in the information obtained that can be used for traffic management purposes. For example, future refinements to the permit system could include building intelligence into the online application system so that real-time decisions can be made on matters such as the assignment of entry and exit points. Furthermore, information regarding the entry and exit points is useful from a traffic signal point of view. Dublin City Council operates SCATS traffic management system in the cordon area. If there is a clear indication that particular cordon points will experience high levels of HGV traffic, additional split plans can be implemented in the system to account to allow SCATS to select a more appropriate signal plan for a particular junction, thus ensuring more efficient operation. It also provides scope in the future for implementing signal prioritisation on designated corridors as an incentive for eco-friendly vehicles entering the cordon area to make deliveries. Finally, the identification of dominant delivery trends also has implications for other users of the road network, particularly pedestrians and cyclists. In providing facilities for such users, local authorities need to be able to provide a safe and sustainable environment while at the same time, safeguarding the economic viability of the city. For example, when designing and implementing cycle tracks, local authorities should be conscious of routes in the city where there are particularly high levels of HGV activity.

	Oranisation	Delivery Address	Cordon Entry	Cordon Exit	Number of Journeys
1	Diageo Ireland	Victoria Quay	North Wall Quay @ New Wapping St	North Wall Quay @ New Wapping St	40942
2	Readymix Public Ltd Co.	East Wall Rd	North Strand Rd @ Fairview Rd	North Strand Rd @ Fairview Rd	14275
3	Diageo Ireland	Victoria Quay	Sth Circular Rd @ St John's Rd West	Sth Circular Rd @ St John's Rd West	5145
4	Sam Dennigan & Co	Halston St, Smithfield	Prospect Rd @ Lyndsay Rd	Prospect Rd @ Lyndsay Rd	4059
5	Diageo Ireland	Victoria Quay	Drumcondra Rd Lwr @ Clonliffe Rd	Drumcondra Rd Lwr @ Clonliffe Rd	2389
6	Total Produce	Beresford St	Sth Circular Rd @ St John's Rd West	Sth Circular Rd @ St John's Rd West	2240
7	JJ Rhatigan & Co	Heuston Sth Quarter, St Johns Rd West	Sth Circular Rd @ St John's Rd West	Sth Circular Rd @ St John's Rd West	2167
8	Diageo Ireland	Victoria Quay	East Wall Rd @ East Rd	East Wall Rd @ East Rd	2089
9	P Elliot & Co Ltd	James Walk, Rialto	Navan Rd @ Ashtown Rd	Navan Rd @ Ashtown Rd	1850
10	Diageo Ireland	Victoria Quay	Navan Rd @ Ashtown Rd	Navan Rd @ Ashtown Rd	1843
11	Diageo Ireland	St James Gate	Dolphins Barn @ Grand Canal	Dolphins Barn @ Grand Canal	1711
12	JJ Rhatigan & Co	Heuston Sth Quarter, St Johns Rd West	Navan Rd @ Ashtown Rd	Navan Rd @ Ashtown Rd	1638
13	Total Produce	Beresford St	North Wall Quay @ New Wapping St	North Wall Quay @ New Wapping St	1625
14	Marks & Spencers Ltd	Mary St	East Wall Rd @ East Rd	East Wall Rd @ East Rd	1307
15	Total Produce	Beresford St	Drumcondra Rd Lwr @ Clonliffe Rd	Drumcondra Rd Lwr @ Clonliffe Rd	1281
16	P Elliot & Co Ltd	James Walk, Rialto	Sth Circular Rd @ Suir Rd	Sth Circular Rd @ Suir Rd	1215
17	Total Produce	Beresford St	North Wall Quay @ New Wapping St	Drumcondra Rd Lwr @ Clonliffe Rd	1203
18	Marks & Spencers Ltd	Grafton St	East Wall Rd @ East Rd	East Wall Rd @ East Rd	925
19	Missing	Missing	Sean Moore Rd @ Sth Bank Rd	Sean Moore Rd @ Sth Bank Rd	888
20	Sitreas Construction Mgt Ltd	North Wall Quay	North Wall Quay @ New Wapping St	North Wall Quay @ New Wapping St	813
				Total	**89605**

Table 4:15: Top Twenty Journey Patterns of Cordon Entry, Delivery Point and Cordon Exit

Figure 4.9: 21 Cordon Entry and Exit Points of the HGV Permit System

4.4.10 Premises

In total, there are 635 premises registered on the permit system over the evaluation period (May 2007 to May 2009). As explained in Section 4.3.1, 229 of these premises relate to registered organisations on the system. During the process of premises registration, applicants must provide supplementary information regarding general delivery activity for the organisation. This information includes:

- Average number of weekly deliveries
- Whether it is possible for the applicant to receive deliveries using HGVs with 3 axles or less
- Whether it is possible to receive deliveries between 7pm and 7am
- Average number of weekly deliveries using a 5+ axle HGV between 7am and 7pm
- Average number of weekly deliveries using a 4 axle HGV between 7am and 7pm

Analysis of the premises table in the database indicates that across all of the premises in the system, the average number of estimated overall weekly deliveries is 10. It was also ascertained from the data that it is possible for 65% of premises to receive deliveries using HGVs with 3 axles or less. While this constitutes a clear majority, it also indicates that there is a certain degree of scope to extend the HGV permit system to include four axle vehicles. Furthermore, just 28% of premises indicate that it is possible to receive deliveries outside the cordon hours (between 7pm and 7am). Upon closer examination of the associated organisations for these premises, it was found that 31% of these premises relate to retail organisations, 27% related to construction organisations, and 21% related to wholesale organisations. The retail category is particularly noteworthy as the breakdown between premises that can and cannot receive deliveries between 7pm and 7am is 46% and 54% respectively. 18% of premises associated with construction related organisations state that it is possible to receive deliveries outside of cordon operation hours. This proportion highlights the potential to implement changes to the urban freight management policies that will affect the behaviour of key, dominant industries to the city.

During the premises registration process, premises are asked to provide an estimate of average number of weekly deliveries made using five plus axle vehicles during the cordon operation hours of 7am to 7pm. An aggregation of this weekly figure to take into account the two-year analysis period, provides a total number of estimated deliveries for all premises of 689,416. The actual number of delivery journeys to premises is 160,466. This dramatic over-estimation of deliveries represents over four times the actual total of journeys to premises. This finding emphasises the level of caution required from drawing conclusions from permit system data that is based on estimated levels of future activity and not on actual proven activity.

Given the gross over-estimation of deliveries using five plus axle vehicles between 7am and 7pm, it is likely that the average number of weekly deliveries using four-axle vehicles is also misjudged. In total, according to system inputs, premises estimate that 3799 deliveries are made on a weekly basis using four-axle vehicles. This is equivalent to over 390,000 deliveries over a two-year period. An evaluation of an extension to the HGV permit system to include four-axle vehicles should not be solely based on estimates from the permit system, as these estimates are likely to be unreliable. Instead reliable traffic counts should be used to identify the likely number of HGVs affected by the extension of the ban to include four axle vehicles.

4.4.10.1 Relationship Between Location of Premises and Cordon Entry and Exit Points Used

Having analysed the frequency of usage of cordon entry and exit points in Section 4.4.9.1, a further area of interest is whether there is a relationship between the location of the premises receiving a delivery and the cordon entry and cordon exit points selected for the journey. Analysis of the Journey_Stop table in the database showed that there are 448 premises receiving deliveries from five plus axle vehicles. Assessing a relationship between individual premises and cordon entry and exit points is difficult as these premises are spread throughout the canal cordon area. In order to facilitate a more meaningful spatial analysis of the data, it was decided to apply a zoning system to the entire cordon area. The area illustrated in Figure 4.10 below was divided into six distinct zones- Northside West, Northside East, Northside Core, Southside West, Southside East, Southside Core. The two core zones represent the key shopping and business areas of the city north and south of the River Liffey. These core zones were further divided into two sub-zones in order to provide greater detail on the area if required.

Having divided the study area into six strategic zones, the next task was to acquire the list of premises identification numbers associated with the 448 premises in the Journey_Stop table. These identification numbers were then crosschecked with the Location Table to ascertain the precise location of the premises in the canal cordon. Once this was done, each of the 448 premises and corresponding locations was assigned a zone number between one and six. In total there were 104 premises with no zones assigned, comprising 23% of the total. This was due to incomplete data in the database, largely attributable to pending addresses and pending organisations, as outlined in Section 4.3.1. Table 4.16 below provides the detailed breakdown of premises in the various zones. In total, 40% of the premises are located North of the River Liffey and 37% are South of the River. 21% of premises are located in the Northside Core Zones, demonstrating a particular reliance in this part of the city on large HGVs.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	104	23.2	23.2	23.2
	Zone 1:Northside West	43	9.6	9.6	32.8
	Zone 2a: Northside Core	68	15.2	15.2	48.0
	Zone 2b:Northside Core	26	5.8	5.8	53.8
	Zone 3: Northside East	42	9.4	9.4	63.2
	Zone 4 Southside West	62	13.8	13.8	77.0
	Zone 5a: Southside Core	29	6.5	6.5	83.5
	Zone 5b: Southside Core	9	2.0	2.0	85.5
	Zone 6:Southside East	65	14.5	14.5	100.0
	Total	448	100.0	100.0	

Table 4.16 : Breakdown of Premises by Zones

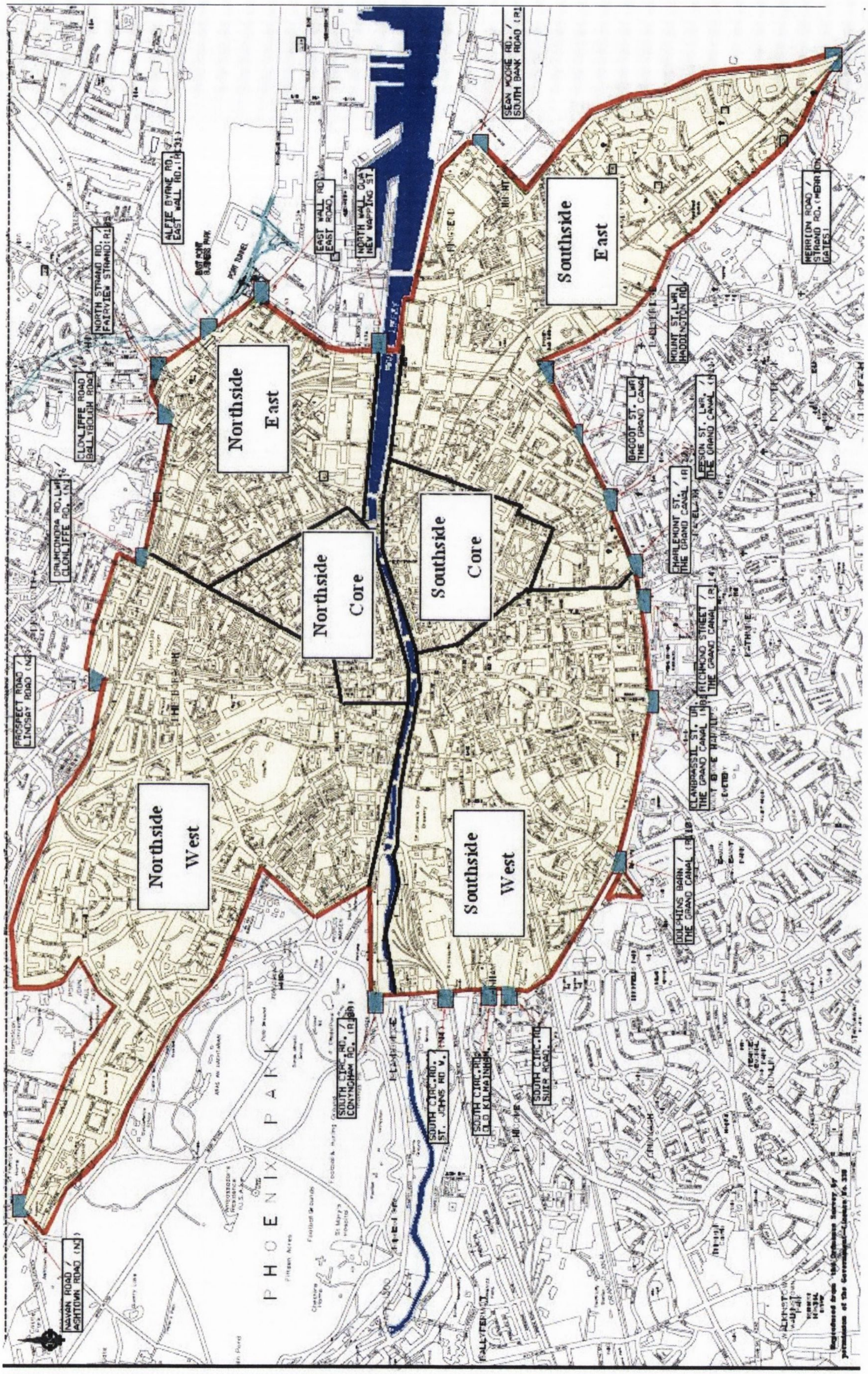


Figure 4.10: Zoning System Applied to Cordon Area

In order to protect referential integrity and general data integrity in the database, a new table was set up containing zone details for each premises and using the premises identification number as the primary key. This table was added to the overall HGV Database System via the Entity Relationship Diagram by creating a one-to-many relationship with the Journey_Stop table. Once this was done, it was then possible to run a SQL command to produce a table to link a zone identification number with each journey. This table was then imported into SPSS for further analysis. Table 4.17 below demonstrates the spread of journey destinations across the six zones. In total, it was ascertained that 50% of journeys in the permit system are destined for the Southside West Zone. This is a direct reflection of the fact that Diageo Ireland has two premises in this zone that account for 25% of all permits obtained. 19% of journeys have a destination in the Northside Core Zone. Again, this zone is the location for one of the major permit generating organisations, Total Produce. Total Produce is responsible for 11 % of all permits obtained. The Northside East Zone is another notable attractor zone for permits with 12% of the total. This zone is the closest zone to the north port area.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	10950	6.8	6.8	6.8
	1:Northside West	5595	3.5	3.5	10.3
	2: NorthsideCore	30775	19.2	19.2	29.5
	3:Northside East	19631	12.2	12.2	41.7
	4:SouthsideWest	80538	50.2	50.2	91.9
	5:Southside Core	5083	3.2	3.2	95.1
	6:Southside East	7894	4.9	4.9	100.0
	Total	160466	100.0	100.0	

Table 4.17: Journeys Categorised Using Canal Cordon Zoning System

In order to assess the relationship between the number of journeys to a particular zone and the number of transits of a particular cordon entry point, a cross-tabulation was set up demonstrating the proportion of journeys to each zone using each cordon entry point. This table can be viewed below in Table 4.18. The table uses a column-based colour coded ranking system to highlight the cordon entry points that experience particularly high usage by the six zones. Figure 4.11 graphically illustrates the number of permits per zone for the top ten cordon entry points.

It was found that 41% of journeys to the Northside West Zone use cordon entry point 21 at North Wall Quay. 23% of the total enter via Navan Road and 9% enter the cordon at East Wall Road. For the Northside Core Zone 25% of journeys originate via the North Wall Quay entry point. 22% use the entry point at South Circular Road at St John's Road with 18% using Prospect Road. For the Northside East Zone 74% of the journeys use North Strand Road as the entry point, 11% use North Wall Quay and 6% use East Wall Road. There appears to be a clear preference for the North Wall Quay entry point for zones on the north of city, except for the Northside East Zone where North Strand Road absorbs the vast majority of entries to the zone due to its close proximity to the zone. The frequency of use of North Wall Quay suggests that vehicles are using the Dublin Port Tunnel as a high-speed route into the city to make deliveries. Vehicles using the DPT must enter the cordon at North Wall Quay. The popularity of St Johns Road as an entry point for deliveries to the core of the Northside suggests the importance of this National Primary Route (N4) for urban freight journeys originating west of the cordon area. The popularity of Navan Road entry point is directly related to its proximity to the Northside West Zone. Similarly, the high number of journeys using Prospect Road to access the Northside Core Zone is due to its proximity to the zone. However the popularity of East Wall Road as chosen entry point for the Northside West Zone is more difficult to rationalise and requires further statistical assessment of the nature of the relationship between zones and cordon entry points.

The dominance of North Wall Quay as an entry point to the city was also reflected in the proportions of trips to zones in the south of the city. The North Wall Quay entry point accounted for 43% of journeys to the South West of the City. 17% of journeys used a cordon point in the west of the city at St. John's Road while 10% used a cordon point in the north of the city at the Navan Road. For journeys to the Southside Core Zone, East Wall Road accounted for 32% of cordon entries with North Wall Quay constituting 12% of the total. The Sean Moore Road entry point located in the east of the city close to the South Port accounted for 9%. For the Southside East Zone of the Cordon, North Wall Quay comprised 17% of cordon entries. East Wall Road and St John's Road accounted for 15% and 13% of the overall total respectively.

While the popularity of the North Wall Quay cordon entry point is again attributable to the use of the DPT by five plus axle vehicles to access the city from the motorway network around the city, the extent of usage of other northside entry points such as the

Navan Road and East Wall Road is more difficult to explain. A statistical exercise is required to provide an assessment of whether there is a relationship between the numbers of journeys using particular cordon points and the number of journeys destined for particular zones.

	Side of City	CORDON ENTRY	NSIDE WEST	NSIDE CORE	NSIDE EAST	SSIDE WEST	SSIDE CORE	SSIDE EAST
1	S	Sean Moore Rd	0%	2%	1%	1%	9%	7%
2	S	Merrion Rd	1%	1%	1%	0%	2%	7%
3	S	Mount St	0%	0%	0%	0%	2%	11%
4	S	Baggot St	2%	0%	0%	0%	0%	5%
5	S	Leeson St Lwr	1%	1%	0%	1%	1%	1%
6	S	Charlemont St	0%	0%	0%	0%	0%	1%
7	S	Richmond St	0%	0%	0%	0%	0%	1%
8	S	Clanbrassil St	0%	0%	0%	1%	1%	0%
9	S	Dolphins Barn	2%	1%	0%	8%	8%	4%
10	S	SCR @ Suir Rd	2%	0%	0%	2%	2%	1%
11	S	SCR @ Old Kilmainham	1%	1%	0%	2%	1%	1%
12	S	SCR @ St Johns Rd	4%	22%	3%	17%	7%	13%
13	N	SCR @ Conyngham Rd	2%	2%	0%	1%	2%	1%
14	N	Navan Rd	23%	3%	1%	10%	6%	3%
15	N	Prospect Rd	3%	18%	1%	2%	4%	4%
16	N	Drumcondra Rd Lwr	2%	11%	1%	5%	4%	2%
17	N	Clonliffe Rd	1%	0%	0%	0%	1%	0%
18	N	North Strand Rd	3%	0%	74%	1%	4%	0%
19	N	Alfie Byrne Rd	2%	5%	1%	2%	3%	5%
20	N	East Wall Rd	9%	9%	6%	5%	32%	15%
21	N	North Wall Quay	41%	25%	11%	43%	12%	17%

	1	2	3	4	5
Rank					

Table 4.18: Percentage of Journeys Travelling Through Each Cordon Entry Point with a Destination in Each of the Six Zones

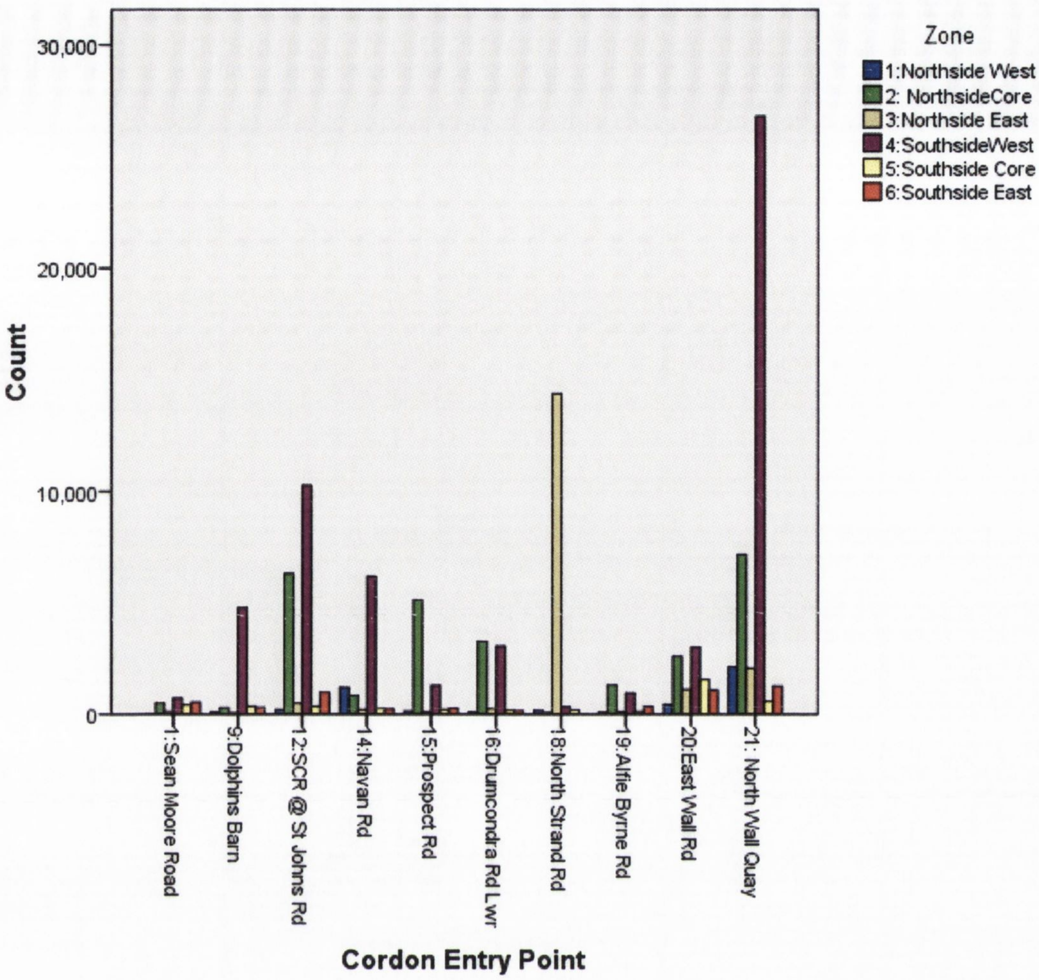


Figure 4.11: Top Ten Cordon Entry Points: Number of Permits Per Zone

To a large extent, it is expected that the pattern of behaviour for vehicles entering the cordon through particular cordon points to access certain zones, is mirrored by vehicles using the same cordon points to exit the cordon. It was found that 64% of journeys have the same cordon entry and exit points. Table 4.19 below provides the breakdown of the proportion of journeys from each zone using each cordon exit point. Again, this table uses a column-based colour coded ranking system to highlight the cordon exit points that experience particularly high usage by the six zones. Figure 4.12 graphically illustrates the number of permits per zone for the top ten cordon exit points.

Table 4.19 demonstrates that in five out of the six zones, there is an exact match of cordon exit points to Table 4.18's entry points. The cordon entry points for the Northside Core Zone differ slightly to the cordon exit points used. St Johns's Road is experiences the greatest proportion of cordon exits from the zone at 27%. Prospect Road and

Drumcondra Road Lower account for 22% and 16% of cordon exits respectively from this zone. The cordon exit points at Prospect Road and Drumcondra Road Lower are directly north of the zone.

	Side of City	CORDON EXIT	NSIDE WEST	NSIDE CORE	NSIDE EAST	SSIDE WEST	SSIDE CORE	SSIDE EAST
1	S	Sean Moore Rd	0%	2%	1%	1%	10%	8%
2	S	Merrion Rd	2%	0%	1%	1%	3%	6%
3	S	Mount St	0%	0%	0%	0%	2%	11%
4	S	Baggot St	0%	0%	0%	0%	1%	3%
5	S	Leeson St Lwr	0%	0%	0%	1%	1%	1%
6	S	Charlemont St	0%	0%	0%	0%	0%	0%
7	S	Richmond St	0%	0%	0%	0%	0%	0%
8	S	Clanbrassil St	0%	0%	0%	0%	1%	0%
9	S	Dolphins Barn	2%	1%	0%	7%	9%	4%
10	S	SCR @ Suir Rd	2%	0%	0%	3%	1%	0%
11	S	SCR @ Old Kilmainham	1%	2%	0%	1%	1%	1%
12	S	SCR @ St Johns Rd	4%	27%	2%	19%	9%	12%
13	N	SCR @ Conyngham Rd	2%	1%	0%	0%	2%	1%
14	N	Navan Rd	26%	4%	1%	11%	7%	3%
15	N	Prospect Rd	3%	22%	0%	3%	4%	4%
16	N	Drumcondra Rd Lwr	2%	16%	1%	5%	2%	3%
17	N	Clonliffe Rd	1%	0%	0%	0%	0%	1%
18	N	North Strand Rd	4%	0%	75%	1%	3%	0%
19	N	Alfie Byrne Rd	2%	3%	1%	1%	2%	4%
20	N	East Wall Rd	8%	8%	5%	5%	28%	18%
21	N	North Wall Quay	42%	13%	11%	40%	13%	18%

Rank: 1 (green), 2 (orange), 3 (red), 4 (blue), 5 (pink)

Table 4.19: Percentage of Journeys Travelling Through Each Cordon Exit Point From Each of the Six Zones

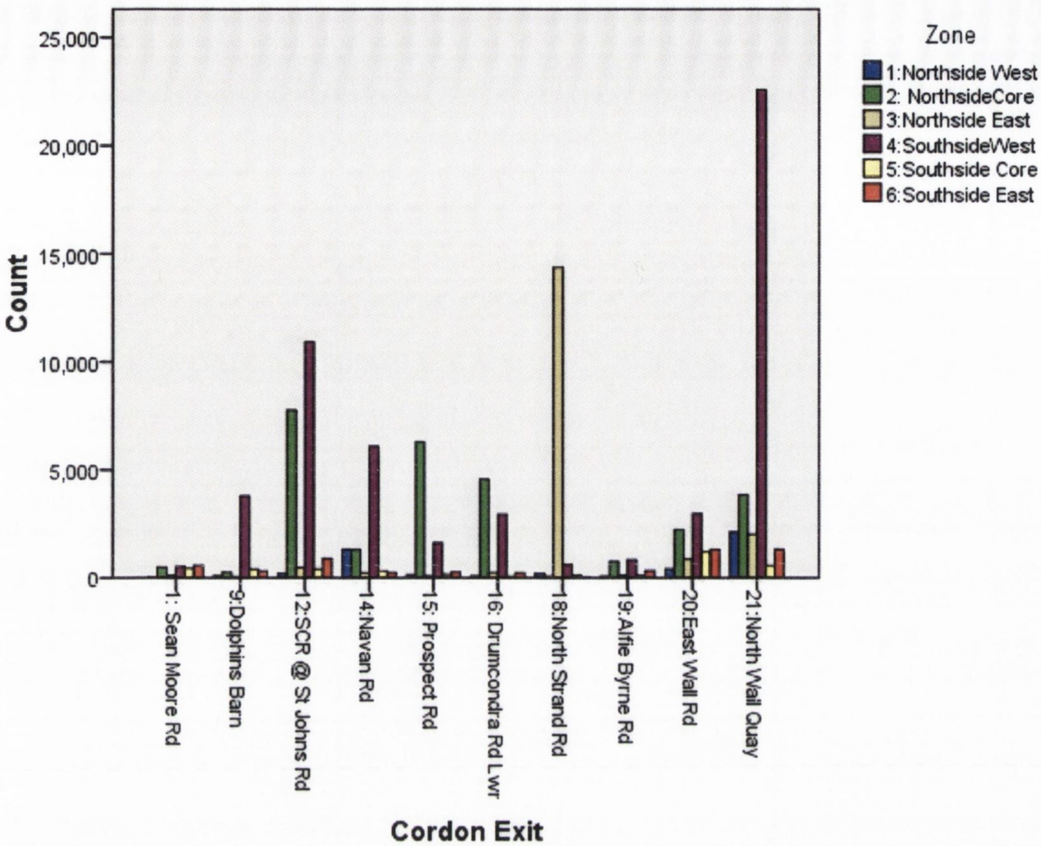


Figure 4.12: Top Ten Cordon Exit Points: Number of Permits Per Zone

From the above analysis, it is clear that North Wall Quay and St John's Road constitute major entry and exit points to and from the cordon, from the North of the City and the West of the City respectively. However, there is also the case of the cordon point at East Wall Road to consider. This particular cordon point is of note because of the fact that it is used frequently to access zones other than Northside East zone, which is adjacent to the cordon point. In particular, East Wall Road is a popular choice for cordon entries and exits for the Southside Core Zone and the Southside East Zone.

One possible reason why East Wall Road is used so frequently is that it provides a direct route via the East Link Toll Bridge for vehicles going to the south of the city. A further incentive for vehicles to take this route is the opportunity to benefit from the toll rebate scheme operated by Dublin City Council. This scheme was introduced to facilitate travel between the North and South Port areas. However, it also facilitates five axle plus vehicles using the East Link Bridge as the most direct routes for deliveries to premises in the south of the city. This is clearly a serious loophole in the system and has severe financial implications for the long-term viability of the HGV Permit System if a significant number of vehicles are taking advantage of it.

4.4.10.2 Statistical Assessment of the Independence of the Data

The analysis of cordon entry points and zone destinations and cordon exit points and zone destinations highlighted some unusual behaviour by vehicles entering and exiting the cordon. In particular, it was noted that the North Wall Quay and East Wall Road points were being used to access zones that were not geographically intuitive. In order to establish if there was an association between the entry point and zone destination and the exit point and zone destination, a chi-square test was carried out. A chi-square test is an extension of a cross-tabulation of variables seen in Table 4.18 and Table 4.19. It is a test of the influence that a subject's value on one variable has on the same subject's value for a second variable. In the case of the permit data, it is a test of the influence of the choice of cordon entry and exit has on the delivery zone visited.

4.4.10.3 Chi-Square Test of Independence for Cordon Entry and Zone

The first key assumption of the chi-squared test is that there is independence of the observations (Hinton, Brownlow, McMurray, Cozens, 2004). In other words journeys with a destination in a particular zone are unrelated to journeys destined for other zones. The second key assumption is that the calculated chi-square statistic is continuous to reflect the chi-square distribution. In practical terms, this means that within the cross-tabulation of variables, it is safer to have large frequency counts in each cell rather than small numbers. Ideally, there should not be any cell in the cross-tabulation with a value less than five. In the case of the cross-tabulation between cordon entries and zones, there are 2 cells with values less than five, constituting 1.4% of the total of cells. For the cross-tabulation between cordon exits and zones, there are 5 cells with values less than 5, constituting 3.4% of the total. Given the large sample size concerned (over 130,000 journeys and 147 cross-tabulation cells), this is deemed acceptable for carrying out a chi-square test (Cramer, 2000, Daimantopoulos & Schlegelmilch, 2006). This is because both cross-tabulations meet the minimum requirements for the chi-square test whereby no more than 20% of the counts in the table have an expected value less than five and none of the expected values are less then one.

The test involves analysing the association between cordon entry point and zone by first of all examining the research hypothesis (H_1) that cordon entry point and zone are dependent or related. This will prove to be true if the observed counts for the categories of the two variables in the data are different from the expected counts. The null hypothesis (H_0) is that cordon entry and zone are entirely independent of each other. This will prove to be true if the observed counts in the sample are similar to the expected counts for all groups.

In the case of the test analysing the association between cordon entry point and the zone visited, the probability of the chi-square test statistic (chi-square = 1.499E5) is .000, which is significant at the $p < .0001$ level. Table 4.20 below shows the Pearson Chi-Square test statistic, degrees of freedom and the probability value. Therefore, the null hypothesis that cordon entry and zone visited are entirely independent is rejected. The research hypothesis that differences in the cordon entry point used are related to differences in the zone visited is supported by this analysis. It is also worth noting that the requirements for the chi-square test are met in terms of the count of cells being less than 5 and the minimum expected count being 4.62. Therefore the sample size requirement for the chi-squared test of independence is satisfied.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.499E5	120	.000
N of Valid Cases	137649		

a. 2 cells (1.4%) have expected count less than 5. The minimum expected count is 4.62.

Table 4.20: Reported Chi-Square Statistic for Relationship Between Cordon Entries and Zones

The full cross-tabulation detailing counts, expected counts, residual values and standard residual values is included in Appendix B. The counts show how many journeys occurred in the dataset using a particular cordon entry point to access a particular zone. The expected counts confirm how many journeys would be expected for each category if the null hypothesis were true. The residual values indicate the difference between the counts and the expected counts. The standardised residual values represent the residual values converted to a Z-score. Standardised residuals that have a positive value imply that the cell is over-represented in the actual sample in comparison to what is expected.

Standardised residuals with a negative value on the other hand imply that the cell is under-represented in comparison with what is expected.

The standardised residual values provide valuable additional information regarding particular cordon entry points that displayed unexpected behaviour in Table 4.18 and Table 4.19.

In the case of journeys using North Wall Quay to access Zone 4, Southside West, a residual value of 60.1 is obtained. This figure greatly exceeds the critical value of 1.96 (at the 0.05 level of significance) indicating that the number of journeys in this category far exceeds what would be expected. The residual value for journeys using North Wall Quay to access Zone 1 (Northside West) is 14.4, again indicating that there are far more subjects in this category than expected. For Zones 2 (Northside Core), 3 (Northside East), 5 (Southside Core) and 6 (Southside East) residual values of -16.5, -49.1, -23 and –20 respectively are obtained. This indicates that there were fewer journeys in these categories than would be expected. The presence of an association between the cordon entry point and the zone visited is demonstrated by the chi-square test. The presence of strongly positive residual values for Zones 1 and 4 indicates that the total number of journeys in these zones is dependent on the number of journeys that use North Wall Quay as an entry point. This points to the strong possibility of the origin of deliveries to these zones being either in Dublin Port or in north of Dublin. Journeys originating directly north of Dublin are likely to use the M1 motorway to access the Dublin Port Tunnel (DPT). Once exiting the DPT, vehicles are then likely to enter the canal cordon via the North Wall Quay entry point. Given that Diageo, the biggest users of the permit system are located in Zone 4 and are dependent the exports of goods, it is likely that a large proportion of their goods originate in the Dublin Port Area and use North Wall Quay to enter the cordon from the Port. Therefore, this trend is indicative of a major route into the city used by the organisation's fleet of five plus vehicles.

East Wall Road was the second cordon entry point that displayed unexpected behaviour regarding zones visited in Table 4.18 and Table 4.19, particularly in relation to the Southside Core Zone and the Southside East Zone. Strong residual values of 62.3 and 22.3 are obtained for Southside Core Zone and Southside East Zone respectively. This signifies that there are far more journeys using East Wall Road to access these zones than would be expected. This further reinforces the theory that trucks are travelling from the north side of the city to the south using the East Link Toll Bridge and taking advantage of the rebate scheme.

The cordon entry point at St John's Road at South Circular Road is identified in Section 4.4.9 as a prominent entry point for vehicles travelling to the Northside Core Zone and the Southside West Zone. This is reflected in the strongly positive standardised residual values of 30.1 and 10.5 obtained in the chi-square test and cross-tabulation exercise for Northside Core and Southside West Zones respectively. This demonstrates that there is a clear relationship between vehicles travelling in from the west of the city via the N4 national route and the number of deliveries in the core area of the northside of the city centre and the southwest area of the city centre. It also serves to identify another route into the city used by Diageo for deliveries to Zone 4.

A further cordon entry point, which displays prominent patterns of journey behaviour is North Strand Road. This entry point is responsible for 74% of journeys with a destination in the Northside East Zone. In this case a residual value of 261.8 is found emphasising an over-representation of journeys in this category. This is attributable to the geographical proximity of the cordon point to the zone.

The final cordon point that merits further statistical investigation following its identification as a frequently used entry point for deliveries to the Northside West Zone and the Southside West Zone is the Navan Road. Residual values of 43.8 and 27.6 are obtained for the aforementioned zones respectively. The over-representation of journeys from the Navan Road to the Northside West zone is attributable to the geographical proximity and convenience of the cordon point. The strong positive residual value for the Southside West Zone helps to identify another route used to access the city by Diageo who are located in this zone.

While each of the five cordon entry points above contribute in different ways to the patterns of delivery within the canal cordon, it is important to note that as the biggest user of permits in the city, Diageo significantly impact on the overall utilisation of cordon points in the city. If the company were to change its delivery routes into the city, this could have a major impact on the performance and capacity of the various cordon entry points. The potential impacts of the disproportionate nature of Diageo's deliveries into the canal cordon is something which Dublin City Council should be monitoring over time.

4.4.10.4 Chi-Square Test of Independence Applied to Cordon Exit and Zone

A chi-square test of independence was also applied to cordon exit data and zone data. The test involves analysing the association between cordon exit point and zone by first of all examining the research hypothesis (H_1) that cordon exit point and zone are dependent or related. This is found to be true if the observed counts for the categories of the two variables in the data are different from the expected counts. The null hypothesis (H_0) is that cordon exit and zone visited are entirely independent of each other. This is found to be true if the observed counts in the sample are similar to the expected counts for all groups.

In the case of the test analysing the association between cordon entry point and the zone visited, the probability of the chi-square test statistic (chi-square = 1.467E5) is .000, which is significant at the $p < .0001$ level. Table 4.21 below shows the Pearson Chi-Square test statistic, degrees of freedom and the probability value. Therefore, the null hypothesis that cordon exit and zone visited are entirely independent is rejected. The research hypothesis that differences in the cordon exit point used are related to differences in the zone visited is supported by this analysis. It is also worth noting that the requirements for the chi-square test are met in terms of the count of cells being less than 5 and the minimum expected count being 2.46. Therefore the sample size requirement for the chi-squared test of independence is satisfied.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.467E5	120	.000
N of Valid Cases	131615		

a. 5 cells (3.4%) have expected count less than 5. The minimum expected count is 2.46.

Table 4.21: Reported Chi-Square Statistic for Relationship Between Cordon Exits and Zones

The full cross-tabulation detailing counts, expected counts, residual values and standard residual values is included in Appendix B. The counts show how many journeys occurred in the dataset using a particular cordon exit point from a particular zone to exit the cordon. The expected counts confirm how many journeys would be expected for each category if the null hypothesis were true. The residual values indicate the difference between the counts and the expected counts. The standardised residual values represent the residual values converted to a Z-score. Standardised residuals that have a positive value imply that the cell is over-represented in the actual sample in comparison to what is expected. Standardised residuals with a negative value on the other hand imply that the cell is under-represented in comparison with what is expected.

A strongly positive value of 68.2 is obtained for journeys visiting the Southside West Zone and exiting the cordon at North Wall Quay. This figure greatly exceeds the critical value of 1.96 (at the 0.05 level of significance), indicating that the number of journeys in this category far exceeds the expected volume. The residual value for journeys using North Wall Quay to exit the cordon from the Northside West Zone is 22.8, again indicating that there are far more cases in this category than expected. For Zones 2 (Northside Core), 3 (Northside East), 5 (Southside Core) and 6 (Southside East) residual values of –41.5, -41, -16.3 and –13 respectively are obtained. This indicates that there were fewer journeys in these categories than would be expected. The presence of an association between the cordon exit point and the zone visited is demonstrated by the chi-square test. The presence of strongly positive residual values for Zones 1 and 4 indicates that the number of journeys that use North Wall Quay as an exit point is dependent on the total number of journeys visiting these zones.

It is likely that the presence of Diageo, a multinational organisation with a reliance on imports and exports has implications for the frequency of use of North Wall Quay as a cordon exit point for Zone 4. It is likely that journeys involving Zone 4 as a destination (76% of which relate to Diageo) are export related, and therefore are using North Wall Quay as a cordon exit point to access the port area. The reliance of organisations on Dublin Port is also likely to explain the popularity of North Wall Quay as an exit point for Zone 1(Northside West). For example, Tesco are responsible for 14% of the total number of journeys to this zone using five plus axle vehicles and the company relies significantly on imports from the UK. Therefore it is reasonable to assume that these journeys are port related thereby explaining why North Wall Quay emerges during analysis as a frequently used exit point.

Table 4.19 emphasised the high levels of use of East Wall Road as a cordon exit for journeys destined for the Southside Core Zone and the Southside East Zone. This is reflected in the residual values of 50.1 and 33.7 for the aforementioned zones respectively. As with the case of cordon entries and zones visited, this signifies that there are far more journeys using East Wall Road to exit the cordon from these zones than would be expected. Again this points to the possibility that trucks are travelling from the south side of the city to the north side using the East Link Toll Bridge and taking advantage of the rebate scheme,

The cordon entry point at St John's Road at South Circular Road is identified in Section 4.4.9 and Table 4.19 as a prominent exit point for vehicles travelling from the Northside Core Zone and the Southside West Zone. This is reflected in the strongly positive standardised residual values of 40.5 and 13.7 obtained in the chi-square test and cross-tabulation exercise for Northside Core and Southside West Zones respectively. This demonstrates that there is a clear relationship between vehicles travelling from the Northside Core Zone and Southside West Zone and using St John's Road as an exit point. It also serves to identify another route from city used by Diageo for the movement of trucks from Zone 4.

A further cordon exit point, which displays prominent patterns of journey behaviour in Table 4.19 is North Strand Road. This exit point is responsible for 75% of journeys that have a delivery destination in Northside East Zone. In this case a residual value of 252.7 is found, emphasising an over-representation of journeys in this category. This is attributable to the geographical proximity of the cordon exit point to the zone.

4.5 IMPACTS OF DUBLIN PORT TUNNEL AND THE HGV MANAGEMENT STRATEGY

4.5.1 Dublin Port Tunnel

On December 20th 2006, the €750 million Dublin Port Tunnel (DPT) officially opened as a dedicated route for Heavy Goods Vehicles between Dublin Port (located in the heart of the city) and the greater road network. It is part of the M50 motorway and completes the northern part of the C-Ring around Dublin city. Prior to the construction of the tunnel, all port-bound traffic was forced to travel through the city centre. The completed infrastructure now ensures that heavy goods traffic can be removed to a large extent from urban streets. Figure 4.13 below illustrates the extent of use of the DPT by various classes of vehicles. This data was acquired from the operators of the DPT. In the first full month of operation of the tunnel (January 2007), a total of approximately 148,000 vehicles used the tunnel. This figure rose to 281,000 in March 2007 following the introduction of the HGV ban in the city. The overall peak month of operation for the DPT to date occurred in May 2008 when 445,000 vehicles passed through the tunnel. More recently in May 2009, this figure had dropped to 381,000. Approximately 12,000 five plus axle vehicles passed through the tunnel in January 2008. The monthly total had increased dramatically in March following the HGV to 120,000. The peak month for five axle plus vehicles occurred in October 2008 when 127,000 of these vehicles used the tunnel. In May 2009, 100,000 vehicles in this class travelled through the tunnel. The Light Goods Vehicle (LGV) class is also prevalent in the DPT. The first full month of operation saw 788 LGVs use the tunnel and by March 2007, this figure had soared to 6921. The peak month for LGVs using the tunnel occurred in November 2007 when 15,500 vehicles in this category used the tunnel. The monthly figure for LGVs in May 2009 was 10,500. A total of 20,000 cars used the tunnel in January 2007 and by March 2007 this figure had risen to approximately 85,000. The peak month for cars using the tunnel occurred in May 2008 with a total of 243,000 vehicles. More recently, in May 2009, the total number of cars using the tunnel was 196,000. HGVs with three axles display remarkably consistent usage of the tunnel with an average of approximately 3600 of these vehicles passing through the tunnel each month. HGVs with four axles and two axles also display relatively stable usage patterns for the tunnel with an average of approximately 30,000 and 25,000 vehicles per month respectively.

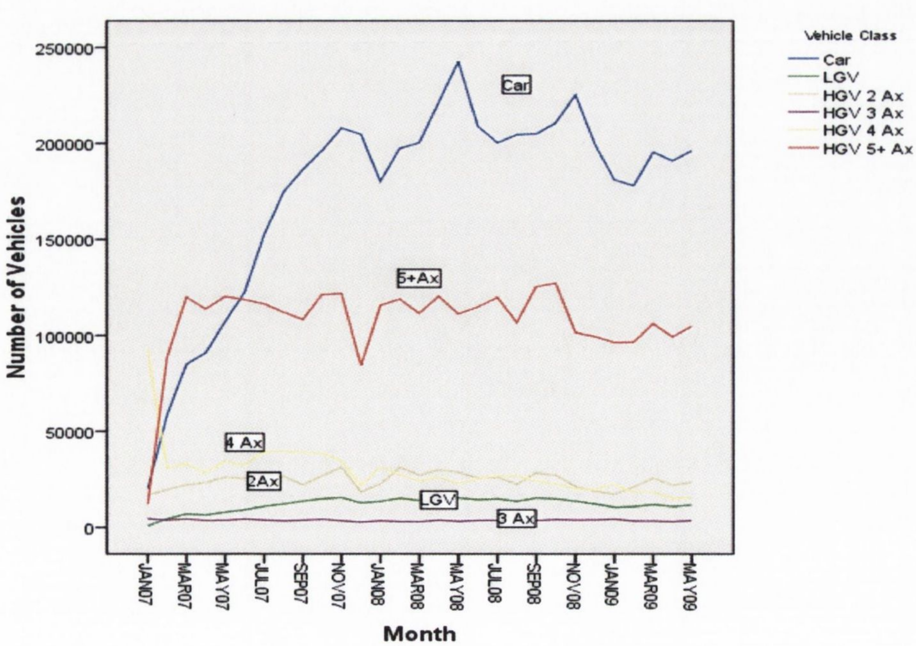


Figure 4.13: Extent of Use of Dublin Port Tunnel from January 2007- May 2009

4.5.2 Eastlink Toll Bridge

The introduction of DPT and the HGV Management Strategy also has implications for the Eastlink Toll Bridge. This is due to the fact that because the HGV Strategy as agreed by Dublin City Council in April 2006 effectively puts in place a closed cordon around both the North and South Port Areas, hauliers moving between the two parts of the port have to pay a toll during the hours of operation of the HGV Strategy as there is no alternative route available to them. The Eastlink toll rebate scheme was then introduced to coincide with the introduction of the HGV Strategy in the cordon area. However, in theory, it is possible for five axle plus vehicles to use the Eastlink Toll Bridge to access the South of the city (particularly the South East) and claim a rebate. This is a loophole in the rebate system and potentially leaves the system open to abuse. Figure 4.14 below demonstrates the extent of use of the Eastlink Toll Bridge from January 2007 to May 2009. Monthly statistics from the toll bridge were acquired from NTR, the current operators of the bridge.

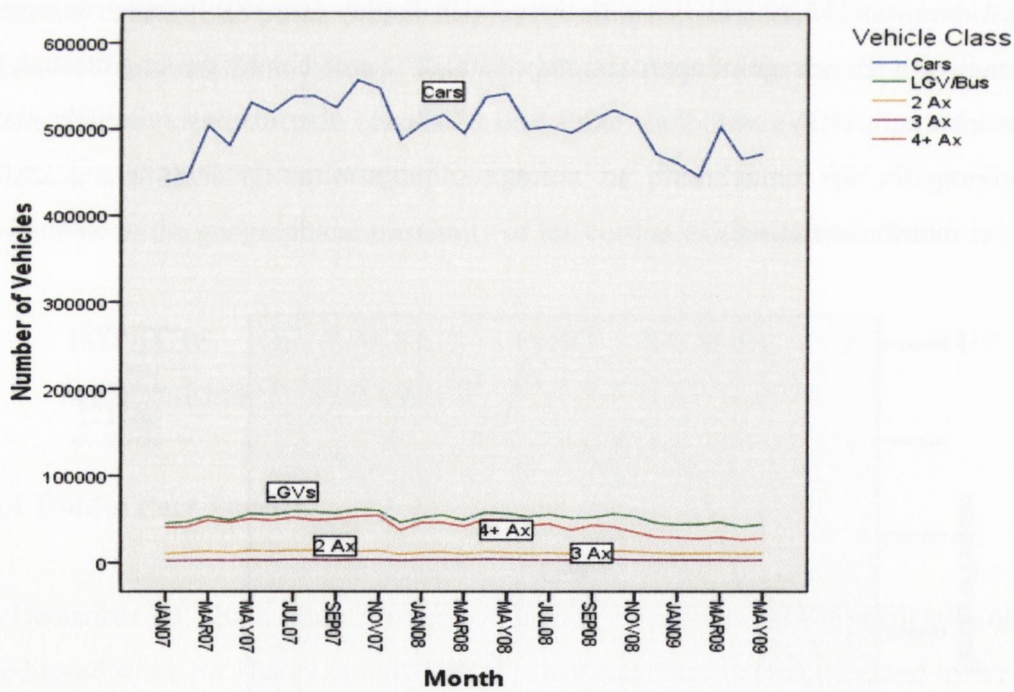


Figure 4.14: Extent of Use of the Eastlink Toll Bridge from January 2007 to May 2009

Figure 4.14 illustrates the level of use of the Eastlink Toll Bridge by five different vehicles classes. Cars constitute the vehicles class most prevalent on the toll bridge. In January 2007, approximately 440,000 cars passed through the toll bridge. The peak month for cars to date occurred in November 2007 when approximately 557,000 cars used the facility. More recently in May 2009, this figure had dropped to 470,000. For the LGV/Bus classification, the peak month occurred in October 2007 when 61,223 of these vehicles used the toll bridge. This is in sharp contrast to January 2007 figures and May 2009 figures when 45,000 and 43,923 respectively of these vehicles used the toll bridge. HGVs using the toll bridge are classified in three categories- two axles, three axles and four plus axles. The peak month for two and three axle HGVs occurred in September 2008 and April 2008 with 15,672 and 4,083 vehicles respectively. As the classification system for the toll bridge does not differentiate between four, five and five plus vehicles, it is not possible to show conclusively that the introduction of the Eastlink Rebate Toll Scheme has led to an increased number of five plus axle vehicles using the toll bridge and therefore potentially taking advantage of the rebate to access the south of the city. However Figure 4.14 shows an increase in the number of four plus axle vehicles over the period January 2007 to November 2007. This increase of 34% represents an additional 13,860 vehicles in this class using the toll bridge. Furthermore, it is noted in the six month review of the HGV Management Strategy by Dublin City Council (Dublin City Council, 2007) that " it is clear that there has been a substantial increase in vehicles crossing the Eastlink Bridge". While economic factors have played their part in an overall reduction in traffic levels in the city, it is vital that Dublin City Council continue to monitor the levels of four plus axle vehicles using the Eastlink Toll Bridge. Furthermore, the toll bridge itself reverts back to Dublin City Council ownership in 2012. In the longer term, this puts the local authority in a stronger position to implement more stringent measures to ensure that the toll rebate scheme for the Eastlink is not open to abuse. One simple measure that the local authority could implement is a definitive classification system, which differentiates between four, five and five plus axle vehicles.

4.5.3 Truck Volumes Using the City Streets

Dublin City Council installed axle counters at five locations in the city prior to the opening of the Dublin Port Tunnel in order to ensure that accurate and timely information was available regarding HGV volumes in the city. Figure 4.15 below illustrates the location of the axle counters. Three of the counters are located on East Wall Road (AC1), North Wall Quay (AC3), Sean Moore Road (AC2) covering the majority of the entry and exit points to Dublin Port. The remaining two axle counters are located on the north and south quays at Arran Quay (AC4) and Essex Quay (AC5) respectively.

In order to acquire the data from the axle counter database maintained by Dublin City Council, a number of SQL queries were set up. These queries related to monthly volumes detected at each axle counter categorised by time of day. Due to the fact that a record of each vehicle passing through the axle counter zone is stored in the database, the queries took a half a day to produce output in some cases indicating the volumes of data involved.

In order to carry out a full assessment of the impacts of the DPT and the HGV Management Strategy on truck volumes on the city streets, the axle counter data was assessed using three distinct categories of time:

1. Over 24 hour periods, overall number of HGVs
2. Over cordon hours from 07:00 to 19:00
3. Outside cordon hours from 19:00 to 07:00.

This was done in order to obtain a full picture of the impacts of the DPT and HGV Management Strategy on haulier behaviour in the city

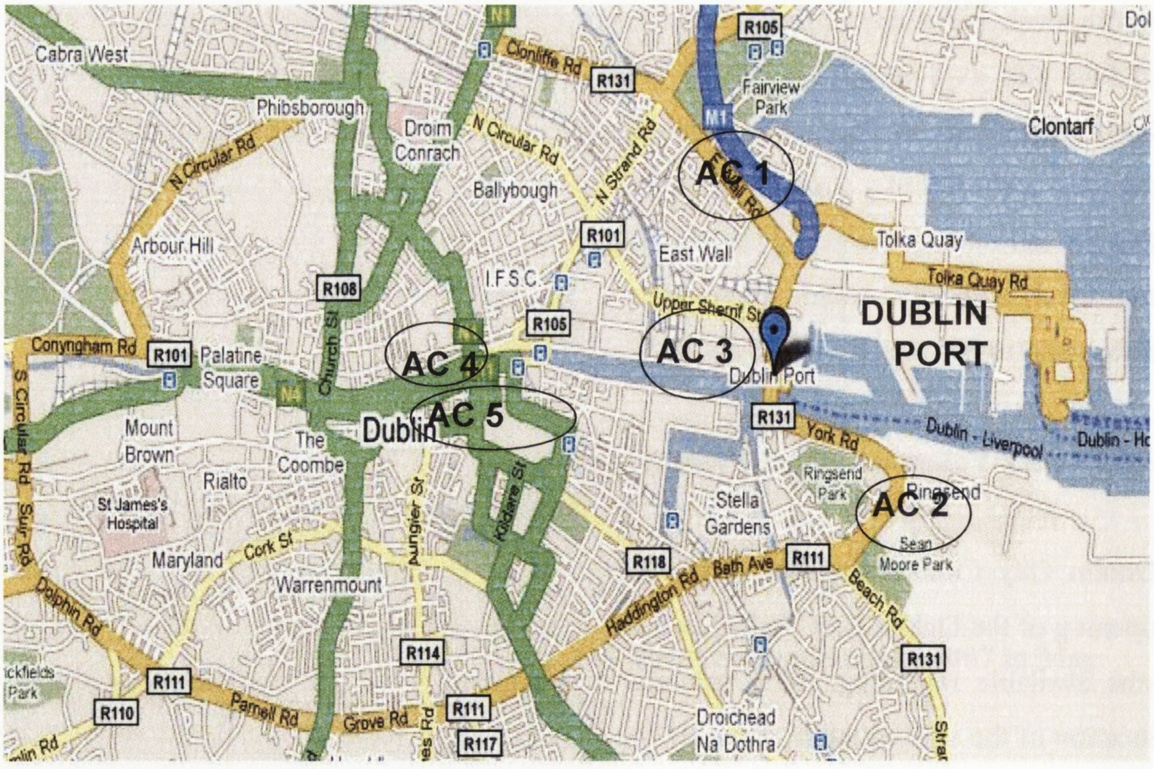


Figure 4.15: Location of the Five Axle Counters in Dublin City Centre

4.5.4 24 Hour Period: Overall Number of HGVs

Table 4.22 below outlines the overall changes in percentage terms from 2006 to immediately post Dublin Port Tunnel (DPT) and also from 2006 to directly post HGV ban. All of the axle counters displayed reductions in the number of five plus axle vehicles immediately following the opening of the DPT. These reductions ranged from 13% for Sean Moore Road to 80% for East Wall Road. Arran Quay, Essex Quay, and North Wall Quay experienced reductions of 24%, 26% and 30%. Following the introduction of the HGV ban there was a further incremental decrease in the number of five plus axle vehicles detected at these axle counter sites. The greatest overall reduction following the introduction of the HGV ban occurred at Sean Moore Road where there was an incremental reduction of 52%. Arran Quay, Essex Quay and North Wall Quay also demonstrated considerable incremental reductions in five plus axle traffic with reductions of 45%, 44% and 43% respectively. East Wall Road experienced a further drop of 10% in the number of five plus axle vehicles detected. These statistics reinforce the need for the HGV Management Strategy to optimise usage of the DPT. Without the HGV ban, it is likely that vast numbers of HGVs would continue to use the streets of the city centre to access the port despite the presence of the DPT. Statistics in Table 4.22 point to a continuing trend of reductions in the numbers of five plus axle vehicles in the city centre on a year by year trend. All of the axle counters show further reductions from 2007 to 2008 and from 2008 to 2009. The exception to this is East Wall, which experiences a 0% change from 2007 to 2008. While there is an argument that further decreases in vehicle numbers over the past twelve months is linked to current economic difficulties and not necessarily to the HGV ban, it is still fair to say that the combination of the DPT and HGV Management Strategy has brought about dramatic change in the overall number of large HGVs on the streets of the city.

While the immediate focus of the output from the axle counters was the impacts of the DPT and HGV ban on five plus axle figures, valuable information regarding three and four axle vehicles is also provided from the counters. Information regarding three and four axle vehicles is of interest in order to ascertain whether organisations have reconfigured delivery fleets with smaller HGVs in order to facilitate city centre deliveries.

In general, using the axle counters as a guide, there is a trend towards a reduced number of four axle HGVs in the city centre. Arran Quay, Essex Quay, East Wall, North Wall

Quay and Sean Moore Road all display reductions in the number of four axle vehicles detected post DPT and post HGV ban. Reductions on 2006 figures following the opening of the DPT and the HGV ban for these locations are 39%, -1%, -76%, -12% and –16% respectively. The trend of reduced numbers of four axle vehicles continues across the five counter locations for the years 2007-2008 and 2008 to 2009.

With regard to three axle HGVs, there is also a trend towards reduced numbers on the streets around Dublin Port. The axle counters on the main entry and exit points to the port, East Wall, North Wall Quay and Sean Moore Road have all experienced reductions of 11%, 55% and 6% respectively in the numbers of three axle vehicles detected. The counters in the core of the city centre, Arran Quay and Essex Quay have experienced increases in the number of three axle HGVs in the order of 90% and 27% respectively. This represents an additional 90 three-axle trucks using Arran Quay daily and suggests a movement towards the use of smaller trucks for deliveries in the city centre.

		3 Axles	4 Axles	5+ Axles
Arran Quay	06 to Post DPT	-36%	-16%	-24%
	06 to Post HGV Ban	-33%	-39%	-69%
	06 to 09	27%	-73%	-79%
	07-to 08	92%	-14%	-13%
	08 to 09	33%	-21%	-18%
	07 to 09	90%	-48%	-44%
Essex Quay	06 to Post DPT	-8%	6%	-26%
	06 to Post HGV Ban	6%	-1%	-70%
	06 to 09	31%	-47%	-81%
	07-to 08	11%	-28%	-29%
	08 to 09	-2%	-28%	-34%
	07 to 09	27%	-45%	-50%
East Wall	06 to Post DPT	-34%	-66%	-80%
	06 to Post HGV Ban	-46%	-76%	-90%
	06 to 09	-56%	-79%	-89%
	07-to 08	-5%	-5%	0%
	08 to 09	-22%	-44%	-43%
	07 to 09	-11%	-24%	-33%
North Wall Quay	06 to Post DPT	-10%	1%	-30%
	06 to Post HGV Ban	0%	-12%	-73%
	06 to 09	62%	-87%	-91%
	07-to 08	-17%	-40%	-35%
	08 to 09	-61%	-71%	-64%
	07 to 09	-59%	-82%	-76%
Sean Moore Road	06 to Post DPT	-6%	-5%	-13%
	06 to Post HGV Ban	1%	-16%	-65%
	06 to 09	-2%	-59%	-78%
	07-to 08	-15%	-25%	-20%
	08 to 09	0%	-42%	-38%
	07 to 09	-6%	-53%	-47%

Table 4.22: Change in Axle Counter Figures from 2006 to Post DPT, from 2006 to Post HGV Ban, from 2006 to 2009, from 2007 to 2008, from 2008 to 2009 and from 2007 to 2009 for 24 Hour Period

4.5.5 Number of HGVs in the City During Cordon Hours of 07:00 to 19:00

Table 4.23 below outlines the overall changes in percentage terms from 2006 to immediately post Dublin Port Tunnel (DPT) and also from 2006 to directly post HGV ban during cordon operation hours of 07:00 to 19:00. There is a blanket reduction across all cordon counter locations on the number of five axle plus HGVs. Initially following the opening of the DPT, the reduction for Arran Quay, Essex Quay, East Wall, North Wall Quay and Sean Moore Road was 4%, 20%, 81%, 25% and 6% respectively. The incremental impact of the HGV ban was dramatic during the cordon operation hours. For Arran Quay and Essex Quay located in the core of the city centre, the incremental decrease following the HGV ban was 71% and 65% respectively. For the remaining counters located on the entry and exit points to Dublin Port, the incremental reduction was 11%, 59% and 73% for East Wall, North Wall Quay and Sean Moore respectively. Again, similar to the statistics for the 24 hour period, the incremental benefits of the HGV ban again serve to reinforce the importance of a two-tiered approach for managing urban freight. The reductions in the number of five plus axle HGVs recorded at this counter locations have continued when volumes are compared from 2007 to 2008 and from 2008 to 2009. For Arran Quay and Essex Quay, reductions of 21% and 33% were found from 2007 to 2008 and further reductions were noted of 19% and 28% from 2008 to 2009. For East Wall, North Wall Quay and Sean Moore Road, reductions for the period 2007 to 2008 of 11%, 39% and 20% respectively were found. For the period 2008 to 2009, reductions of 46%, 64% and 38% respectively were identified. The reduction in the number of five plus axle HGVs during cordon operation hours highlights the success of the DPT and the HGV ban. Further reductions in vehicles in the last twelve months are likely to be related to current economic difficulties. For this reason, it is vital that Dublin City Council monitors the numbers of five plus axle HGVs closely over the next number of years to ensure that the volumes in the city do not increase as the economy begins to recover.

For four axle vehicles, the data indicates a general reduction in the numbers of vehicles in this category present on the city's streets between 07:00 and 19:00. Arran Quay, East Wall, North Wall Quay and Sean Moore Road all experienced reductions in 4 axle HGV traffic upon the opening of the DPT and had further incremental reductions following the HGV ban implementation. Reductions following the implementation of the HGV were 36%, 74%, 10% and 14% for the aforementioned counter locations respectively. This trend towards reduced usage of four axle HGVs in the city has continued for the periods 2007 to 2008 and 2008 to 2009. In particular, reductions along East Wall and North Wall Quay have been as high as 46% and 71% for the period 2008 to 2009. Essex Quay on the other hand initially displayed increasing trend for the number of four axle vehicles detected during cordon hours. Increases of 14% and 4% were found following the opening of the DPT and the implementation of the HGV ban respectively. In the last two years, this trend has been reversed with reductions of 29% and 30% for 2007-2008 and for 2008-2009 respectively. Again, it is worth emphasising that this trend may be attributable to current economic circumstances and is not necessarily directly linked to the HGV Management Strategy.

The increased use of smaller HGVs on Essex Quay is also noted in an assessment of the volume of three axle vehicles detected at this counter location. An increase of 19% in three axle vehicles is found at this location following the HGV ban. Although a comparison of 2008 and 2009 volumes points to a decrease of 4%, it cannot be taken for granted that this is primarily due to the HGV Management Strategy. This is reinforced by the increase found in three axle vehicles detected on Arran Quay from 2007 to 2008 and from 2008 to 2009 of 34% and 40% respectively. The counters close to Dublin Port, on the other hand show decreases in the number of vehicles in this class detected across the board. The increased use of smaller HGVs along Essex Quay and Arran Quay is a trend, which Dublin City Council should be monitoring.

		3 Axles	4 Axles	5+ Axles
Arran Quay	06 to Post DPT	-32%	-6%	-4%
	06 to Post HGV Ban	-29%	-36%	-75%
	06 to 09	29%	-73%	-85%
	07-to 08	34%	-12%	-21%
	08 to 09	40%	-18%	-19%
	07 to 09	87%	-49%	-56%
Essex Quay	06 to Post DPT	4%	14%	-20%
	06 to Post HGV Ban	19%	4%	-85%
	06 to 09	43%	-51%	-89%
	07-to 08	1%	-29%	-33%
	08 to 09	-4%	-30%	-28%
	07 to 09	25%	-49%	-54%
East Wall	06 to Post DPT	-30%	-64%	-81%
	06 to Post HGV Ban	-43%	-74%	-92%
	06 to 09	-60%	-79%	-94%
	07-to 08	-5%	-3%	-11%
	08 to 09	-26%	-46%	-46%
	07 to 09	-19%	-24%	-48%
North Wall Quay	06 to Post DPT	-3%	4%	-25%
	06 to Post HGV Ban	8%	-10%	-84%
	06 to 09	-60%	-89%	-95%
	07-to 08	-20%	-41%	-39%
	08 to 09	-63%	-71%	-64%
	07 to 09	-63%	-83%	-80%
Sean Moore Road	06 to Post DPT	-2%	1%	-6%
	06 to Post HGV Ban	3%	-14%	-79%
	06 to 09	-13%	-56%	-87%
	07-to 08	-16%	-23%	-23%
	08 to 09	-12%	-41%	-38%
	07 to 09	-19%	-52%	-52%

Table 4.23: Change in Axle Counter Figures from 2006 to Post DPT, from 2006 to Post HGV Ban, from 2006 to 2009, from 2007 to 2008, from 2008 to 2009 and from 2007 to 2009 for Cordon Hours (07:00-19:00)

4.5.6 Number of HGVs in the City During Cordon Hours of 19:00 to 07:00

One of the potential impacts of the HGV Management Strategy was a substantial movement by hauliers and organisations delivering within the cordon area towards night-time deliveries. This potential substantial shift in haulier delivery behaviour was the motivation for assessing the number of HGVs detected by the axle counters during the hours of 19:00 to 07:00. Table 4.24 below displays the percentage change in HGV volumes across different time periods for three, four and five plus axle vehicles. The fear of a potential shift to out of cordon hours deliveries instead of using the DPT appears to be unfounded. Again, dramatic reductions in five plus axle HGVs were found for all five counters upon the opening of the DPT and the implementation of the HGV ban. Overall reductions were found in five plus axle HGVs following the HGV ban for Arran Quay, Essex Quay, East Wall, North Wall Quay and Sean Moore Road of 62%, 44%, 86%, 50% and 26% respectively were found. Further reductions were identified from 2007 to 2008 and from 2008 to 2009 for Arran Quay, Essex Quay, North Wall Quay and Sean Moore Road. East Wall showed a slight increase of 3% from 2007 to 2008. However this trend was reversed the following year with a reduction of 41%.

A significant decrease in four axle vehicles was also found following assessment of the axle counter figures. The opening of the DPT coincided with a decrease in four axle vehicle volumes at all five counter locations between 19:00 and 07:00. This decrease ranged from 8% (North Wall Quay) to 33% (Arran Quay). A decrease in four axle HGVs figures has continued across 2008 and 2009 as Table 4.24 shows.

The number of three axle HGVs also decreased at all five counter locations following the opening of the DPT. Reductions of 45%, 35%, 47%, 28% and 27% were found at Arran Quay, Essex Quay, East Wall, North Wall Quay and Sean Moore Road respectively. Some increases over time of vehicles in this class have been found, particularly at Arran Quay, which experienced an increase of 89% in volumes of three axle vehicles between 19:00 and 07:00. While this is something Dublin City Council should be noting, it is not necessarily something to be unduly concerned about. The principle concern of the Dublin City Council is to ensure that hauliers are not using the time period from 19:00 to 07:00 to make deliveries using five plus axle HGVs instead of using the DPT and following assessment of the axle counter data, it can be stated categorically that there is evidence that this is not occurring.

		3 Axles	4 Axles	5+ Axles
Arran Quay	06 to Post DPT	-45%	-33%	-48%
	06 to Post HGV Ban	-43%	-43%	-62%
	06 to 09	22%	-74%	-71%
	07-to 08	89%	-17%	-3%
	08 to 09	15%	-27%	-17%
	07 to 09	106%	-46%	-28%
Essex Quay	06 to Post DPT	-35%	-24%	-37%
	06 to Post HGV Ban	-25%	-17%	-44%
	06 to 09	2%	-32%	-66%
	07-to 08	14%	-19%	-21%
	08 to 09	5%	-21%	-36%
	07 to 09	37%	-24%	-38%
East Wall	06 to Post DPT	-47%	-79%	-77%
	06 to Post HGV Ban	-57%	-83%	-86%
	06 to 09	-40%	-77%	-81%
	07-to 08	-1%	-16%	3%
	08 to 09	0%	-35%	-41%
	07 to 09	29%	-24%	9%
North Wall Quay	06 to Post DPT	-28%	-8%	-41%
	06 to Post HGV Ban	-17%	-19%	-50%
	06 to 09	-66%	-84%	-83%
	07-to 08	-8%	-38%	-27%
	08 to 09	-55%	-73%	-64%
	07 to 09	-49%	-79%	-69%
Sean Moore Road	06 to Post DPT	-27%	-28%	-35%
	06 to Post HGV Ban	-9%	-24%	-26%
	06 to 09	47%	-67%	-53%
	07-to 08	-9%	-33%	-8%
	08 to 09	63%	-47%	-38%
	07 to 09	75%	-58%	-28%

Table 4.24: Change in Axle Counter Figures from 2006 to Post DPT, from 2006 to Post HGV Ban, from 2006 to 2009, from 2007 to 2008, from 2008 to 2009 and from 2007 to 2009 for Outside Cordon Hours (19:00-07:00)

4.5.7 Remaining Numbers of HGVs in the City

Having analysed the impact of the DPT and the HGV ban on the number of HGVs in Dublin City Centre, it is worth highlighting the number of five plus axle HGVs that are still present on the city's streets. The last recorded month of data downloaded from the axle counters for the purposes of this thesis was April 2009. Table 4.25 below shows the number of five plus HGVs detected at each counter in total, for the cordon period and outside cordon hours.

Location	Total Number	Number Between 07:00 and 19:00	Number Between 19:00 and 07:00
Arran Quay	4394	2659	1735
Essex Quay	5222	3339	1983
East Wall	3363	2044	1399
North Wall Quay	4624	2947	1677
Sean Moore Road	2695	1538	1167

Table 4.25: Number of Five Plus Axle HGVs at Each Axle Counter Location in April 2009

In addition to the axle counter data, Dublin City Council also conduct annual traffic counts at 33 locations around cordon formed by the Royal and Grand Canals. The counts are conducted during the Month of November each year. Three full year's cordon counts was obtained from Dublin City Council for analysis. The number of goods vehicles entering the canal cordon between 07:00 and 10:00 has decreased from 2291 in 2006 by 37% in 2007 to 1445 and by a further 15% to 1223 in 2008 (Dublin City Council, 2009).

A further assessment of the number of HGVS still present in the cordon area was carried out by extracting the number of five plus axle inbound movements for key traffic count points that also constitute cordon entry/exit points or are very close to cordon entry/exit points. The locations of North Wall Quay, St John's Road, Navan Road and Binns Bridge (close to the Drumcondra Road Lower cordon point) were selected as these were also featured earlier as frequently used cordon points in Section 4.4.9. It was found that at North Wall Quay, inbound five plus axle vehicle numbers decreased from 1275 in 2006 to 175 in 2007 with a further decrease to 108 in 2008. At St. John's Road the number of inbound five plus axle vehicles decreased from 979 to 31 in the period from 2006 to 2007.

This figure increased marginally to 44 in 2008. At Navan Road, year on year decreases were found from 178 in 2006 to 34 in 2007 and 12 in 2008. Finally at Binn's Bridge (close to Drumcondra Road cordon point), significant decreases were also noted from 147 in 2006 to 15 in 2007 and 2 in 2008.

In total, large decreases in five plus axle vehicles have been observed on a monthly basis via the axle counters. This trend has been mirrored in the numbers of five plus axles observed in the annual canal cordon traffic counts. There are vast amounts of data available to Dublin City Council in order to put in place a structured framework for monitoring trends emerging from the HGV Management Strategy. However, to date, analysis has been largely piecemeal and has been produced in response to queries from elected members and the Department of Transport. A more proactive approach to monitoring HGV trends would ensure that patterns of HGV behaviour emerging in the future are quickly identified in order to ensure that decrease observed in the number of large HGVs on the city's streets continues in the long term.

4.5.8 Impact of the HGV Management Strategy on Non-HGV Traffic

One of the risks of freeing up road space previously used by large HGVs is that private traffic will utilise this newly available space and the numbers of cars entering the cordon could potentially increase dramatically in line with the HGV reduction. Having ascertained that the two-tiered approach for managing urban road freight in Dublin using the Dublin Port Tunnel and the HGV Management Strategy has brought about significant reductions in the numbers of HGVs access the city's streets, it is also important to evaluate the effects on non-HGV traffic. This is done using the annual Dublin City Council Canal Cordon Traffic Count data. Table 4.26 below shows the Canal Cordon Counts for 2006, 2007 and 2008 from 07:00 to 10:00 for cars and taxis inbound. The table illustrates that there was an increase of 3% in the number of cars entering the canal cordon between 2006 and 2008. This suggests that the road space freed up by the reduced number of five plus axle HGVs has been filled by private commuter traffic. This points to a missed opportunity by Dublin City Council to take advantage of this recently freed up road space in the network for public transport or for cycling.

LOCATION	2006	2007	2008
Ringsend Rd	1738	1715	1867
Mount St Bridge	1601	1913	1860
Baggot St Bridge	2161	2179	2083
Leeson St Bridge	3924	3627	3786
Charlemont St Bridge	1511	1294	1447
Rathmines Rd	2076	2127	1954
Harolds Cross Bridge	2972	2972	2976
Sallys Bridge	2150	2176	1895
Dolphins Barn Bridge	2572	2731	2942
South Circular Rd	1491	1751	1899
Old Kilmainham	1845	2060	2107
St Johns Rd West	2876	2699	2767
Conyngham Rd	2206	2702	2683
Blackhorse Avenue	2376	2292	2306
Old Cabra Rd	1410	1505	1660
New Cabra Rd	1369	1268	1386
Phibsborough Rd	2774	2911	2741
Drumcondra Rd	5079	5466	5442
Clarke's Bridge	3958	4419	4260
Newcomen Bridge	3014	3251	3315
Grand Canal St Bridge	1615	1727	1615
Huband Bridge	459	450	437
Herberton Bridge	2122	2259	2320
Kilmainham Lane	432	294	669
Annamoe Rd	711	656	619
Charleville Rd	699	721	660
Royal Canal Bank	263	35	38
Russel St Bridge	1313	1310	1162
Ossory Rd	405	217	205
Sheriff St Lwr	1406	1341	1521
North Wall Quay	1202	887	979
TOTAL	59730	60955	61601
% CHANGE 2006-2009	3%		
% CHANGE 2006-2007	2%		
% CHANGE 2007-2008	1%		

Table 4.26: Canal Cordon Inbound Car/Taxi Counts for 2006, 2007 and 2008

4.6 COMPLIANCE ISSUES

To date, An Garda Siochana (Irish Police Force) has recorded over 150 truck drivers for violations of the HGV cordon. However, information is unavailable from the police force regarding the number of charges brought against HGV drivers in violation of the permit system.

Dublin City Council itself uses an ad-hoc approach for checking the compliance of HGVs with the permit system. HGV vehicle registration plates are crosschecked with the permit system in response to queries from members of the public and the Dublin Cycling Campaign. An Automatic Number Plate Recognition (ANPR) system is in place on North Wall Quay. This ANPR system is also linked to axle counting equipment at the same location. This system is accessed at various times by Dublin City Council staff to check permit details for five plus axle HGVs captured on the system. When a HGV is found that does not have a permit, a letter of warning is sent to the company associated with the vehicle. A copy of this letter can be seen in Appendix C. The letter simply states that Dublin City Council has noted the presence of the vehicle in the cordon area on a particular date without a permit. The letter requests that the company get in contact to discuss the issue. To date 93 such letters have been issued (Dublin City Council, 2009c). Although the letter restates the penalties for breaches of cordon conditions, no details of the letters sent have been sent onto the police force.

A one-week survey has also been undertaken to ascertain compliance levels of five plus axle HGVs on North Wall Quay with the permit system (RTE, 2009). North Wall Quay is an important route for HGVs travelling to and from Dublin Port. It was found that 81% of vehicles travelling along this route were in compliance with the permit system. While this figure is high and points to a general adherence to the HGV Management Strategy by HGV drivers, there has been no cordon wide survey of compliance undertaken by Dublin City Council. A survey of this kind should be carried out bi-annually and publicised to ensure that HGV drivers are aware that the HGV movements are being monitored regularly.

4.7 COSTS OF THE DUBLIN PORT TUNNEL AND HGV MANAGEMENT STRATEGY

The final cost of the Dublin Port Tunnel (DPT) is estimated to be €751 million (NRA, 2006). However, this cost is the total cost of the infrastructure and aside from regular maintenance and barring unexpected events, it is not anticipated that the DPT will require further significant financial outlay from Dublin City Council or indeed the Exchequer. The HGV Management Strategy on the other hand is a long-term policy implemented by Dublin City Council and as such has resulted in both initial outlay costs incurred at the outset and also additional ongoing costs.

Costs incurred as part of the development and implementation of the HGV Management Strategy include (Dublin City Council, 2009a)

- Computer Services (Design of the online system by consultant)
- Computer Hardware/Software
- Legal expenses
- Survey
- CCTV installation
- Construction/Refurbishment Materials
- Purchase of tools and equipment
- Purchase of plant and machinery
- Electrical repairs and maintenance
- Other miscellaneous costs

In total, the cumulative costs for the HGV Management Strategy up to August 31st 2009 total €1,949,778. Budgeted costs allocated for the project totalled €400,000. The total income received via grants, national funding from the Department of the Environment and receipts from permits is €1,670,079. Permit receipts alone produced €570,079. This has led to a budget deficit of €279,699.

The budget deficit is further exacerbated by the costs of the Eastlink Toll Rebate Scheme. For the first six months of the Strategy rebates totalled €200,000, costing an average of €33,333 per month. For the first nine months of the Strategy the cost per month of rebates had risen to €42,778 per month. The cumulative cost of the rebates from March 2007 up to the end of August 2009 was €1,567,405, representing an average cost per month of €52,246. The increasing costs of monthly rebates is extremely worrying for the long term viability of the HGV Management Strategy. While the Eastlink toll bridge will revert to the ownership of Dublin City Council in 2012, the fact remains that the local authority will continue to incur significant monthly costs arising from the loose implementation of the rebate system. The ability of Dublin City Council to continue to meet this considerable monthly financial demand is constrained in the current economic environment where local authority budgets are already under pressure. While the DPT is the primary tool for removing large HGVs from the streets of the city centre, the HGV ban has contributed to a further incremental reduction in the overall volumes of these HGVs.

As pointed out in Section 4.5.2 and Section 4.4.9.1, there are trends observed that point to the exploitation of the rebate scheme by vehicles using the toll bridge to access the south of the city rather than to access the south port as originally intended by Dublin City Council. This is a potentially serious source of revenue loss for the Council. Currently hauliers are simply required to produce a record of toll payment (provided by the toll operator). There is currently no requirement for hauliers claiming a rebate to provide evidence of a requirement to access the south (or north) port.

Clearly, the long term costs of the HGV Management Strategy must be addressed to ensure its continued viability. The existing rebate loophole is an obvious starting point for Dublin City Council.

4.8 DISCUSSION

The implementation of a two-tiered approach for managing HGVs in Dublin via the Dublin Port Tunnel and the HGV Management Strategy represents an innovative step in the field of urban freight. In total, over a two year time period from May 2007 to May 2009, over 94,000 permits have been issued, 80,000 of which relate to delivery (stop) permits. The chapter sets out in detail the statistics and trends behind these permits. The analysis described is based on outputs from a database developed as part of the thesis and imported into SPSS. This database was created using flat text files acquired from the Permit System itself as input. The online nature of the Permit System has proved to be a rich resource for data regarding urban freight movements in Dublin. Permit trends observed include issues such as the level of advanced planning of permits, the age profile of the vehicle fleet used for deliveries and the number of deliveries per permit. It was found that 88% of permits are acquired either on the day they are needed or one day in advance. Vehicles recorded in the permit system have a reasonably young age profile with 85% of the total aged nine years or less. The majority of permits (61%) are used for one delivery stop.

The nature of organisations receiving deliveries is also of interest in this chapter. It is observed from the data analysis that retail, construction and wholesale companies are the dominant organisational types for permit applications.

A full assessment of the journeys undertaken for each delivery trip is carried out. Each delivery to the cordon area has an entry and exit point. The most frequently used entry and exit points are identified as North Wall Quay, South Circular Road/St John's Road, North Strand Road, Navan Road and East Wall Road. Out of 160,000 journeys recorded on the Permit System, there are 7,900 individual journey types representing a particular combination of cordon entry point, premises visited and cordon exit point. Comprehensive statistical tests are carried out examining the relationship between cordon entry and exit points and the location of premises for deliveries. These tests require a full analysis of the proportion of journeys travelling through each cordon entry point with a destination in each of the six zones, which are defined as part of a zoning classification system applied to the HGV cordon area. A similar exercise is carried out in relation to cordon exit points. Chi-square tests carried out substantiate a research hypothesis that there is an association between the cordon entry and exit points used and the zones visited in the cordon for deliveries.

Analysis from the permit system is assessed in the context of other datasets. These datasets include traffic counts from the Dublin Port Tunnel, the Eastlink Toll Bridge, and annual classified traffic counts. Annual classified traffic counts indicate an increase in car traffic since the implementation of the HGV ban. Furthermore, data from five axle counters located at key points in the city is also analysed. It is noted that the HGV Management Strategy has not resulted in an increase in HGVs outside of cordon operation hours. Overall, reductions in HGVs with five or more axles have been in the range of 78-91% across the five axle counter locations.

While the evidence suggests that the dual approach of the Dublin Port Tunnel coupled with the HGV Management Strategy had radically reduced the number of large HGVs on the streets of the city centre, there are a number of operational issues regarding the Strategy, which are of concern. Firstly, Dublin City Council does not have procedures in place for regular monitoring of compliance levels. Monitoring is done on an ad-hoc basis and in response to queries from members of the public and representative organisations such as the Dublin Cycling Campaign. Secondly, the costs of the Eastlink Rebate Toll Scheme threaten the long-term viability of the HGV Management Strategy. The Eastlink Rebate Scheme was introduced because the HGV Strategy imposed a closed cordon around both the North and South Port Areas. Therefore, hauliers moving between the two parts of the port would have to pay a toll during the hours of cordon operation, as there would be no alternative route available to them. However, hauliers do not have to produce evidence of travelling to the North or South Port in order to claim a rebate. As a result, Dublin City Council face considerable monthly rebate costs. The cumulative cost of the rebates from March 2007 up to the end of August 2009 was €1,567,405. The ability of Dublin City Council to continue to meet this considerable monthly financial demand is and will continue to be constrained in the current economic environment where local authority budgets are already under pressure. While the DPT is the primary tool for removing large HGVs from the streets of the city centre, the HGV ban has contributed to a further incremental reduction in the overall volumes of these HGVs and therefore its continued operation as part of the two-tiered approach for managing urban freight is essential.

4.9 CONCLUSIONS AND CONTRIBUTION TO KNOWLEDGE

Overall the two-tiered approach for managing urban freight via the Dublin Port Tunnel and the HGV Management Strategy has been a success in the first two years of operation. This success has been demonstrated on the ground by dramatic reductions in the number of five axle plus HGVs in the canal cordon area. The Permit System itself has proved to be an extremely useful resource for urban freight data in Dublin. Finally, there are some operational issues, relating to costs and monitoring which need to be addressed in order to ensure the long term viability of the HGV Management Strategy.

Contributions to knowledge in this chapter consist of the following:

- The first comprehensive analysis of the HGV Management Strategy
- The first assessment of the impacts of the rebate system, which allows hauliers to claim a refund via the Eastlink Toll Rebate Scheme, even when they are not travelling between North and South Ports.
- Evidence that hauliers have not changed their behaviour in response to the HGV Management Strategy by switching to night-time deliveries or other out of hours deliveries.

CHAPTER 5: TOWARDS A POLICY BASED PERMIT SYSTEM

5.1 INTRODUCTION

During the analysis of the HGV Management Strategy in Chapter Four, a number of key findings relating to cost were made that have implications for the long term viability of the Strategy. Firstly, a loophole in the system regarding the Eastlink Rebate Toll Scheme was identified. This loophole, which allows all five plus axle HGV traffic to claim a rebate on the toll paid for the Eastlink Bridge as opposed to just the five plus HGVs moving between the North and South Ports (the original intention) increases the annual operational cost of the HGV Management Strategy. Secondly, following a cost assessment, it was noted that the income received as part of the Strategy is far exceeded by the ongoing monthly costs imposed on the Strategy by the rebate scheme. The continuation and sustainability of the HGV Management System in its current form is questionable in the light of these findings.

This chapter sets out an innovative methodology to tackle the cost issues associated with the Strategy. To start with, an investigation to observe what type of variables may be driving the need for permits is completed. The relationships between a number of key economic factors and the number of permits issued on an annual basis were analysed. The factors considered are construction employment levels, gross domestic product (GDP) and the retails sales index (RSI). Of the factors considered, the RSI showed a strong relationship with the number of permits generated. This chapter uses this relationship to propose a means of establishing a breakeven cost position for the HGV Permit System. A key contribution of this chapter is a proposed framework for a revised permit charging structure for the HGV Management Strategy based on wider transport imperatives. This revised charging structure involves an examination of a breakeven system of pricing for permits and the development of a Policy Driven Variable Price Model (PDVPM). The PDVPM enables the implementation of a more integrated approach to transport policy in Dublin by implementing pricing signals that encourage and discourage use of particular cordons on the basis of national and local policy imperatives. The PDVPM is an innovative approach that extends the functionality of the HGV Management Strategy from a HGV traffic management tool to a wider policy reinforcement tool.

5.2 ASSESSING THE FACTORS INFLUENCING THE VOLUME OF PERMITS

Given that eleven of the top twenty organisations receiving deliveries are construction related, it is inevitable that the effects of current significant economic difficulties will also have repercussions on the number of permits issued on an annual basis. In order to establish a model that could be used to predict the number of permits in future years, three key relationships were evaluated. The first relationship involved the correlation between historic quarterly construction indicators and the number of permits issued. The second relationship involved the correlation between quarterly historic Gross Domestic Product figures and the number of permits issued and the third relationship involved the correlation between the Retail Sales Index and the number of permits issued.

5.2.1 Construction Indicator: Construction Employment

Currently the construction industry in Ireland is experiencing a sharp and painful adjustment to much lower levels of activity compared to the boom economic years. Overall investment levels in the economy in Quarter 4 of 2008 have fallen back to Quarter 4 2000 levels, following a decline of almost 20% in 2008. By the end of 2009, it is estimated that the construction industry will have shrunk to 13% of Gross National Product compared with almost 25% at the peak (DKM, 2009). One of the key indicators of construction performance is construction employment. In total, almost 53,000 direct jobs have been lost in construction between the peak (Quarter 1 2007) and Quarter 4 2008. This statistic highlights the vulnerability of the sector to the economic recession.

Figure 5.1 illustrates a downward trend for stop permit applications during the same period. In order to explore the possible reasons for this trend, a correlation exercise was carried out on quarterly construction employment levels from Quarter 3 2007 to Quarter 4 2008 with the number of permits issued for each quarter in that period. Table 5.1 below demonstrates the output of a Pearson's correlation exercise. Figure 5.1 provides a graphical illustration of the relationship between the two variables. A Pearson Correlation test statistic of 0.976, significant at the 0.01 level for a one-tailed prediction test is obtained with an associated probability of 0.001. As the correlation value reported is significantly positive, it can be inferred from the results that there is a very strong correlation between levels of construction employment and the number of delivery permits issued each quarter.

The corollary of this finding is that the economic downturn with its significant impacts on the construction industry has had a major impact on the number of permits issued. It is likely that further contraction of the construction industry, indicated by further direct job losses will have a negative impact on the number of delivery permits issued each quarter.

		QuarterlyPermit Totals	Quarterly Construction Employment
QuarterlyPermit Totals	Pearson Correlation	1.000	.976**
	Sig. (2-tailed)		.001
	N	6.000	6
Quarterly Construction Employment	Pearson Correlation	.976**	1.000
	Sig. (2-tailed)	.001	
	N	6	6.000

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.1: Correlation Between Quarterly Permit Totals and Quarterly Construction Employment over the Period Quarter 3, 2007 to Quarter 4, 2008

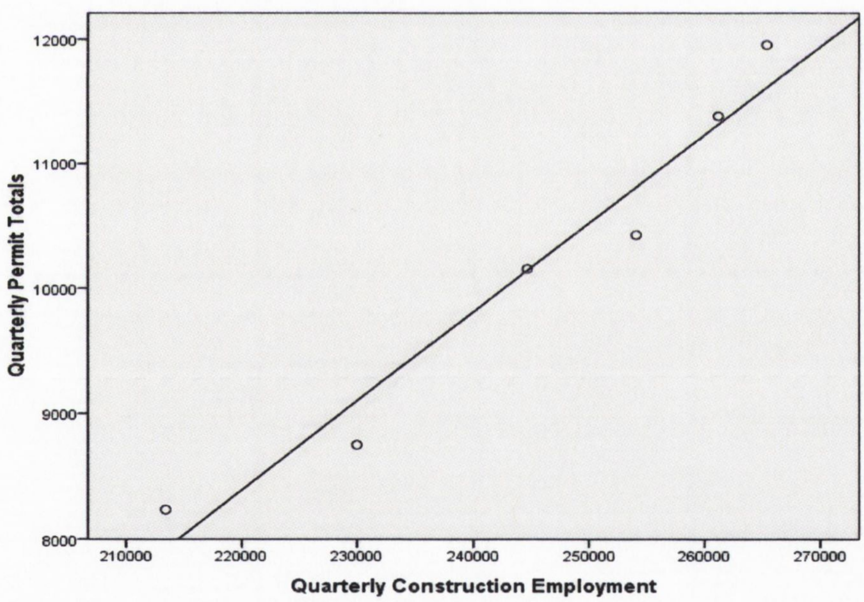


Figure 5.1: Scatterplot Demonstrating Correlation Between Quarterly Permit Totals and Quarterly Construction from Quarter 3 2007 to Quarter 4 2008

5.2.2 Economic Indicator: Gross Domestic Product

It is also important to assess the more generalised relationship between the widely recognised and accepted indicator of overall economic performance, Gross Domestic Product (GDP) and the number of stop permits issued. GDP represents the total value added (output) in the production of goods and services in the country (CSO, 2009). GDP in Ireland is calculated across a number of key sectors including:

- agriculture, forestry and fishing
- industry, building and construction
- distribution, transport and communications
- other services (including rent)

Table 5.2 below reports a Pearson Correlation test statistic of 0.750 significant at the 0.05 level for a one-tailed prediction test with an associated probability of 0.043. Figure 5.2 provides a graphical illustration of the relationship between the two variables. As the correlation value reported is significantly positive, it can be inferred from the results that there is a strong correlation between the levels of GDP and the number of stop permits issued each quarter. The corollary of this finding is that significant declines in GDP will result in reduced numbers of stop permits.

		QuarterlyPermit Totals	Quarterly_GDP
QuarterlyPermit Totals	Pearson Correlation	1.000	.750*
	Sig. (1-tailed)		.043
	N	6.000	6
Quarterly_GDP	Pearson Correlation	.750*	1.000
	Sig. (1-tailed)	.043	
	N	6	6.000

*. Correlation is significant at the 0.05 level (1-tailed).

Table 5.2: Correlation Between Quarterly Permit Totals and Quarterly Gross Domestic Product over the Period Quarter 3, 2007 to Quarter 4, 2008

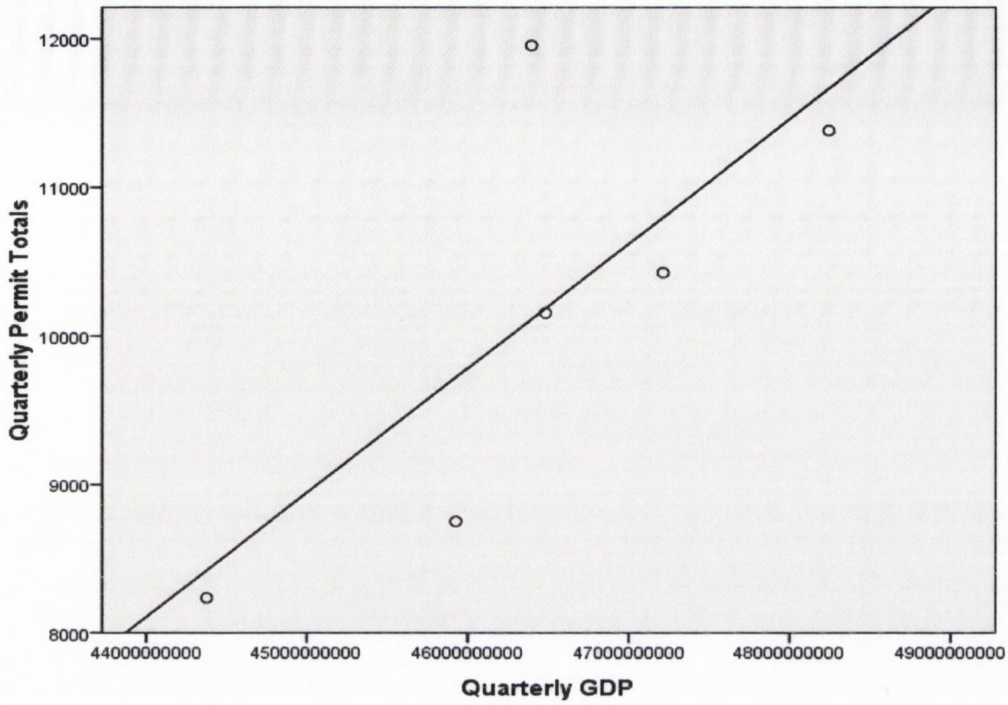


Figure 5.2: Scatterplot Demonstrating Correlation Between Quarterly Permit Totals and Quarterly GDP from Quarter 3 2007 to Quarter 4 2008

5.2.3 Retail Indicator: Retail Sales Index

The Retail Sales Index (RSI) is a national statistical index that covers, on a sample basis the retail sales of retail businesses, wholesale businesses with sizeable retailing activity and the separate sales establishments of non-distribution enterprises. The RSI essentially provides a measure of retail sales and due to the importance of deliveries for sales, it was decided to carry out an assessment of the relationship between RSI and the number of permits generated. Table 5.3 below demonstrates the strength of the correlation between the RSI quarterly volume index and the number of permits generated per quarter. A Pearson Correlation test statistic of .952 was obtained, significant at the 0.01 level for a two tailed prediction test with an associated probability of .003.

Figure 5.3 provides a graphical illustration of the relationship between the two variables. As the correlation value reported is significantly positive, it can be inferred from the results that there is a very strong correlation between the RSI volume index and the number of stop permits issued each quarter. The corollary of this finding is that significant declines overall sales reflected in a reduced RSI will result in decreased numbers of stop permits.

		QuarterlyPermit Totals	Quarterly_RSI
QuarterlyPermit Totals	Pearson Correlation	1.000	.952**
	Sig. (2-tailed)		.003
	N	6.000	6
Quarterly_RSI	Pearson Correlation	.952**	1.000
	Sig. (2-tailed)	.003	
	N	6	6.000

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.3: Correlation Between Quarterly Permit Totals and Retail Sales Index over the Period Quarter 3, 2007 to Quarter 4, 2008

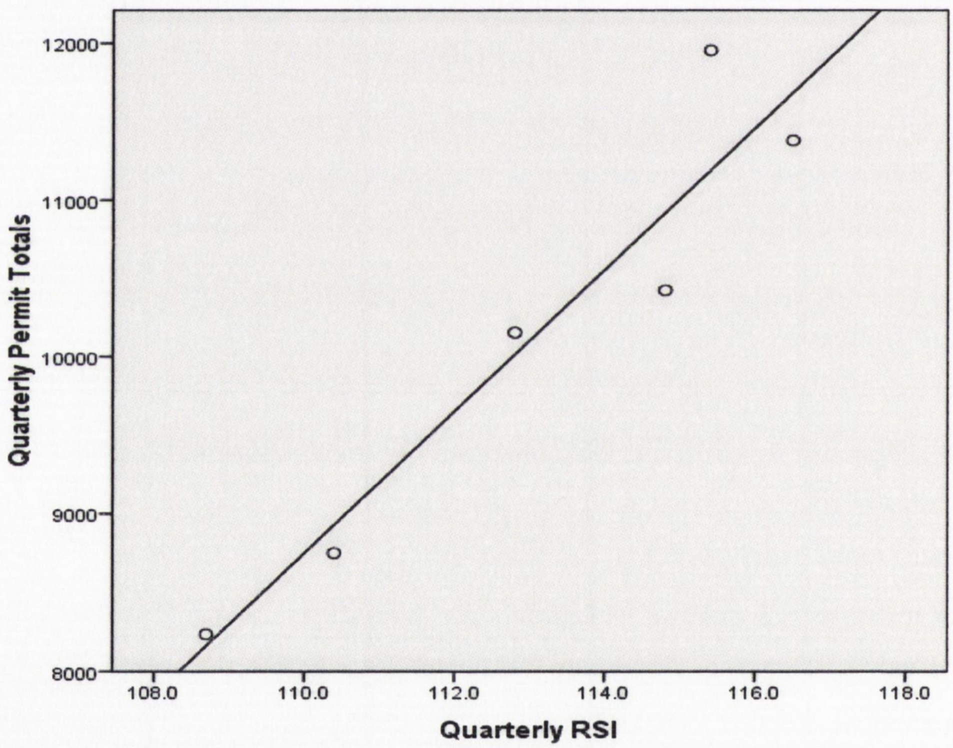


Figure 5.3: Scatterplot Demonstrating Correlation Between Quarterly Permit Totals and Quarterly Retail Sales Index from Quarter 3 2007 to Quarter 4 2008

5.3 PREDICTING THE FUTURE NUMBER OF PERMITS

Having ascertained that there is a statistically significant relationship between construction employment and the number of permits, and GDP and the number of permits, the next step is to further investigate these relationships by examining whether both variables reliably predict the number of permits. This is done using a linear regression model.

5.3.1 Using a Construction Indicator to Predict Future Numbers of Permits

The regression line equation to ascertain the future number of permits based on national construction levels of activity may be written as Y = a + bX where:

Y= predicted number of permits
a= coefficient to be calculated, measuring the intercept on the Y axis
b=coefficient to be estimated measuring the slope of the regression line
X=Number employed in construction

Tables 5.4, 5.5 and 5.6 below provide the output from SPSS of the linear regression exercise. Table 5.4 reports the Pearson Correlation Coefficient as highlighted in Section 5.2.1. The R Square Value represents the amount of variance in the number of stop permits issued per quarter that can be explained by the construction indicator. In this case, the independent variable of construction employment accounts for 83% of variance in the number of stop permits.

Table 5.5 provides details of the significance of the regression model. It is noted from the table that $F(1,4) = 19.575$, where the probability <0.05. Therefore, it can be concluded that the regression is statistically significant. This permits the development of the regression model using the coefficients output table provided in Table 5.6. The Unstandardised Coefficients B Column in Table 5.6 provide the value of the intercept (for the constant row) and the slope of the regression line (from the Quarterly Construction Employment Row). This ultimately provides the following regression equation:

Quarterly Number of Stop Permits = -8274.732 + 0.070(Quarterly Construction Employment).

Equation 5.1: Regression Equation for Permit Numbers Using Construction Employment

The regression equation was tested using permit totals for quarter one 2009 giving the following equation:

Quarterly Number of Stop Permits = -8274.732 + 0.070(181,500).

Equation 5.2: Test Regression Equation for Permit Numbers Using Construction Employment for Quarter 1 2009 Totals

This gave a value of 4471 and since permit totals for Quarter 1 2009 were 7746, it is noted that construction indicators are not an appropriate predictor for permit totals.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.976a	.953	.942	350.150

a. Predictors: (Constant), QuarterlyConstructionEmployment

Table 5.4: Linear Regression Model Output Showing Correlation Coefficient Output-Construction Employment

ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9988853.491	1	9988853.491	81.472	.001a
	Residual	490420.009	4	122605.002		
	Total	10479273.500	5			

a. Predictors: (Constant), QuarterlyConstructionEmployment

b. Dependent Variable: QuarterlyPermitTotals

Table 5.5: Linear Regression Model Output Showing the Significance of the Regression-Construction Employment

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-7215.855	1929.302		-3.740	.020
	Quarterly Construction Employment	.071	.008	.976	9.026	.001

a. Dependent Variable: QuarterlyPermitTotals

Table 5.6: Linear Regression Model Output Providing Output for the Regression Equation- Construction Employment

5.3.2 Using Gross Domestic Product to Predict Future Numbers of Permits

The regression line equation to ascertain the future number of permits based on GDP may be written as Y = a + bX where:

Y= predicted number of permits

a= coefficient to be calculated, measuring the intercept on the Y axis

b=coefficient to be estimated measuring the slope of the regression line

X=GDP

Tables 5.7 and 5.8 below provide the output from SPSS of the linear regression exercise. Table 5.7 reports the Pearson Correlation Coefficient as highlighted in Section 5.2.2. The R Square Value represents the amount of variance in the number of stop permits issued per quarter that can be explained by the construction indicator. In this case, the independent variable of construction employment accounts for 75% of variance in the number of stop permits.

Table 5.8 provides details of the significance of the regression model. It is noted from the table that F (1,4) = 5.130, where the probability of .086 >0.05. The "F" value represents the test statistic in the table. Therefore, it can be concluded that the regression is not statistically significant. This does not allow development of the regression model based on GDP.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.750[a]	.562	.452	1071.357

a. Predictors: (Constant), Quarterly_GDP

Table 5.7: Linear Regression Model Output Showing Correlation Coefficient Output-GDP

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5888050.469	1	5888050.469	5.130	.086[a]
	Residual	4591223.031	4	1147805.758		
	Total	10479273.500	5			

a. Predictors: (Constant), Quarterly_GDP

b. Dependent Variable: QuarterlyPermitTotals

Table 5.8: Linear Regression Model Output Showing the Significance of the Regression-GDP

5.3.3 Using the Retail Sales Index to Predict Future Numbers of Permits

The regression line equation to ascertain the future number of permits based on RSI may be written as Y = a + bX where:

Y= predicted number of permits
a= coefficient to be calculated, measuring the intercept on the Y axis
b=coefficient to be estimated measuring the slope of the regression line
X=Retail Sales Index

Tables 5.9, 5.10 and 5.11 below provide the output from SPSS of the linear regression exercise. Table 5.9 reports the Pearson Correlation Coefficient as highlighted in Section 5.2.3. The R Square Value represents the amount of variance in the number of stop permits issued per quarter that can be explained by the construction indicator. In this case, the independent variable of RSI accounts for 90% of variance in the number of stop permits.
Table 5.10 provides details of the significance of the regression model. It is noted from the table that F (1,4) = 38.831, where the probability <0.05. The "F" value represents the test statistic in the table. Therefore, it can be concluded that the regression is statistically significant. This permits the development of the regression model using the coefficients output table provided in Table 5.11. The Unstandardised Coefficients B Column in Table 5.11 provide the value of the intercept (for the constant row) and the slope of the regression line (from the Quarterly Construction Employment Row). This ultimately provides the following regression equation:

Quarterly Number of Stop Permits = -40,982 + 452(Quarterly RSI)

Equation 5.3 Regression Equation for Permit Numbers Using RSI

The regression equation was tested using permit totals for quarter one 2009 giving the following equation:

Quarterly Number of Stop Permits = -40,982 + 452(106.3).

Equation 5.4: Test Regression Equation for Permit Numbers Using RSI for Quarter 1 2009 Totals

This gave a value of 7066, which is within 5% of the actually total for Quarter 1 2009 (7446). Furthermore, when calibrated for 2008, the following equation is obtained:

Quarterly Number of Stop Permits = -40,982+452(111.3).

Equation 5.5: Test Regression Equation for Permit Numbers Using RSI for 2008 Totals

This gives a value of 9552, which aggregates to an annual figure of 38,208. The actual number of permits in 2008 was 37,566. Therefore the regression model was within 1.7% of the actual figure.

Although further tests of calibration for the linear regression model are required, it appears that as an overall indication of the level of national sales, the RSI offers a potential prediction model for estimating the future number of permits.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.952[a]	.907	.883	494.638

a. Predictors: (Constant), Quarterly_RSI

Table 5.9: Linear Regression Model Output Showing Correlation Coefficient Output -RSI

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9500606.627	1	9500606.627	38.831	.003[a]
	Residual	978666.873	4	244666.718		
	Total	10479273.500	5			

a. Predictors: (Constant), Quarterly_RSI

b. Dependent Variable: QuarterlyPermitTotals

Table 5.10: Linear Regression Model Output Showing the Significance of the Regression-RSI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-40982.964	8208.210		-4.993	.008
	Quarterly_RSI	452.108	72.553	.952	6.231	.003

a. Dependent Variable: QuarterlyPermitTotals

Table 5.11: Linear Regression Model Output Providing Output for the Regression Equation-RSI

5.4 DEVELOPING A BREAKEVEN COST MODEL FOR THE HGV PERMIT SYSTEM

While the HGV Management Strategy has undoubtedly contributed positively to improving the overall environment of the area within the canal cordon, the high ongoing financial costs associated with the system in the form of the Eastlink Toll Rebate Scheme are unsustainable at a practical level for Dublin City Council. There is an argument that the overall benefits of the Dublin Port Tunnel coupled with the introduction of the HGV permit system justify the ongoing expense of the rebate scheme. However while this might be true in theory, the practical reality of reduced resources for local authorities will cause schemes such as the HGV Management Strategy to move towards self-financing models in the future or risk being shelved in the long term. The development of a self-financing model also provides an incentive to introduce and reinforce a range of initiatives, which would bring about a more joined-up policy approach to transport within the canal cordon.

The starting point for the development of a self-financing model for the HGV Permit System lies in the identification of the breakeven point for the cost of a permit. Table 5.12

below sets out the actual cost for 2008, the number of permits applied for in that year and the required cost per permit in order to reach the breakeven point. The table also sets out the estimated cost, number of permits and associated breakeven cost per permit for 2009 and 2010. The first row of the table provides the actual costs for 2008 and the actual number of permits issued in that same year. A breakeven cost of €16.70 is arrived at by dividing the cost of the permit system by the number of permits. The costs included in the breakeven price specifically relate to Eastlink toll rebate costs. Capital costs have been excluded for the purposes of this analysis, as they are sunk costs that do not arise on an ongoing annual basis and may be construed as the state's contribution to the Permit System.

The second row of the table shows estimated costs and permit numbers for 2009. Again, costs were related to Eastlink toll rebates. In 2008, the average number of Eastlink Toll Trips for four plus axle vehicles was 42,326. The average cost per month of the system was approximately €52,000. A rebate of €4.24 is provided for each trip by a five plus axle vehicle. This translates into 12,265 monthly trips. This figure represents 28% of the four plus axle monthly total that receive rebates from Dublin City Council. The average number of four plus axle trips in the first five months of 2009 was 28,142. Assuming that the percentage of trips claiming rebates remains at 28% of monthly volumes, the number of estimated total trips per month claiming rebates is 7,880 (28% of 28,142). Therefore, the annual aggregated cost is €400,922 (7,880 X 12 X 4.24).

The relationship identified between the Retail Sales Index (RSI) and the number of permits in Section 5.3.3 is used to estimate the future number of permits for 2009. Again, the following linear regression model equation (Equation 5.3 from above) is used:

$$\text{Quarterly Number of Stop Permits} = -40{,}982 + 452(\text{Quarterly RSI})$$

Equation 5.6 Regression Equation for Permit Numbers Using RSI

An average of the RSI for the first two quarters in 2009 is obtained to give the following equation:

Quarterly Number of Stop Permits = -40,982 + 452(105.3)

Equation 5.6 Regression Equation for Permit Numbers Using RSI for First Two Quarters of 2009

Equation 5.6 provides a quarterly permit total of 6,613. When this is aggregated to an annual basis a total of 26,454 permits are estimated for 2009. Given that the number of permits for the first five months of 2009 totalled 12,142, this is a reasonable annual total bearing in mind seasonal fluctuations. Overall, a breakeven cost per permit of €15.15 is obtained.

Rows three, four and five of Table 5.12 show the estimated costs and number of permits for 2010. The base scenario of 2010 assumes that costs and the number of permits will remain in line with 2009 figures. This assumes that the number of HGVs receiving toll rebates is similar to 2009 figures. It also assumes that the RSI remains on average at 105.3. Since it has been demonstrated that the number of permits is closely related to the Retails Sales Index, two sensitivity tests to predict the number of permits have also been carried out for 2010 estimates. The first sensitivity test demonstrates the impact of an increase in the RSI of 2.5% and is shown in Equation 57. A total of 31,155 permits is estimated from Equation 5.7. This equates to an individual breakeven permit cost of €18.40.

Quarterly Number of Stop Permits = -40,982 + 452(107.9)

Equation 5.7: Regression Equation for Permit Numbers Using RSI-Sensitivity Test 1 (RSI +2.5%)

The second sensitivity test demonstrates the impact of a decrease in the RSI of 2.5% and is shown below in Equation 5.8. A total of 21,754 permits is estimated from Equation 5.8. This equates to an individual breakeven permit cost of €12.90.

Quarterly Number of Stop Permits = -40,982 + 452(102.7)

Equation 5.8: Regression Equation for Permit Numbers Using RSI-Sensitivity Test 1 (RSI -2.5%)

	Year	Cost	Number of Permits	Breakeven Cost Per Permit
Actual	2008	626952	37566	€16.70
Estimated	2009	400922	26454	€15.15
Estimated Base Case RSI=105.3	2010	400922	26454	€15.15
Sensitivity Test 1: Reduction of 2.5% (RSI)			21754	€18.40
Sensitivity Test 2: Increase of 2.5% (RSI)			31155	€12.90

Table 5.12: Actual and Estimated Annual Costs, Number of Permits and Breakeven Cost Per Permit for 2008, 2009 and 2010

5.4.1 Breakeven Cost per Cordon

While Table 5.12 above provides details of the breakeven cost per permit, another method exists for defining the breakeven cost of the permit system in more specific terms. Currently the charge per permit is based on an arbitrary permit price, which increases by one euro every year up to ten euro in 2012. Each permit allows up to five journeys through the cordon on a single permit. Five journeys require the input of five associated sets of cordon entries and exits into the permit system. The nature of the structure of the HGV database favours analysis by journey rather than by permit. Each journey record provides details of the cordon entry and exit selected, premises visited and the unique journey identification number. In total, there are approximately 160,000 journeys representing over 80,000 permits. In 2008, there were approximately 74,000 journeys representing 37,566 permits. Therefore, the opportunity exists to provide a journey breakdown cost and more specifically a cordon breakdown cost. In 2008 the journey breakdown cost is calculated to be €8.40. This is obtained by dividing the total cost for the year by the total journeys for the year. So, for example, the breakeven cost for a permit with two journeys is €16.80.

However, a more useful measure is the breakeven cost per cordon. Each journey on a permit must have a cordon entry and a cordon exit. In 2008 the total number of cordon entries and exits was 126,335. Therefore the breakeven cost per cordon is the annual cost divided by the total number of cordon entries and exits for the year. A breakeven cost of €4.96 is obtained. For practical reasons this is rounded up to €5. The identification of the cordon breakeven cost allows the implementation of a pricing model that can discriminate between cordons based on price. This allows the development of a Variable Pricing Driven Model for the Permit System.

5.5 DEVELOPING A POLICY DRIVEN VARIABLE PRICING MODEL (PDVPM)

While the exercise of identifying a breakeven permit cost demonstrates how far the current permit charge is from covering ongoing expenses, a blanket breakeven cost model does not allow for any innovation with regard to using the HGV Management Strategy to promote various other policies. This is where the concept of a Policy Driven Variable Pricing Model (PDVPM) comes into play. In simple terms, variable pricing essentially involves applying a positive or negative weighting factor to the identified breakeven cost. A PDVPM can be designed to reinforce certain national and local transport polices. Prices can be structured so that certain cordon entry and exits are favoured or penalised to support particular policy imperatives.

There are advantages and disadvantages of the PDVPM. The major advantage of the PDVPM is that it supports a joined-up approach to transport policy in Dublin City Centre by integrating the HGV Management Strategy with other transport polices. One disadvantage is that the pricing model does not necessarily guarantee a full recovery of all costs incurred by Dublin City Council in the operation of the Strategy. However, this may be a less important factor than achieving various other agreed policy objectives, provided it makes a reasonable contribution to the annual running cost of the permit system. It is also less important in light of the fact that the current arbitrary pricing system has already meant that Strategy costs far exceed Strategy revenues. A further disadvantage is that variable pricing by its nature requires some initial assumptions to be made about the behaviour of hauliers and other organisations delivering to the city centre. This assumption relates to the impact of cost increases and decreases on the usage of cordon points. The identification of the breakeven cost per cordon allows the implementation of three policies that require three different variable pricing strategies.

5.5.1 Policy 1: Reinforcing a National Policy: The National Cycle Policy Framework

In April 2009, the Department of Transport published Ireland's first national cycle policy (Department of Transport, 2009). In response to a trend of declining cycling numbers nationally since the 1980s, the Policy sets out a range of interventions to reverse this trend. It is stated in the Policy that measures introduced to encourage cycling need to integrate with wider transportation policies as well as other policy fields such as land -use planning, road safety and health. One particular Government objective stated in the Policy, which is of relevance to HGVs is to "Ensure that the urban road infrastructure (with the exception of motorways) is designed/retrofitted so as to be cyclist-friendly and that traffic management measures are also cyclist friendly".

In order to assess the current levels of cycling at entries and exits to the cordon, the 2008 Dublin City Council Cordon Count Data was assessed. The Cordon Count area is bounded by the Royal and Grand Canal and broadly corresponds to the HGV cordon. There are 33 different count locations and details of the number of cyclists entering the cordon area are captured as part of the overall count information. It was noted from the count information analysed that the overall number of cyclists entering the cordon has increased by 18% from 2006 to 2008. This coincides with the timing of the HGV Management Strategy and the opening of the Port Tunnel and therefore there is an argument to suggest that the reduced number of HGVS on the streets around the City Centre has already had a positive impact on the number of cyclists. Analysis of the Cordon Count Data showed that the top five entry points into the cordon on the south side for cyclists in 2008 were Portobello Bridge, Leeson Street Bridge, Harold's Cross Bridge, Charlemont Street Bridge and Baggot Street Bridge. These cordon points accounted for 7877 bicycle trips between 07:00 and 10:00. The top five entry points for cyclists into the cordon on the north side were Newcomen Bridge, Binn's Bridge, Phibsboro Road, Clark's Bridge and North Wall Quay. These cordon points accounted for 5076 bicycle trips between 07:00 and 10:00.

The National Cycle Policy Framework (Department of Transport, 2009) emphasises the potential use of demand management measures to provide a safer travelling environment for cyclists. The Policy notes "We will use demand management measures to make cities and town centres more attractive for cyclists". Accordingly, one policy that could form part of the PDVPM framework could be to encourage hauliers and other organisations delivering to the city centre using five plus axle vehicles to use cordon points away from those that are along corridors with strong bicycle use. Essentially the policy would involve a two-tiered approach. Firstly, the price of entry and exit for selected cordon points is increased in order to discourage large HGVs. Secondly, the price of other entry and exit at other points is decreased to make these points more attractive.

In the case of the south side of the city, it was noted from the permit system data that the cordon points generating high numbers of cyclists did not have a corresponding high level of five plus axle HGVS. For example, the HGV cordon points corresponding to the cordon counts at Portobello Bridge (Richmond Street), Leeson St Bridge (Leeson Street Lower), Harold's Cross Bridge (Clanbrassil Street), Charlemont Street Bridge (Charlemont Street) account for just 2% of the total number of cordon points used. Conversely, it was noted that the HGV cordon points corresponding to the cordon counts at Binn's Bridge (Drumcondra Road Lower) and Newcomen Bridge (North Strand Road) accounted for 5% and 11% of the total number of cordon points used. Therefore it was decided to introduce a pricing strategy to discourage five plus axle HGVs from the cordon points at Drumcondra Road Lower and North Strand Road. As part of this pricing strategy, it was also decided to decided to encourage five plus axles to use the cordon entry points at the Navan Road and also at Clonliffe Road/Ballybough Road. The former was selected as the next nearest cordon point to Drumcondra Road Lower with a low number of cyclists. The latter was selected due to its proximity to the North Strand cordon point.

Key features of the policy are to amend the prices of the "encouraged" cordon point and the "discouraged" cordon point. This requires subtracting a discount from the breakeven cordon cost for encouraged cordon points and adding a premium to the breakeven cordon cost for discouraged cordon points. A further important element of the policy involves assumptions regarding the change in behaviour of hauliers in terms of the cordon point used. In economic terms, this is regarded as the elasticity of the cordon point selection. Although there have been a number of studies evaluating the impacts of road pricing on the behaviour of passenger car users (e.g. Sullivan and El Harake, 1998, Supernak et al., 2003), there is a dearth of information available regarding the impacts of variable pricing in urban areas on hauliers. This is the case for a number of reasons. Firstly, the number of urban HGV pricing initiatives is very small. Secondly, because of the fragmented nature of the haulage industry, it is very difficult to collect reliable behavioural data. As a result of this, there is very limited data available regarding how hauliers react to variable pricing initiatives. However there is one useful example that examines the impacts of time of day pricing on the behaviour of freight carriers in a congested urban area (Holguin-Veras et al, 2006). The paper describes the complexity of the behavioural responses to truck pricing in New York. The project described related to Port Authority of New York and New Jersey's time of day pricing initiative on the behaviour of commercial hauliers. It was found that 15% of hauliers changed behaviour because of time of day pricing. Another significant output of the study was that carriers face significant constraints (imposed by customers) that prevent them from carrying out their deliveries outside of restricted hours. This finding suggests that the majority of organisations receiving goods do not have a compelling commercial reason to accept deliveries outside restricted operating hours. This study is of relevance to the Policy Driven Variable Pricing Model in a number of ways. Firstly, it provides a good starting point for estimating the premium charged and also the impact of that premium on traffic volumes. Secondly, the study clearly demonstrates the limitations of a variable price model based on time of day. In many cases, the time of the delivery is to a large extent driven by the customer and not the haulier. Therefore, it is unfair to charge a premium for entering the chargeable area at particular times when the haulier has limited control over those times.

The study describes the implementation of an increased truck charge from $4 to $6 during peak hours, representing a premium of 50%. The study points to a shift in behaviour of 15% of hauliers as a result of this premium. In the case of the variable pricing model for Dublin, as a reasonable starting point, a premium of 33% is applied because this is considered to be more reasonable than the New York rate in an Irish context, particularly in light of the fact that each trip into the cordon area requires an entry and an exit. Therefore, it is assumed that the cost of using a discouraged cordon is increased from €5 to €6.65. The cost of using an encouraged cordon point is reduced from €5 to €3.35. Similarly it is also assumed that there will be a 15% diversion of trucks from the discouraged cordon points to the encouraged cordon points. In the case of the discouraged cordon points for Policy 1, (Drumcondra Road Lower cordon and the North Strand Cordon), 7.5% of each of the totals using each cordon is allocated to each of the encouraged cordon points (Navan Road and Clonliffe Road). Table 5.13 below illustrates the re-allocation of trips to encouraged cordons from discouraged cordons applied to 2008 data and also shows the new premium and discount pricing regime as applied to that period.

Table 5.13 demonstrates that the volumes of HGVs do not change overall. The assumption of static volumes was made for two reasons. Firstly, the original assessment of the HGV permit data in Chapter 4 proved that a shift to deliveries outside of cordon hours did not occur with the introduction of the HGV ban, thereby showing that haulier behaviour is not particularly elastic. Furthermore, in the New York study it was noted that since timing of deliveries is customer driven, the movement to off-peak deliveries is very limited. Overall, it was found that the introduction of the new variable pricing regime produces revenue totalling €641,040. The green rows in Table 5.13 represent the encouraged cordons and the red rows represent the discouraged cordons. This exceeds the breakeven total of €626,952 identified in Table 5.12 earlier in the chapter.

CORDON POINT	OLD VOLUMES	OLD CORDON PRICE	OLD REVENUE	NEW VOLUMES	NEW CORDON PRICE	NEW REVENUE
Sean Moore Rd	2733	5	13665	2733	5	13665
Merrion Rd	1897	5	9485	1897	5	9485
Mount St	1155	5	5775	1155	5	5775
Baggot St	463	5	2315	463	5	2315
Leeson St Lwr	969	5	4845	969	5	4845
Charlemont St	110	5	550	110	5	550
Richmond St	137	5	685	137	5	685
Clanbrassil St	291	5	1455	291	5	1455
Dolphins Barn	5205	5	26025	5205	5	26025
SCR @ Suir Rd	1037	5	5185	1037	5	5185
SCR @ Old Kilmainham	1567	5	7835	1567	5	7835
SCR @ St Johns Rd West	21848	5	109240	21848	5	109240
SCR @ Conyngham Rd	1357	5	6785	1357	5	6785
Navan Rd	8433	5	42165	9967	3.35	33390
Prospect Rd	7884	5	39420	7884	5	39420
Drumcondra Rd Lwr	6632	5	33160	5637	6.65	37487
Clonliffe Rd	209	5	1045	1743.05	3.35	5839
North Strand Rd	13822	5	69110	11748.7	6.65	78129
Alfie Byrne Rd	2364	5	11820	2364	5	11820
East Wall Rd	9230	5	46150	9230	5	46150
North Wall Quay	38992	5	194960	38992	5	194960
Total	**126335**		**631675**	**126335**		**641040**

Table 5.13: Impact of Diverted Trips and New Pricing Regime of Policy on Revenues for Policy 1

5.5.2 Impacts of Policy 1 on Random Sample of 100 Permits

In order to further test the impact of this variable price policy, 100 permits from 2008 were randomly selected from the permit system database. A comparison was made between the application of existing permit system charges, the breakeven system charges and the Policy Driven Variable Pricing Model. The 100 permits constituted eight five-stop permits, zero four-stop permits, five three-stop permits sixteen two stop permits and 71 1-stop permits. Revenue from these permits priced at current permit rates (€7) is €700. In 2010, the price per permit will rise to €8 and therefore the new revenue received from 100 permits in 2010 will be €800. If the breakeven price per cordon is applied (€5 from Section 5.4.1), the total revenue received would be €1470. Finally with the PDVPM, the revenue received for the random sample of 100 permits would be €1642, with an average price per permit of €16.42.

A cost for hauliers of €1642 for 100 permits represents an increase of 135% on the current charge of €7 per permit and an increase of 105% on the 2010 proposed charge of €8 per permit. This clearly imposes a considerably increased financial burden on hauliers wishing to make deliveries to the cordon area between 07:00 and 19:00.

An alternative to this pricing system, which still retains the variable policy angle, is to set a target of achieving 75% cost recovery of the breakeven point and to set premium and discount prices around achieving this target. The original breakeven cordon cost was set at a base rate of €5 with premium rate of €6.65 and discount rate of €3.35. Therefore to achieve a 75% cost recovery, 75% of the original cost of €626,952 is calculated and divided by the original volumes using each cordon point to give a new base break even cost per cordon of €3.70. The premium and discount rates on the new base are calculated to be €4.90 and €2.50. The application of these new rates to the sample of 100 permits provides a new overall cost for hauliers of €1212, with an average price per permit of €12. However, depending on the permits used the price per permit can be greater or lesser than the average price. For example, a permit which has just one stop and enters and exits using encouraged cordons will cost €5. A permit which has just one stop and enters and exits discouraged cordons will cost €9.80. A permit which enters an encouraged cordon and exits a discouraged cordon will cost €7.40. However, at the other end of the scale a permit with five stops which requires five separate cordon entries and exits will cost €25 if only encouraged cordons are used and €49 if only discouraged cordons are used. Table 5.14 below shows the charge for hauliers for each of the pricing schemes.

Variable Pricing: Policy 1	Current Prices 2009 Rate	Future Prices 2010 Rate	Breakeven Price	Original PDVPM	PDVPM With 75% Costs
Encourage HGVs to Use Cordon Points Away from Heavily Used Cycling Routes	700	800	1470	1642	1212

Table 5.14: Costs for Each of the Permit Pricing Schemes Applied to a Sample of 100 Permits from the HGV Database-Policy 1

This alternative pricing system offers a more reasonable approach for Dublin City Council to recoup some of the Eastlink rebate costs while implementing a pricing structure that supports and reinforces national policy. Furthermore, in light of the fact that there appears to be a certain proportion of toll rebate claims that are taking advantage of a weakness in the system, it is unfair to penalise hauliers for this shortcoming of the HGV Management Strategy. Overall, it is fair to say that if the toll rebate scheme became more discriminating, ongoing costs of the HGV Management Strategy would decrease resulting in reduced variable prices.

5.5.3 Policy 2: Reinforcing Local Policy: Establishing A Civic Spine Along the Quays

In 2009, Dublin City Council produced its City Centre Transport Plan (Dublin City Council, 2009b). The purpose of the document is to provide a framework and a context for movement in the city. The plan identifies the transport needs of a growing city against a backdrop of international, national regional and local policies. The city is viewed as a place, as opposed to a "confluence of traffic routes" and as such requires a comprehensive vision for catering for movement across the various transport modes in the city.

One key objective identified in the City Centre Transport Plan is the need to re-establish the River Liffey as the "civic spine". The Plan outlines that currently; it is not possible to remove significant amounts of general traffic from the quays. The evening peak traffic when all home journeys from work originate inside the canal ring is dependent on the quays to provide sufficient outbound capacity to prevent gridlock in the city centre. The Plan also states "It is recognised that the city itself would benefit from a pedestrian friendly environment along the river". Therefore, there is a strong case for reducing the number of HGVs using cordon points that feed large HGVs directly onto the North Quays in the city. Given the fact that the cordon point at St John's Road accounts for 13% of cordon entries and 14% of cordon exits and the natural route for these vehicles is to use the north quays, it is appropriate to examine a pricing strategy that discourages use of this cordon point.

Key features of the implementation of variable pricing model based on a local authority desire to reduce the number of large HGVs along an important civic spine in the city, are to amend the prices of the "encouraged" cordon point and the "discouraged" cordon point. This requires subtracting a discount from the breakeven cordon cost for encouraged cordon points and adding a premium to the breakeven cordon cost for discouraged cordon points. A further important element of the policy involves assumptions regarding the change in behaviour of hauliers in terms of the cordon point used.

Again, similar to Policy 1, the work done by Holguin-Veras et al (Holguin-Veras et al., 2006) is used as a guide to estimate initial HGV displacement to other cordons and also the premium charged on the base rate to divert large HGVs away from discouraged cordon points.

In the case of the variable pricing model for Dublin, based on local authority policy imperatives, it is assumed that the cost of using a discouraged cordon is increased from €5 to €6.65. The cost of using an encouraged cordon point is reduced from €5 to €3.35. Similarly it is also assumed that there will be a 15% diversion of trucks from the discouraged cordon points to the encouraged cordon points. In the case of the discouraged cordon points for Policy 2, (St John's Road and Conyngham Road), 7.5% of each of the totals using each cordon is allocated to each of the encouraged cordon points (Navan Road and South Circular Road/Old Kilmainham). As mentioned previously, St. John's Road is a primary feeder cordon for the quays, thereby justifying its classification as a discouraged cordon point. Although Conyngham Road does not currently account for a large number of HGVs, it offers a geographically intuitive route for drivers to access the quays. Accordingly, this cordon point is also classified as discouraged to avoid a situation whereby drivers switch to Conyngham Road to access the city centre and continue to use the quays to traverse through the city. Navan Road and South Circular Road/Old Kilmainham are classified as encouraged cordons for this policy scenario. This is primarily due to their geographical proximity to the discouraged zones and also to the fact that both cordons offer geographically intuitive routes into the city centre that do not involve accessing the quays.

Table 5.15 below illustrates the re-allocation of trips to encouraged cordons from discouraged cordons applied to 2008 permit data and also shows the new premium and discount pricing regime as applied to that period. Table 5.15 demonstrates that the volumes of HGVs do not change overall. Again, the assumption of static volumes is made to reflect the original assessment of the HGV permit data in Chapter 4, which proved that a shift to deliveries outside of cordon hours did not occur with the introduction of the HGV ban. This assumption is also reflective of the New York study, which notes that since timing of deliveries is customer driven, the movement to off-peak deliveries is very limited. Overall, it was found that the introduction of the new variable pricing regime produces revenue totalling €627,291. The green rows in Table 5.15 represent the encouraged cordons and the red rows represent the discouraged cordons. This marginally exceeds the breakeven total of €626,952 identified in Table 5.12 earlier in the chapter.

CORDON POINT	OLD VOLUMES	OLD CORDON PRICE	OLD REVENUE	NEW VOLUMES	NEW CORDON PRICE	NEW REVENUE
Sean Moore Rd	2733	5	13665	2733	5	13665
Merrion Rd	1897	5	9485	1897	5	9485
Mount St	1155	5	5775	1155	5	5775
Baggot St	463	5	2315	463	5	2315
Leeson St Lwr	969	5	4845	969	5	4845
Charlemont St	110	5	550	110	5	550
Richmond St	137	5	685	137	5	685
Clanbrassil St	291	5	1455	291	5	1455
Dolphins Barn	5205	5	26025	5205	5	26025
SCR @ Suir Rd	1037	5	5185	1037	5	5185
SCR @ Old Kilmainham	1567	5	7835	4844	6.65	32214
SCR @ St Johns Rd West	21848	5	109240	18571	3.65	67783
SCR @ Conyngham Rd	1357	5	6785	1153	3.65	4210
Navan Rd	8433	5	42165	8637	6.65	57433
Prospect Rd	7884	5	39420	7884	5	39420
Drumcondra Rd Lwr	6632	5	33160	6632	5	33160
Clonliffe Rd	209	5	1045	209	5	1045
North Strand Rd	13822	5	69110	13822	5	69110
Alfie Byrne Rd	2364	5	11820	2364	5	11820
East Wall Rd	9230	5	46150	9230	5	46150
North Wall Quay	38992	5	194960	38992	5	194960
Total	**126335**		**631675**	**126335**		**627291**

Table 5.15: Impact of Diverted Trips and New Pricing Regime of Policy on Revenues for Policy 2

5.5.4 Impacts of Policy 2 on Random Sample of 100 Permits

In order to further test the impact of this variable price policy, 100 permits from 2008 were randomly selected from the permit system database. A comparison was made between the application of existing permit system charges, the breakeven system charges and the Policy Driven Variable Pricing Model. The 100 permits constituted six five-stop permits, zero four-stop permits, five three-stop permits fourteen two stop permits and 75 1-stop permits. Revenue from these permits priced at current permit rates (€7) is €700. In 2010, the price per permit will rise to €8 and therefore the new revenue received from 100 permits in 2010 will be €800. If the breakeven price per cordon is applied (€5 from Section 5.4.1), the total revenue received would be €1470, reflecting the fact that the 100 permits cater for 147 journeys. Finally, overall with the PDVPM, the revenue received for the random sample of 100 permits would be €1471, with an average price per permit of €14.71.

A cost for hauliers of €1471 for 100 permits represents an increase of 110% on the current charge of €7 per permit and an increase of 84% on the 2010 proposed charge of €8 per permit. Similar to the implementation of the variable price model based on Policy 1, this variable pricing arrangement also imposes a considerably increased financial burden on hauliers wishing to make deliveries to the cordon area between 07:00 and 19:00.

As highlighted in Chapter 4 of this thesis, it is unfair to establish a variable pricing strategy that forces hauliers to cover the full costs of the Eastlink toll rebates given the inherent weaknesses in the rebate system. Therefore it is prudent to re-adjust the pricing signals to fit with the target of achieving 75% cost recovery of the breakeven point.

The original breakeven cordon cost was set at a base rate of €5 with premium rate of €6.65 and discount rate of €3.35. Therefore to achieve a 75% cost recovery, 75% of the original cost of €626,952 is calculated and divided by the original volumes using each cordon point to give a new base break even cost per cordon of €3.70. The premium and discount rates on the new base are calculated to be €4.90 and €2.50. The application of these new rates to the sample of 100 permits provides a new overall cost for hauliers of €1089, with an average price per permit of €11.However, depending on the permits used the price per permit can be greater or less than the average price. For example, it has been identified in Chapter 4, that 61% of permits have just one stop. A permit which has just one stop and enters and exits encouraged cordons will cost €5. A permit which has just one stop and enters and exits discouraged cordons will cost €9.80. A permit which enters an encouraged cordon and exits a discouraged cordon will cost €7.40. However, at the other end of the scale a permit with five stops which requires five separate cordon entries and exits will cost €25 if only encouraged cordons are used and €49 if only discouraged cordons are used. Table 5.16 below shows the charge for hauliers for each of the pricing schemes.

Variable Pricing: Policy 1	Current Prices 2009 Rate	Future Prices 2010 Rate	Breakeven Price	Original PDVPM	PDVPM With 75% Costs
Encourage HGVs to Use Cordon Points Away from Heavily Used Cycling Routes	700	800	1470	1471	1089

Table 5.16: Costs for Each of the Permit Pricing Schemes Applied to a Sample of 100 Permits from the HGV Database-Policy2

5.5.5 Policy 3: Reinforcing a National Policy: Smarter Travel and the Promotion of Public Transport Through Improved Levels of Operations

The Department of Transport recently published "Smarter Travel: A Sustainable Transport Future" (Department of Transport, 2009a), which sets out the national vision for achieving sustainability in transport. The Policy sets out five key goals:

1. To reduce overall travel demand
2. To maximise the efficiency of the overall transport network
3. To reduce reliance on fossil fuels and
4. To reduce transport emissions
5. To improve accessibility to transport

Linked to these five key goals are a number of ambitious targets, one of which is to ensure that walking, cycling and public transport are supported and provided for to the extent that they account for 55% of all commutes to work by 2020. Bus modal share is now at 28% in Dublin (Dublin City Council, 2009b). The Smarter Travel Policy emphasises the need to encourage further modal shift to public transport, particularly buses, by providing bus services that are reliable, frequent and have journey times that are favourably comparable to the car. One way of ensuring that buses have more reliable journey times is to reduce the amount of interaction they have with other vehicles on the road, and also reducing the extent to which they are affected by the presence of these vehicles on the road network.

Accordingly, one policy that could form part of the PDVPM framework could be to encourage hauliers and other organisations delivering to the city centre using five plus axle vehicles to use cordon points away from those that coincide with heavily used bus corridors. The implementation of this policy would involve a two-tiered approach. Firstly, the price of entry and exit for selected cordon points is increased in order to discourage large HGVs. Secondly, the price of other entry and exit at other points is decreased to make these points more attractive.

In order to identify cordon entry and exit points along heavily used bus corridors, the 2008 Dublin City Council Cordon Count Data was analysed. The data is collected at 33 strategic entry points to the canal cordon, many of which match the HGV cordon points. It was found that there has been an increase of 13% in the number of buses entering the canal cordon over the period 2003 to 2008. The top five locations for the bus numbers in 2008 were identified as being at Drumcondra Road Lower (Binns Bridge) Leeson Street Bridge, Rathmines Road (Portobello Bridge), Dolphin's Barn Bridge and St. John's Road West. These locations match the cordon points at Drumcondra Road Lower/Clonliffe Road, Leeson Street/Grand Canal, Richmond Street/Grand Canal Dolphin's Barn/Grand Canal and St John's Road West/South Circular Road.

In the case of the south side of the city, similar to Policy 1, it was noted from the permit system data that the cordon points generating high numbers of buses did not have a corresponding high level of five plus axle HGVS. For example, the HGV cordon points corresponding to the cordon counts at Richmond Street, Leeson Street and Dolphins Barn, combined account for just 5% of the total number of cordon points used. Conversely, it was noted that the HGV cordon points corresponding to the cordon counts at Drumcondra Road Lower and St John's Road West accounted for 5% and 17% of the total number of cordon points used respectively. Therefore it was decided to introduce a pricing strategy to discourage five plus axle HGVs from the cordon points at Drumcondra Road Lower and St John's Road West. As part of this pricing strategy, it was also decided to encourage five plus axles diverting from Drumcondra Road Lower to use the cordon entry points at Prospect Road/Lyndsay Road and at Clonliffe Road/Ballybough Road. These encouraged cordons were selected due to their proximity to Drumcondra Road and also because of the relatively low numbers of buses using these cordons. The encouraged cordon points for five plus HGVs diverting from St John's Road West are South Circular Road/Old Kilmainham and South Circular Road/Suir Road. These points were also selected due to their proximity to the discouraged cordon and the presence of only a low number of buses.

In the case of the variable pricing model for Dublin based on national policy imperatives to facilitate the movement of buses, it is assumed that the cost of using a discouraged cordon is increased by 33% from €5 to €6.65 based on the Holguin-Veras et al study (Holguin-Veras, 2006). The cost of using an encouraged cordon point is reduced at the same scale from €5 to €3.35. Again, as used in policies one and two discussed earlier, influenced by findings of the Holguin-Veras study, it is also assumed that there will be a 15% diversion of trucks from the discouraged cordon points to the encouraged cordon points. In the case of the discouraged cordon points for Policy 3, (St John's Road and Drumcondra Road Lower), 7.5% of the St John's Road West total is allocated to each of the designated encouraged cordon points (South Circular Road/Old Kilmainham and South Circular Road/Suir Road) while 7.5% of the Drumcondra Road Lower total is allocated to north side encouraged cordon points (Prospect Road/Lyndsay Road and Clonliffe Road/Ballybough Road).

Table 5.17 below illustrates the assignment of trips to encouraged cordons from discouraged cordons applied to 2008 permit data and also shows the new premium and discount pricing regime applied to that period. Just as in Policies 1 and 2, the volumes of HGVs are assumed to remained constant overall with no reassignment of HGVs to outside cordon operation hours. This is to a reflection of the fact that the introduction of the HGV Management Strategy did not result in a switch to widespread deliveries occurring between 19:00 and 07:00. Overall, it was found that the introduction of the new variable pricing regime produces revenue totalling €651,410. The green rows in Table 5.17 represent the encouraged cordons and the red rows represent the discouraged cordons. This marginally exceeds the breakeven total of €626,952 identified in Table 5.12 earlier in the chapter by approximately €25,000.

CORDON POINT	OLD VOLUMES	OLD CORDON PRICE	OLD REVENUE	NEW VOLUMES	NEW CORDON PRICE	NEW REVENUE
Sean Moore Rd	2733	5	13665	2733	5	13665
Merrion Rd	1897	5	9485	1897	5	9485
Mount St	1155	5	5775	1155	5	5775
Baggot St	463	5	2315	463	5	2315
Leeson St Lwr	969	5	4845	969	5	4845
Charlemont St	110	5	550	110	5	550
Richmond St	137	5	685	137	5	685
Clanbrassil St	291	5	1455	291	5	1455
Dolphins Barn	5205	5	26025	5205	5	26025
SCR @ Suir Rd	1037	5	5185	2676	3.65	9765.94
SCR @ Old Kilmainham	1567	5	7835	3206	3.65	11700.44
SCR @ St Johns Rd West	21848	5	109240	18571	6.65	123495.82
SCR @ Conyngham Rd	1357	5	6785	1357	5	6785
Navan Rd	8433	5	42165	8433	5	42165
Prospect Rd	7884	5	39420	8381	3.65	30592.11
Drumcondra Rd Lwr	6632	5	33160	5637	6.65	37487.38
Clonliffe Rd	209	5	1045	706	3.65	2578.36
North Strand Rd	13822	5	69110	13822	5	69110
Alfie Byrne Rd	2364	5	11820	2364	5	11820
East Wall Rd	9230	5	46150	9230	5	46150
North Wall Quay	38992	5	194960	38992	5	194960
Total	**126335**		**631675**	**126335**		**651410**

Table 5.17: Impact of Diverted Trips and New Pricing Regime of Policy on Revenues

5.5.6 Impacts of Policy 3 on Random Sample of 100 Permits

In order to further test the impact of this variable price policy, 100 permits from 2008 were randomly selected from the permit system database. A comparison was made between the application of existing permit system charges, the breakeven system charges and the Policy Driven Variable Pricing Model. The 100 permits constituted six five-stop permits, zero four-stop permits, five three-stop permits, twenty two stop permits and 70 1-stop permits. Revenue from these permits priced at current permit rates (€7) is €700. In 2010, the price per permit will rise to €8 and therefore the new revenue received from 100 permits in 2010 will be €800. If the breakeven price per cordon is applied (€5 from Section 5.4.1), the total revenue received would be €1410 (accounting for 141 journeys with two pairs of cordons per journey). Finally, with the PDVPM, the revenue received for the random sample of 100 permits would be €1643, with an average price per permit of €16.43.

A cost for hauliers of €1643 for 100 permits represents an increase of 135% on the current charge of €7 per permit and an increase of 105% on the 2010 proposed charge of €8 per permit (coincidentally the same percentage increases as Policy 1). Such an increase in charges for hauliers making deliveries to the cordon area between 07:00 and 19:00 adds considerably to the financial burden of operating in the canal cordon.

An alternative to this pricing system, which still retains the variable policy angle, is to set a target of achieving 75% cost recovery of the breakeven point and to set premium and discount prices around achieving this target. This proposal is used in all three policies for variable pricing in order to establish a more equitable charging system for the PDVPM. The original breakeven cordon cost was set at a base rate of €5 with premium rate of €6.65 and discount rate of €3.35. Therefore to achieve a 75% cost recovery, 75% of the original cost of €626,952 is calculated and divided by the original volumes using each cordon point to give a new base break even cost per cordon of €3.70. The premium and discount rates on the new base are calculated to be €4.90 and €2.50. The application of these new rates to the sample of 100 permits provides a new overall cost for hauliers of €1212, with an average price per permit of €12. However, depending on the permits used the price per permit can be greater or less than the average price. For example, one permit using a standard charge cordon to enter the cordon area and a discouraged cordon to exit the area is charged €8.60. Another permit using discouraged cordons to both enter and exit the cordon area is charged €9.80 and a further permits using encouraged cordons to enter and exit five times is charged €25. Table 5.18 below shows the charge for hauliers for each of the pricing schemes.

Variable Pricing: Policy 1	Current Prices 2009 Rate	Future Prices 2010 Rate	Breakeven Price	Original PDVPM	PDVPM With 75% Costs
Encourage HGVs to Use Cordon Points Away from Heavily Used Cycling Routes	700	800	1410	1643	1213

Table 5.18: Costs for Each of the Permit Pricing Schemes Applied to a Sample of 100 Permits from the HGV Database-Policy 3

5.6 DISCUSSION

The overall purpose of this chapter is to establish an innovative permit cost framework that justifies the implementation of a Policy Driven Variable Pricing Model. The chapter commences with an evaluation of the influence of independent, external factors on the number of permits generated. Essentially, the number of permits generated is a reflection of the level of urban delivery activity inside the HGV cordon area. The relationship between three distinct indicators and the volume of permits generated is described. These indicators are construction employment, gross domestic product (GDP) and retail sales index (RSI). All three indicators display a strong correlation with permit volumes.

However, only the RSI proved to be a suitable measure of future permit numbers. The linear regression equation was calibrated for Quarter 1 2009 and the full year of 2008 and shows promising results in terms of the ability to predict future numbers of permits based on RSI performance. In order to establish definitively that RSI is an absolutely reliable long-term predictor of permit numbers, an ongoing evaluation of RSI on a quarterly basis is required over a ten year period.

The chapter then examines a breakeven cost model for the permit system based on the annual cost of the system divided by the number of permits. The linear regression equation using RSI to predict the number of permits is used to estimate the figures for 2009 and 2010. A sensitivity test of plus and minus 2.5% of RSI is also carried out to estimate 2010 permit numbers. In terms of breakeven costs, it is noted in the chapter the cordon breakeven cost is a more useful form of breakeven indicator. This is because the identification of the cordon breakeven cost allows the implementation of a pricing model that can discriminate between cordons based on price.

The concept of a breakeven cost per cordon is introduced as part of the development of the Policy Driven Variable Pricing Model. The application of a variable price technique is applied to three different policies and the results are discussed and analysed. The policies analysed were based on national policy imperatives from the Department of Transport and a local transport imperative from Dublin City Council. The national policy imperatives analysed in this chapter are the promotion of cycling and the improvement of bus operations by encouraging five plus axle HGVs to divert from routes into the city centre that are recognised as high volume bus or cycling corridors. External survey data was used to identify prominent bus corridors and cycle corridors into the city. The local transport policy imperative evaluated in this chapter involved the movement towards creating a more pedestrian friendly environment along the quays of the River Liffey, the "civic spine" of the city.

The development of the Policy Driven Variable Pricing Model requires a number of assumptions to be made regarding haulier behaviour. However, there is a dearth of data currently available regarding how hauliers react to a range of pricing initiatives in an urban environment. This is largely due to the fact that because of the fragmented nature of the haulage industry, it is very difficult to collect reliable behavioural data. Therefore, assumptions regarding the response of organisations to variable pricing are based on a particularly relevant piece of work carried out in New York and are also based on the observed reactions to date to the HGV Management Strategy. Findings from Chapter 4 indicate that shift to deliveries outside of cordon hours did not occur with the introduction of the Strategy. This is a likely indication of the customer driven nature of deliveries in Dublin City Centre, which means that many customers do not have a compelling commercial reason to accept deliveries outside cordon operating hours and therefore are unlikely to move to this model. As an initial estimation of shift in behaviour, each of the three policies estimate a diversion amounting to 15% of the total of HGVs using a particular cordon point. This figure is based on the New York project and is a conservative estimate of HGV diversion rates. Premium and discount cordon cost rates are also set with reference to the New York model and represent a 33% surcharge and reduction respectively.

While it is acknowledged that a dearth of data and information exists regarding how hauliers react to a range of pricing initiatives in an urban environment, information is available regarding typical HGV vehicle costs in Ireland. It is useful to present these costs in order to put the cost of permits under the proposed variable pricing system in context.

Table 5.18 below sets out the estimated costs for a 44 tonne articulated truck for 2010. (IRHA, 2010). 44 tonnes is the maximum allowable weight in Ireland for a HGV with five axles (Department of Transport, 2003). Table 5.18 shows that fixed or standing costs for a HGV requiring a permit would typically amount to €345 per day. These fixed costs include wages, depreciation, road tax, insurance, interest and general overheads per vehicle. These costs are incurred regardless of the level of activity of the HGV. Variable or running costs are those costs, which are incurred on a kilometre basis. For a HGV, running costs comprise of fuel costs, tyre costs and the cost of maintenance and repairs. The table shows that the running costs per kilometre in 2010 for a HGV requiring a permit are €0.56.

Fixed costs, by their nature will not be affected by the Policy Driven Variable Pricing Model. Running costs per kilometre on the other hand, are affected since all three policies proposed require deviations in terms of cordon entry and exit points. Therefore, it is worth noting the various distances between the pairs of discouraged and encouraged cordon points. Table 5.19 below shows the distance in kilometres between each of the pairs of discouraged and encouraged cordon points for each of the three policies proposed in the Policy Driven Variable Pricing Model. The table also contains a column showing additional annual running cost based on 2008 data. The cost is obtained by multiplying the distance between the encouraged and discouraged cordon points by the number of vehicles diverted by the average HGV running cost per kilometre. The total additional running costs for HGV operators for 2008 as a result of implementing all three policies is estimated to be €9448.

Vehicle Type	**44 Tonne Articulated**
Cost Basis	
Vehicle Cost	€96,000
Depreciation Years	6
Average KMS Annually	120,000
Working Days Annually	240
Average Tyre Life KMS	70,000
Standing Cost per Annum	
Wages	€40,325
Depreciation	€16,000
Road Tax	€2,600
Insurance	€4,860
Interest	€3,840
Overheads per Vehicle	€15,260
Standing Cost per Annum	€82,885
Standing Cost per Day	**€345**
Running Cost per Km	
Cost of 1 Litre of Fuel (net of vat)	€1.14
Litres per 100 Km's	40
Km's per litre;	2.5
Fuel Cost per Km	€0.46
Tyres	€0.06
Maintenance / Repairs	€0.04
Running Cost per Km	**€0.56**

Table 5.19: Estimated Fixed and Operating Costs for a 5 Axle HGV

Policy	Discouraged Cordon Point	Encouraged Cordon Point	Distance (KM)	Additional Annual Running Cost (€)
Policy 1	Drumcondra Road Lower	Navan Road	4.5km	3866
Policy 1	North Strand Road	Clonliffe Road	0.64km	550
Policy 2	Conyngham Road	Navan Road	3.88km	443
Policy 2	St John's Road	Old Kilmainham	0.97km	1780
Policy 3	Drumcondra Road Lower	Prospect Road	1.08km	301
Policy 3	St John's Road	South Circular Road/Suir Road	1.47km	1349
Policy 3	Drumcondra Road Lower	Clonliffe Road	0.9km	250
Policy 3	St John's Road	South Circular Road/Old Kilmainham	0.99km	909
Total				9448

Table 5.20: Distances Between Proposed Encouraged and Discouraged Cordon Points

The implications of the Policy Driven Variable Pricing Models for the three policies are tested on 2008 permit journey data. In the case of each of the policies, revenue is produced which exceeds breakeven revenue. A random sample of 100 permits is then selected and the variable prices are applied to each of the permits. An average cost per permit of €16.42, €14.71 and €16.43 is obtained for Policy 1(promotion of cycling) Policy 2(improvement of bus operations) and Policy 3(restoring the civic spine along the River Liffey Quays) respectively. However, the point is made that the costs of the system are determined by the total amount of Eastlink toll rebates paid. An unintended consequence of the Permit System is that it allows toll rebates to be claimed for any five plus axle vehicle using the Eastlink Toll Bridge (not just those travelling between the North and South Port areas.). It is not equitable to penalise hauliers for this unintended consequence of the HGV permit system by passing on the full cost. Therefore, an alternative variable price model is proposed that recommends cordon costs should achieve 75% cost recovery of the breakeven point and sets base, premium and discount cordon rates around this target.

Using this methodology, an average cost per permit of €12, €11 and €12 is obtained for Policy 1(promotion of cycling) Policy 2(improvement of bus operations) and Policy 3(restoring the civic spine along the River Liffey Quays) respectively based on the sample of 100 permits. This version of the Policy Driven Variable Pricing Model is the most equitable system having regard to all relevant factors. The introduction of the new system should be done on a phased basis.

One further point to note is that while the policies are assessed individually, there is scope for introducing variable pricing based on the integration of all three policy objectives. There is a broad level of consensus across the three policies regarding the list of encouraged and discouraged cordon points. Encouraged cordon points for the three policies are Navan Road, Clonliffe Road, South Circular Road/Kilmainham, South Circular Road/Suir Road and Prospect Road. Discouraged cordon points for the three policies are Drumconda Road Lower, North Strand Road, South Circular Road/St. John's Road and South Circular Road/Conyngham Road. Therefore the option is available to Dublin City Council to implement a variable pricing system that takes the objectives of all three policies into account.

5.7 CONCLUSIONS AND CONTRIBUTION TO KNOWLEDGE

Overall the Policy Driven Variable Pricing Model offers a means of regulating haulier behaviour to achieve particular objectives. Firstly, it allows for the possibility directing five plus axle HGVs to certain "favoured" cordon points and away from "disfavoured" cordon points. Secondly, the price of the permit is structured to reward hauliers who keep the number of journeys to a minimum, thus reducing overall traffic volumes within the cordon area. Thirdly, the permit system is extended beyond its original policy objectives in order to support other transport policy imperatives.

Contributions to knowledge in this chapter consist of the following:

1. A relationship is established between the Retail Sales Index and the number of permits generated. This relationship is developed to produce a linear regression equation to predict permit volume.
2. The development of a methodology for establishing the breakeven point for the permit system based on permits, journeys and cordons

3. The integration of the permit system with other local and national policy imperatives and from this the development of a Policy Driven Variable Pricing Model.

CHAPTER 6: EVALUATING AND MODELLING URBAN CONSOLIDATION SCENARIOS IN A DUBLIN CONTEXT

6.1 INTRODUCTION

In a number of European cities, Urban Consolidation Centres (UCC) play a role in the delivery of urban freight. The concept of a UCC is introduced in Chapter 2. Essentially, the value of a UCC lies in the fact that it allows road freight to be dealt with in two parts: the first part involves the inside core delivery area of a city and the second part involves outside the core area of the city. Consolidating outside a city centre makes it possible to benefit from the advantages of large vehicles for long haul transport outside the city without having the disadvantages of these large trucks in the urban area. This chapter summarises the critical success factors for UCCs based on international experiences. In addition, a case study of a privately owned Irish UCC is also evaluated.

This chapter also examines the potential for UCCs in Dublin at two locations identified from the survey of deliveries to the city centre and from the analysis of the data from the HGV Permit System. Findings from the survey of city centre organisations described in Chapter 3 indicate that a large proportion of goods being delivered to the city centre originate in the south west of the city. Furthermore, it was found in Chapter 4 that North Wall Quay is the most frequently used cordon entry and exit point in the HGV Permit System. The introduction of UCCs outside of the HGV cordon area facilitates the use of smaller, more eco-friendly vehicles to be used for deliveries to the city centre. This chapter evaluates the traffic impacts within the core city centre area of establishing UCCs at two different locations and using smaller vehicles to transport goods to the city centre from the UCC using a Q-Paramics microsimulation model.

6.2 USE OF URBAN CONSOLIDATION CENTRES TO DATE

The concept of Urban Consolidation Centres has formed part of the discussion on urban freight problems and potential solutions over the past twenty-five years. Cost 321 (1998) describes a UCC as a place of transhipment from long distance traffic to short distance (urban) traffic where consignments can be sorted and bundled. Its main purpose is to achieve a high degree of collection in goods flows in order to supply efficient transport from the UCC to the city centre and vice versa. The continued interest in the concept is derived from a number of factors (Whiteing & Edwards, 1996):

1. Awareness on behalf of local planners and policy makers that innovative and perhaps radical solutions to freight distribution are needed to cope with chronic city congestion
2. Established transport and distribution operators striving to obtain competitive advantage through new and improved freight consolidation and urban delivery operations
3. Heightened awareness of the environmental problems linked to road freight transport resulting in pedestrianisation schemes, time bans on deliveries and weight restrictions on lorries in towns and cities
4. The increased popularity of co-operation and partnerships along the supply chain, for example between retailers and major contract distribution companies
5. Growing congestion in urban areas, encouraging 'own-account' transport operators in particular to rethink their approach to city centre deliveries

One of the main benefits of UCCs is that they facilitate the implementation of other freight management measures. UCC strategies can be linked to time of day or vehicle size restrictions in city centres. In the light of the HGV Management Strategy in Dublin, UCCs offer further scope for defining the type of vehicles that are prevalent in the city centre. This is a point also highlighted by Whiteing et al (2003) where it is pointed out that because the fleet of goods vehicles present in the city centre are dedicated to urban delivery work, individual vehicles can be specified more appropriately to the town or city in question. For example, attention can be given to suitable vehicle size, and more environmentally friendly vehicles, perhaps with quieter engines and improved emissions.

There are, however a number of perceived difficulties associated with the implementation of UCCs in a city. Firstly, employment of a UCC ultimately adds an additional step in the supply chain where different agents and organisations control transport activities. This can complicate the relationship between customer and supplier. Also, further handling of goods during loading/unloading may increase the risk of damage (Beuthe and Kreutzberger, 2001). Compared to direct delivery, transport involving a transfer at one point from one mode or means to another is a source of additional transhipment costs. These costs are incurred through handling damage, information discontinuity, and an additional possibility in schedule unreliability. Other costs incurred can relate to detours that lengthen trip distance, thereby increasing overall costs. In terms of ownership of UCCs, Ogden (1992) points to three possible scenarios:

1. Ownership by a single private corporation, perhaps owned in turn by one or more freight companies
2. A cooperative venture in which each freight company using the facility contributes to its operation expenses and/or receives income from it
3. A public corporation, usually owned and operated by the municipality of the area concerned

6.3 LESSONS LEARNED FROM INTERNATIONAL URBAN CONSOLIDATION CENTRE CASE STUDIES

One of the best-known UCC initiatives can be seen in Monaco (Van Binsbergin and Visser, 2001). Operation of the UCC commenced in 1989 and strict regulations were also introduced for trucks as part of the initiative. The government provided generous subsidies to ensure that the cost for retailers of receiving deliveries from the UCC was not prohibitive. Although a successful model, this example of a UCC is not transferable to other cities largely because the huge financial support provided by the government is not feasible in other cities.

A further example of a UCC initiative can be seen in La Rochelle (Patier, 2006). A UCC was set up in 2001 with a considerable starting subsidy and electric vehicles were used for deliveries to the historical city area. However, problems associated with the initiative soon emerged. Firstly, although regulation prohibits heavy goods vehicles from entering the affected area, enforcement is lacking. Secondly, there has been an increase in urban congestion as a result of the limited capacity of the electric vehicles. Furthermore, legal issues arose with regard to the ability of the local authority to deny access to the city core for non-UCC users. The final issue, which limited the success of the UCC in La Rochelle was the fact that there was no registered interest amongst commercial organisations in response to the tender for the UCC management. Another example of an unsuccessful UCC can be seen in Leiden in the Netherlands. The UCC commenced operations in 1997 with the aim of improving quality of life in the historical centre of Leiden (Schoemaker, 2002). Deliveries from the UCC were allowed to take place outside prescribed time-windows and were carried out by small, noiseless and clean electric vehicles. However, the maximum speed of the vehicles used of 25 kilometres per hour was a major disadvantage of the initiative. The slow speeds of the vehicles hindered other traffic and consequently resulted in high levels of opposition to the UCC in the city. Furthermore, the number of customers for the UCC was insufficient to reach the break-even volume. The project ceased to operate in 2000. Schoemaker (2002) identifies some crucial reasons that contributed to the failure of the UCC:

- The UCC was located too far away from both surrounding motorways and from the city centre itself
- The supporting policy measures in the form of time-windows and vehicle restrictions were considered unfair ways to keep the municipality's unprofitable UCC alive, instead of making the city more attractive, resulting in opposition against the UCC
- Reluctance amongst members of the transport industry to use the UCC
- Electric cars slowed down all traffic in the city
- More city distribution centres were started. Companies could benefit from the advantages of the municipality's UCC by starting their own UCCs if they fulfilled some non-onerous regulations

There have also been a large number of unsuccessful UCC initiatives in Germany. Browne et al. (2005) find that of the approximately 200 planned or implemented schemes in the country, only five were still operating in 2005. Two successful German examples of UCCs currently operating can be found in Nurnberg (Nurnberg City Logistics Initiative) and Regensburg (Regensburg City Logistics Project). Koehler (2004) lists the following common attributes of these projects:

- Restricted traffic conditions in the cities
- Mediator between stakeholders
- Scientific support in initial phase
- Integration of a freight traffic centre in the initiative
- Enforcement of regulations by local authorities
- Early involvement of all actors
- Collection of waste to improve utilisation of vehicles by including the loads for the return trips to the UCC

There have also been a number of UCCs in the UK, which have experienced reasonable levels of success in recent years. These UCC initiatives include Bristol Freight Consolidation Centre, Norwich Freight Consolidation Centre, Heathrow Airport Consolidation Centre, Meadowhall Shopping Centre Sheffield and London Construction Consolidation Centre. Funding for these initiatives has involved European level funding (often for trial phases) and subsidies from local authorities and other stakeholders. In the case of the Meadowhall Shopping Centre, the initiative has become self-sustaining through the provision of additional services to retailers. Only the Heathrow Airport Consolidation Centre imposes compulsory participation by the retailers. While the primary objective of these centres is to facilitate the consolidation of part loads in order to reduce vehicles trips, some of the initiatives also use more environmentally friendly vehicles to make deliveries. For example, a nine tonne electric truck is used for the Bristol Scheme, an electric truck is used for the Heathrow Centre and vehicles using alternative fuels such as LPG and bio-diesel are used for the London Construction Consolidation Centre.

6.4 IRISH EXAMPLE OF AN URBAN CONSOLIDATION CENTRE: MUSGRAVE GROUP CASE STUDY

6.4.1 Company Background

All of the international examples of UCCs described earlier in the chapter conform to the ownership models outlined by Ogden (1992), whereby the UCC is a cooperative venture by individual companies or the UCC is owned and operated by the municipality of the area concerned. One prominent Irish example of an Urban Consolidation Centre owned by a single private corporation occurs in the case of the Musgrave Distribution Centre in Kilcock, County Kildare.

The Musgrave Group is one of the largest privately owned companies in Ireland. The Group is family controlled and over 30,000 people are employed either directly by the Group or indirectly through retail franchisees. The Musgrave Group own the franchise to SuperValu and Centra convenience stores (over 590 stores nationally). This division of the Group is known as Musgrave SuperValu Centra (MSVC) and is responsible for providing a centralised purchasing and distribution service to franchisees. Musgraves also operate a wholesale services division. This division is divided into two separate sections- Musgrave

Food Services and Musgrave Retail Services. Furthermore, the company has three distinct businesses, which operated under the two sections. These businesses include a delivered retail business, a delivered food service business and a cash and carry business. Nine purpose built facilities for the cash and carry business are located in Cork, Limerick, Galway, Waterford, Belfast, Derry and three in Dublin. These facilities are wholesalers for hundreds of small independent retailers and catering companies throughout the country. Musgrave Food Services on the other hand provide a one-stop multi-temperature food delivery service to the catering sector in Ireland while Musgrave Retailer Services supplies 32,000 regular retail and catering trade customers. (Musgrave, 2008). In 1998, the Musgrave Group became the first Irish retailer to use centralised chilled, fresh and frozen food distribution to the Irish grocery retail industry through their four national ambient and chill distribution centres (Cork, Galway, Dublin and Belfast). Prior to centralised distribution, retailers received their goods through a more traditional distribution system. This often involved retailers receiving numerous deliveries from many different suppliers throughout the week. The onus was on suppliers to deliver to individual stores. This resulted in high transport costs because of the vast number of SuperValu and Centra stores. Often smaller suppliers had a limited delivery range and were restricted to delivering to stores in their locality. Each individual delivery that arrived at the store required attention from a staff member and resulted in fewer staff members on the shop floor. Furthermore, delays in deliveries could often result in stock-outs, which compromised customer service. Centralised distribution at the national centres now allows for consolidation of products from various suppliers into deliveries for the individual stores. This means the minimisation of deliveries into these stores. Prior to the opening of the Kilcock Distribution Centre, suppliers delivered to one of Musgrave Group's four central warehouse facilities and deliveries of certain ambient goods to Dublin stores arrived via the Cork warehouse.

6.4.2 Development of an Urban Consolidation Centre at Kilcock

The new Musgrave Distribution Centre in Kilcock commenced operations in January 2005 and was fully operational by June 2005. Kilcock is located in North County Kildare, close to the border with County Meath and around 30 kilometres west of Dublin. The new warehousing and distribution facility was developed on a 21-acre site at a cost of approximately €35 million. This figure forms part of the overall €70 capital investment in logistics infrastructure and information technology for the company. The centre comprises of 150,000 square feet of warehousing, loading bays, offices, canteen and other facilities. There is potential for further developing the distribution centre in accordance with any future Group expansion plans. Motivation for establishing the new distribution centre in Kilcock was prompted by a number of key issues. Firstly, sustained growth (16% sales growth annually from 2000) and expansion in the market (combined market share for SuperValu and Centra total 24%) placed existing logistics infrastructure under increasing pressure. Prior to the opening of the Kilcock facility, distribution capabilities were operating at their limit. Stock-outs of particular goods were a regular occurrence. The distribution centre in Kilcock therefore forms an important part of the company's overall growth strategy for the future. The second reason for the development of the facility lies in the fact that it enhances the Musgrave Group's control over their supply chain. Again this relates to the service provided to retailers in terms of the on-shelf availability of products. Thirdly, Musgrave Group stores are historically underrepresented in the Dublin Area in comparison to the rest of the country. However, with the expansion in the number of SuperValu and Centra shops in Dublin over the past number of years, this is a trend which is changing. This is a factor that has impacted on the choice of location for the distribution centre. Kilcock is a location that is accessible to Musgrave Group stores both in Dublin itself and the Dublin hinterlands. It is connected to Dublin via the N4 (national road) and recently completed M4 (motorway). Regional roads also traverse Kilcock (R125, R407, R 148 and R158) contributing to the good road network in the area. Therefore overall, the location and scale of operations of the distribution centre facilitate centralised distribution for SuperValu and Centra shops in the Dublin Area, with a particular focus on shops located in the core city area.

6.4.3 Traffic Benefits of the Distribution Centre

In order to quantify the benefits of the Kilcock operation, a comparison was made using 16 key city centre stores between past delivery operations (prior to the implementation of the Kilcock facility) and current delivery operations (using the Kilcock facility). Figure 6.1 below illustrates the location of both planned and existing Musgrave Group stores in Dublin.

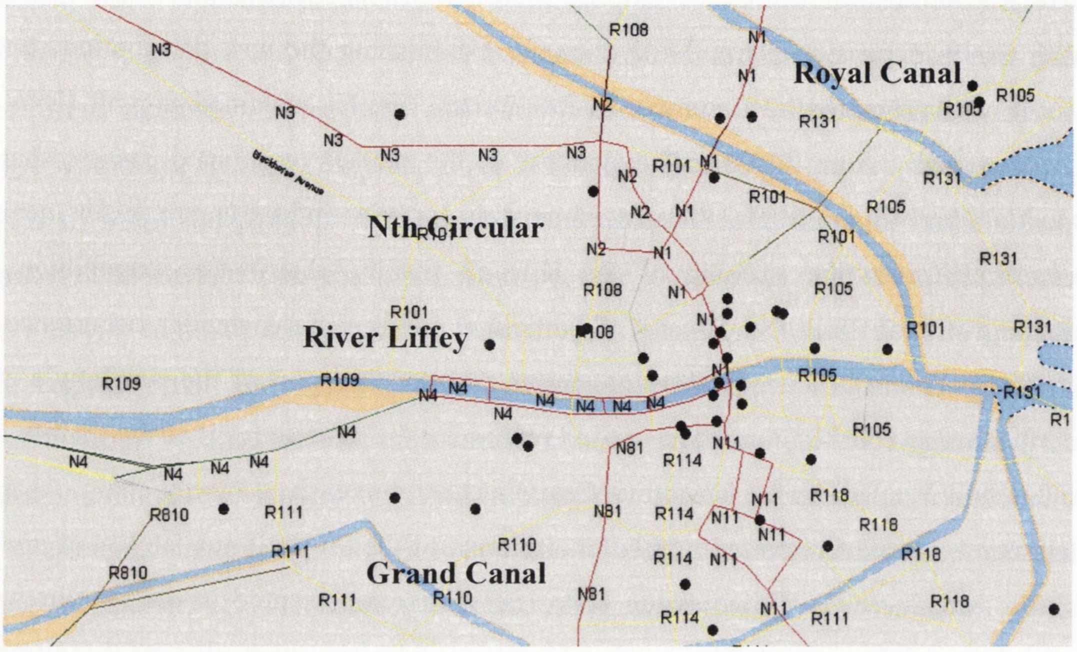


Figure 6.1: Locations of Planned and Existing Musgrave Group Stores in Dublin

Key areas of interest for the 16 stores include delivery frequency per week, average volume delivered (in cases) and distance involved in deliveries (in miles). Table 6.2 shows the numbers involved for these areas of interest. Overall, Musgrave deliveries to these 16 stores have increased from 17 to 60 per week. This represents an increase of 253% in delivery frequencies. However, this is offset by the fact that Musgraves have removed the need for 17 suppliers to deliver direct to all of these stores. Most of these suppliers would deliver twice a week to these stores. Therefore 544 (representing 16 stores X 17 suppliers X 2 deliveries per week) individual deliveries are eliminated from the supply chain by using the Kilcock Distribution Centre. This represents a net benefit of a reduction of 501 deliveries to the city centre. Vehicles used for deliveries from the Kilcock facility are generally DAF 95 tractor-trailers with ambient box type trailers. The fleet is made up of four and five axle heavy goods vehicles. The Kilcock operation allows suppliers to deliver full loads to the centre where consolidation then occurs with products from other suppliers to ensure that the company delivers full loads. The average volume in delivery cases for all sixteen shops has increase by 80% (from 4775 to 8617). On average, the number of cases delivered to each store via the new distribution centre has increased by 90%. In terms of the average mileage for the routes to the city centre, Table 6.1 below illustrates the extent of delivery distances travelled. At first glance these distances appear to be quite high, however it is important to remember that the delivery rounds include trips where city centre stores may be serviced on routes that also service stores outside of Dublin.

Day	Total Mileage	No. of Delivery Routes	Average Mileage
Monday	448	6	75
Tuesday	593	4	148
Wednesday	593	5	119
Thursday	547	4	137
Friday	976	7	139
Saturday	534	4	134
Total	3691	30	123

Table 6.1: Average Mileage for the City Centre Routes

	Before Kilcock Distribution Centre						Using Kilcock Distribution Centre					
Location	Old Frequency	Average Volume-Old	Distance Delivery (Miles)	Distance Delivery and return	Trunk Mileage	Total Delivery Dist (Miles)	New Frequency	Average Volume-Now	Distance Delivery (Miles)	Distance Delivery and return	Trunk Mileage	Total Delivery Dist (Miles)
Rialto	1	566	4	8	312	320	5	846	20	40	0	200
Cathal Brugha St	1	175	5	10	312	322	3	338	21	42	0	126
Dame St.	1	380	5	10	312	322	3	703	21	42	0	126
Camden St	1	303	5	10	312	322	4	520	21	42	0	168
O'Connell St	1	380	5	10	312	322	5	647	21	42	0	210
O'Connell St	1	262	5	10	312	322	4	594	21	42	0	168
Talbot Street	2	156	5	10	312	644	4	405	21	42	0	168
Dorset Street	1	389	5	10	312	322	4	724	21	42	0	168
Capel St.	1	146	5	10	312	322	3	328	21	42	0	126
Westmoreland St.	1	372	5	10	312	322	5	768	21	42	0	210
Nth King St	1	164	4	8	312	320	3	359	20	40	0	120
Millennium Mall	1	167	5	10	312	322	4	374	21	42	0	168
Charlemount Street	1	301	5	10	312	322	4	565	21	42	0	168
Phibsboro	1	252	5	10	312	322	3	387	21	42	0	126
Nassau Street	1	413	5	10	312	322	3	585	21	42	0	126
Stoneybatter	1	349	4	8	312	320	3	474	20	40	0	120
TOTAL	17	4,775	77	154	4992	5,468	60	8,617	333	666	0	2,498

Table 6.2: Details of Delivery Frequency, Delivery Volumes and Delivery Distance Before and After Kilcock UCC

Another important benefit of the Kilcock Distribution Centre is that it assists in the process of backhauling, which is currently a priority for the Musgrave Group as part of a policy of reducing the environmental impact of the company's transport fleet. Backhauling involves the use of the company's trucks, which have been emptied after deliveries to collect produce from suppliers on the return trips to the distribution centre. This process helps to eliminate replica journeys by the company's suppliers when dispatching goods to the warehouse (Musgrave Group 2002). The effectiveness of the backhauling practice is enhanced by high levels of coordination that the distribution centre provides through the comprehensive logistics systems in place. The vehicle routing and scheduling system allows for distribution involving routes that return to the base depot, out-only routes, multi-drop or single drop routes, multi-day routes, daily or weekly scheduling, deliveries and collections, multiple drivers' shift details and drivers' hours regulations (Paragon 2004). The system can also accommodate goods that must be delivered within a given time window and this added constraint is incorporated into the overall transport plan. In the case of the Musgrave Group, it is a priority to deliver to city centre stores before 07:00am. This was a priority prior to the implementation of the HGV ban in 2007 and remains a priority. Delivery times for the most of the city centre stores are between 05:30am and 07:00am largely because the operation of bus lanes in the city centre restricts unloading conditions after 07:00am. A further reason for deliveries occurring before 07:00am is because city centre stores often form part of a wider route that includes deliveries outside of the Dublin area. For theses routes, it is important to depart from the city centre very early in the morning in order to make other drops on schedule.

6.5 CRITICAL SUCCESS FACTORS FOR URBAN CONSOLIDATION CENTRES

An Urban Consolidation Centre should not be an objective in itself. Boerkamps and Van Binsbergen (1999) and Patier (2006) make the case for large government subsidies, because of the positive associated environmental impacts. The identification of a potential UCC initiative must be in response to specific urban freight situation in a city. From the assessment of the various case studies of UCCs, a number of factors that offer potential for the successful implementation of a UCC are identified. These include:

1. The presence of a freight consultation forum

An informal relationship should be established that brings together all stakeholders involved in a potential UCC (transport industry, retailers, community members, local and national authorities). The Bristol Freight Consolidation Centre involved a high level of consultation between Bristol City Council, DHL Exel Supply Chain (scheme operator), The Broadmead Board, The Galleries Shopping Centre, Cabot Circus and Business West (formerly the Chamber of Commerce).

2. High levels of technology

Coordination of logistical activities is imperative to the operation of a UCC. Information technology such as the Paragon System used by the Musgrave Group offers strong potential for increased efficiencies in terms of consolidating and routing activities.

3. Local knowledge and appreciation for local conditions

Local knowledge involves a clear understanding of local conditions, the transport network, obstacles and delivery conditions. It can be an invaluable source of information that can make the set up and operation of a UCC run more smoothly. In the case of the Musgrave distribution centre in Kilcock, transport specialists in the company have a comprehensive understanding of the impacts of bus lane operating hours on unloading activities and consequently, deliveries to city centre stores are carried out outside bus lane operating hours as much as possible.

4. Location Close to Key Markets and Good Transport Network

Consolidation and distribution costs depend heavily on the location of the distribution centre. Therefore the location of the platform is critical to its success. Promising UK case studies of UCCs tend to have a clearly defined market for deliveries. For example the Bristol Freight Consolidation Centre serves the core central retailing area Broadmead, The Mall Galleries and Cabot Circus, the London Construction Centre focuses on four construction sites in central London and the Heathrow Consolidation Centre serves all airport terminals.

5. High Proportion of Own-Account Transport

Generally, own account transport (where the company transports its own goods from one place to another) offers more potential for consolidation or transhipment into smaller vehicles. It is more difficult to tap into the supply chain of professional transport operators who already have highly streamlined logistical operations. Thus, the higher the share of own-account transport in the city, the greater the potential for a UCC.

6. Value added services as an additional revenue stream

The provision of value added services as part of the overall functionality of the UCC has implications for the financial sustainability of such initiatives. Meadowhall in Sheffield has managed to become self-sustaining through retailers paying for all of the various services provided at the centre (Hapgood, 2009). The Bristol and Heathrow consolidation centres rely on a level of subsidy along with retailers paying for the consolidation service and value added services to fund the ongoing operation. The implication from the UK experience is that in order to be a viable operation, UCCs must offer value adding services such as stock management, receipt and inspection of stock and deliveries to stores with minimum response times.

Given the costs and benefits of UCCs, it is clear that each individual case must be evaluated on its own merits with strong consideration to the nature of urban freight patterns and trends in the area concerned. While the presence of the six factors will not necessarily guarantee the success of a UCC initiative, they form a useful framework for assessing potential UCCs.

6.6 THE APPLICATION OF AN URBAN CONSOLIDATION CENTRE SCENARIO TO DUBLIN

The Musgrave Urban Distribution Case Study described earlier is a good example of how a distribution centre operated by a private organisation can bring about higher levels of load consolidation, thereby reducing the number of HGV trips required for the city centre. However, currently there is no Irish example of how a UCC could be used as a mechanism to influence the type of vehicles used for goods deliveries in the city centre. In light of the

HGV Management Strategy, which seeks a move towards the use of smaller vehicles for deliveries in the city centre by minimising the number of large HGVs on the streets of the city centre, it is appropriate to evaluate UCC scenarios in the city where smaller, more eco-friendly vehicles carry out the final link in the supply chain by delivering to the end customer in the cordon area. The move towards the use of smaller vehicles in the city is consistent with other policies discussed in Chapter 5 such as the promotion of cycling at a national level and the development of the quays of the River Liffey as a pedestrian civic spine in the city. However, the use of a larger number of smaller vehicles may have implications for the facilitating the movement of public transport in the city. This requires a comprehensive assessment of traffic in the area concerned and is dealt with later in this Chapter in Section 6.7.

Selecting an appropriate location for a UCC is a critical decision and Young, Richie and Ogden (1980) found that the four main influences affecting the location of freight facilities were:

1. Proximity to arterial roads, freeways and services
2. Proximity to customers and other facilities
3. Site availability
4. Labour availability

Analysis of data from the HGV Permit System in Chapter 4 points to the fact that North Wall Quay is the most frequently used entry and exit cordon point for five plus axle HGVs accounting for 26% of all entries to the cordon and 21% of all exits to the cordon. North Wall Quay is the geographically intuitive cordon point for HGVs arriving from or travelling to Dublin Port. Furthermore, it is also located close to Dublin Port Tunnel. It is a logical point of access to the city centre for HGVs using the Dublin Port Tunnel to access the city centre, in cases where permits are required (for five plus axle vehicles) and also for cases where permits are not required (for HGVs with four axles or less). Therefore, one potential scenario for a UCC in Dublin is to establish a UCC around the Dublin Port (North) area, just outside of the HGV cordon. Figure 6.2 below demonstrates the potential area in Dublin Port. This scenario would involve the use of smaller, more eco-friendly vehicles for deliveries to the city centre from the UCC.

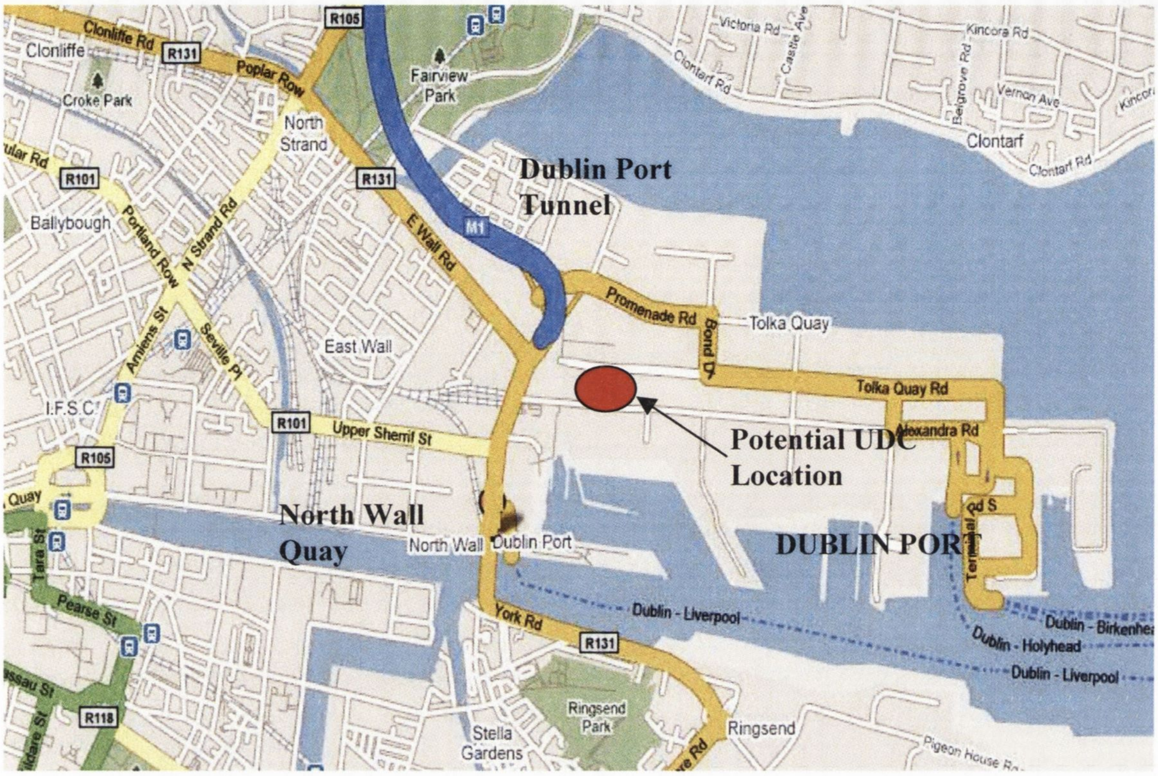


Figure 6.2: Potential Location of UCC Near Dublin Port

The Musgrave Case Study demonstrates the potential in terms of trip savings that a UCC has for deliveries of food supplies to the city centre. In Chapter 3, it is noted from the analysis of the survey of deliveries to city centre businesses that the south of the city and the south west of the city are the particularly high delivery generating zones accounting for 20% and 11% of deliveries respectively. Furthermore, it is noted that 46% and 47% of the goods originating from the South West of the city and from the South of the city are food related. Therefore, a further potential scenario for a UCC in Dublin is to establish a UCC in the South West of the city close to Dublin's C-Ring Motorway the M50. Figure 6.3 below demonstrates the potential area for such a scenario. This scenario would also involve the use of smaller, more eco-friendly vehicles for deliveries to the city centre from the UCC.

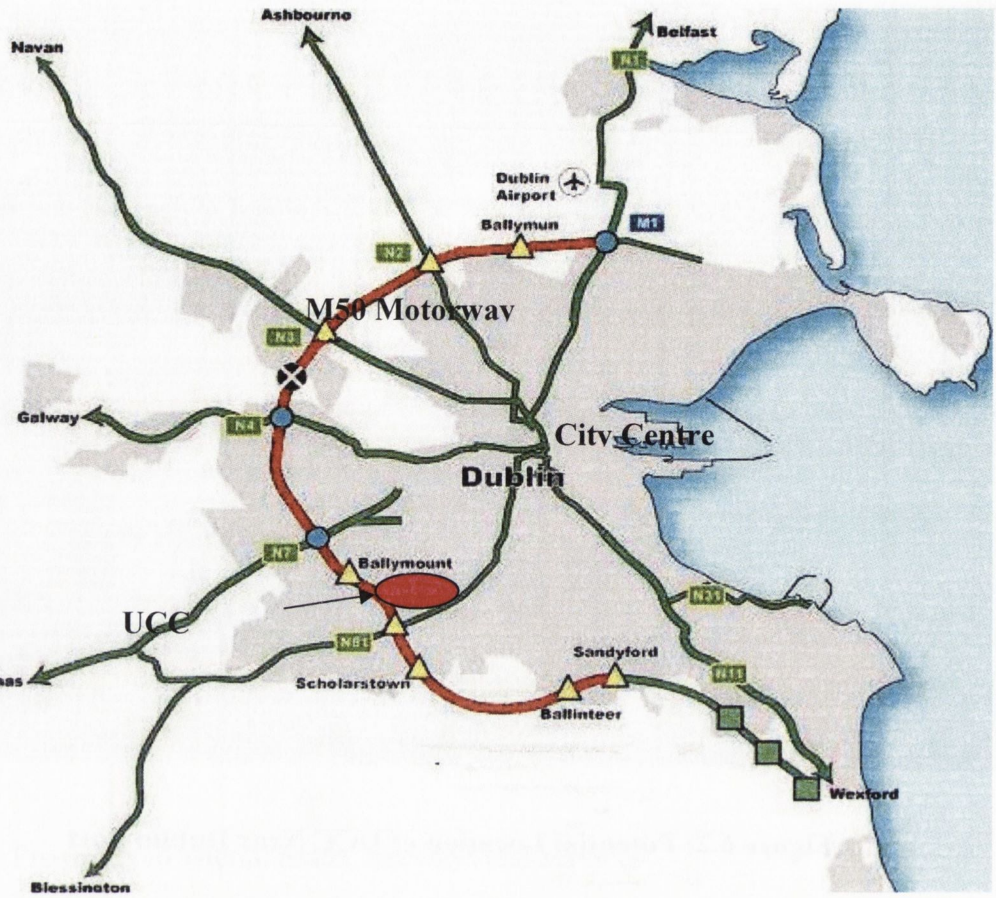


Figure 6.3: Potential Location of UCC in South West Dublin

6.6.1 The Application of Critical Success Factors to Potential UCC Location Scenarios

Section 6.5 of this chapter outlines a number of critical success factors (CSFs) for Urban Consolidation Centres. This section uses the CSFs as a framework for evaluating the two UCC scenarios identified at Dublin Port and in the south west of the city.

1. Presence of freight consultation forum

The development of a UCC in Dublin is likely to involve a number of stakeholders such as Dublin City Council, Dun Laoghaire Rathdown Council, Fingal County Council, South Dublin County Council, the Department of Transport, logistics service providers, representatives of the business community, Dublin Port Company, Irish Road Haulage

Association and the National Roads Authority. A Dublin freight consultation forum consisting of the aforementioned stakeholders would facilitate a partnership approach to freight initiatives in the city. A Dublin freight consultation forum would be similar in approach to the Freight Quality Partnerships, which have been widely used in the UK in recent years. The first partnerships were established in the mid-90's and by 2003, 31 FQPs were in place. They have produced agreements on routing, load sharing and town centre access, helping to reduce congestion, emissions and the number of vehicles in urban centres (DfT, 2003). Approximately 30 local authorities in the UK have already put in place formal agreements and arrangement for a FQP. These include Hampshire, Southampton City, Surrey, Kent, Ripon, Northamptonshire, the West Midlands, Leicestershire and Nottinghamshire (Browne et al, 2003). The interactive nature of a forum would help to provide local authorities with a clearer understanding of the operational needs of businesses and the freight industry. Conversely, business and freight operators would gain a greater appreciation for local authority policies and the difficulties involved in developing an urban freight strategy for the city.

2. High levels of technology

There is scope for integrating Dublin City Council's HGV Permit System with the introduction of a UCC scenario in the city. One potential approach is the development of an integrated scheduling system for deliveries. In broad terms, this would involve assigning time slots to five plus axle HGV deliveries and then scheduling deliveries from the UCC for periods outside of these slots. This would ensure a more balanced delivery pattern in the cordon area.

3. Local knowledge and appreciation for local conditions

Local knowledge involves a clear understanding of local conditions, the transport network, obstacles and delivery conditions. In effect this requires an understanding of the impacts within the cordon of using smaller, more eco-friendly delivery vehicles for deliveries. To date, while intuitively there may be reasons for not implementing a system whereby multiple vans replace one truck, there has been no traffic model assessment of this scenario in the Dublin area. Section 6.7 of this chapter provides such an assessment.

4. Location Close to City Centre with Good Access to Dublin Port Tunnel and M50

The location of the area around Dublin Port for an Urban Consolidation Centre offers a number of advantages in terms of proximity to key transport infrastructure and target markets. A location close to Dublin Port would allow trucks travelling from the port to the cordon area to deliver directly to the UCC. Trucks using the Dublin Port Tunnel nearby to access the city centre could also deliver directly to the UCC. The city centre is approximately 2.5 kilometres from Dublin Port. This type of distance is ideally suited to electric vehicles.

With regard to South West Dublin, the location of a UCC in this area would benefit from proximity to national roads (N4, N7, N81) as well as the M50 motorway for trucks travelling to and from the facility. Distance to the city centre from this location is approximately 12 kilometres. Given that the scenario involves the use of eco-friendly, potentially electric vehicles the distance from the city may be a limiting factor for the selection of this location.

5. High Proportion of Own-Account Transport

It has already been identified that own account transport offers more potential for application to UCCs than haulier transport. The dispersed nature of the organisations carrying out deliveries in Dublin City Centre is reflected in the fact that 88% of organisations do not operate their own fleet for deliveries. This statistic is an output from the analysis of the HGV Permit System in Chapter 4.

6. Value added services as an additional revenue stream

Similar to the UK case studies of promising UCCs, in order to become viable operations in the long term, Irish scenarios must look to value adding services such as stock management, receipt and inspection of stock and acting as a collection point for customers to collect selected goods and products on behalf of online shopping facilities.

6.7 USING MICROSIMULATION TO ASSESS THE TRAFFIC IMPACTS OF USING SMALLER ECO-FRIENDLY VEHCILES TO TRANSPORT GOODS TO THE CITY CENTRE

6.7.1 Introduction

One of the key issues for the assessment of the UCC scenarios is the impact on traffic conditions within the cordon area of using smaller vehicles. In the case of the UCC in Leiden, the use of vans for deliveries to the city centre had major repercussions on the overall movement of vehicles in the affected area. Ultimately, traffic problems led to public opposition to the UCC and the failure of the project. The evaluation of a potential UCC where smaller vans are used to make deliveries instead of large HGVs must include a robust assessment of likely traffic impacts. One method, which can be used to assess the network impacts of a UCC is the use of a traffic microsimulation model. Traffic microsimulation is the modelling of individual vehicle movements on a second or sub-second basis for the purpose of assessing traffic performance of the transport network for both vehicles and pedestrians. Microsimulation models are useful for testing options that change vehicle characteristics and driver behaviour (California Department of Transportation, 2002). A scenario where there is a significant change to the type of vehicles present on the network and which may lead to changes in driver behaviour such as the UCC scenario is therefore suitable for testing using microsimulation.

6.7.2 Background to the Model Development

It was decided to use a Q-Paramics microsimulation model to test the traffic impacts of the UCC scenarios at Dublin Port and in the South West of the City. This model was developed by a project team led by the author and is the intellectual property of Dublin City Council. The Dublin City Council Q-Paramics model area covers the core city centre area and is bound to the south by the Grand Canal and to the north by Dorset St as displayed in Figure 6.4 below. Figure 6.4 also shows the HGV cordon area superimposed onto the map. The model considers the PM peak period (16:00-19:00) for 2008 traffic conditions and traffic activity for private, public and commercial vehicles.

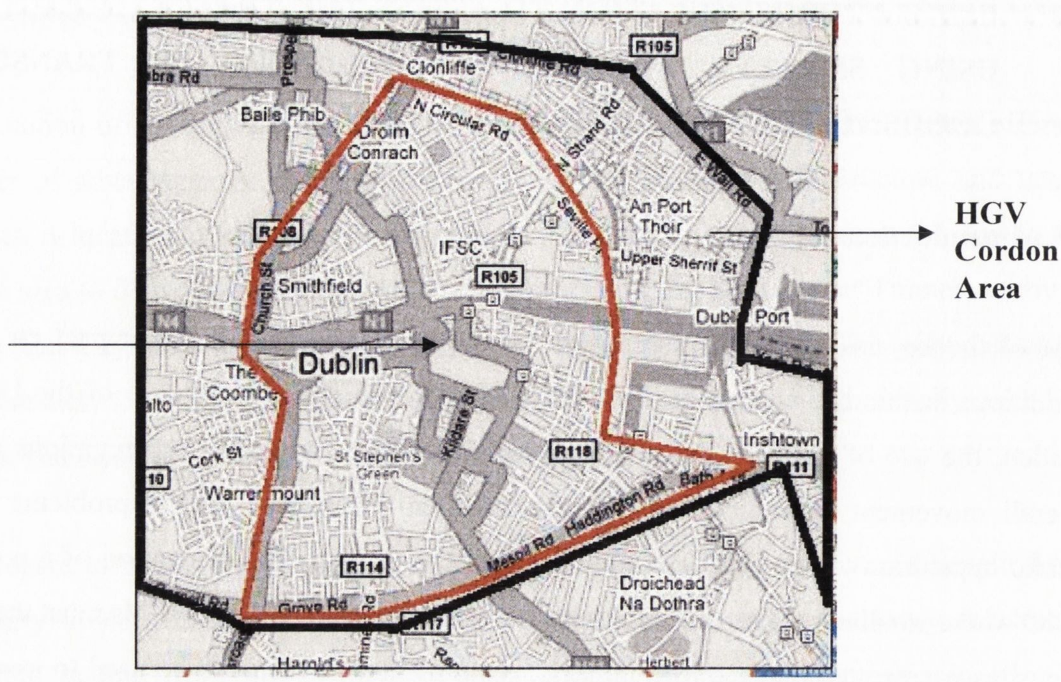


Figure 6.4: Q-Paramics Model Area and HGV Cordon Area

The microsimulation model was developed using the Quadstone Paramics simulation software (version 5.2.2). Azalient plugin software (CeeJazz52D10) was also used to provide additional functionality for lane choice and route choice. Added reporting capability was given through the use of the 'validator' plugin, mainly used to display comparison of modelled traffic volumes and travel times to observed data. The development of the model utilised extensive data sources to help define the positions of roadside kerbs, lane markings, traffic signal timings, bus route information and detailed travel demand data. The primary data source used for building the road network was a DXF overlay, which acted as a template for the network coding. This data was supplemented with information taken from site visits where stop line positions, carriageway markings, and lane markings were checked and verified.

Further site visits of the entire study area were conducted over consecutive weeks. Observations of vehicle behaviour were recorded throughout the PM peak period, with information such as lane usage being checked. The Q-Paramics model network coverage is displayed in Figure 6.5 below.

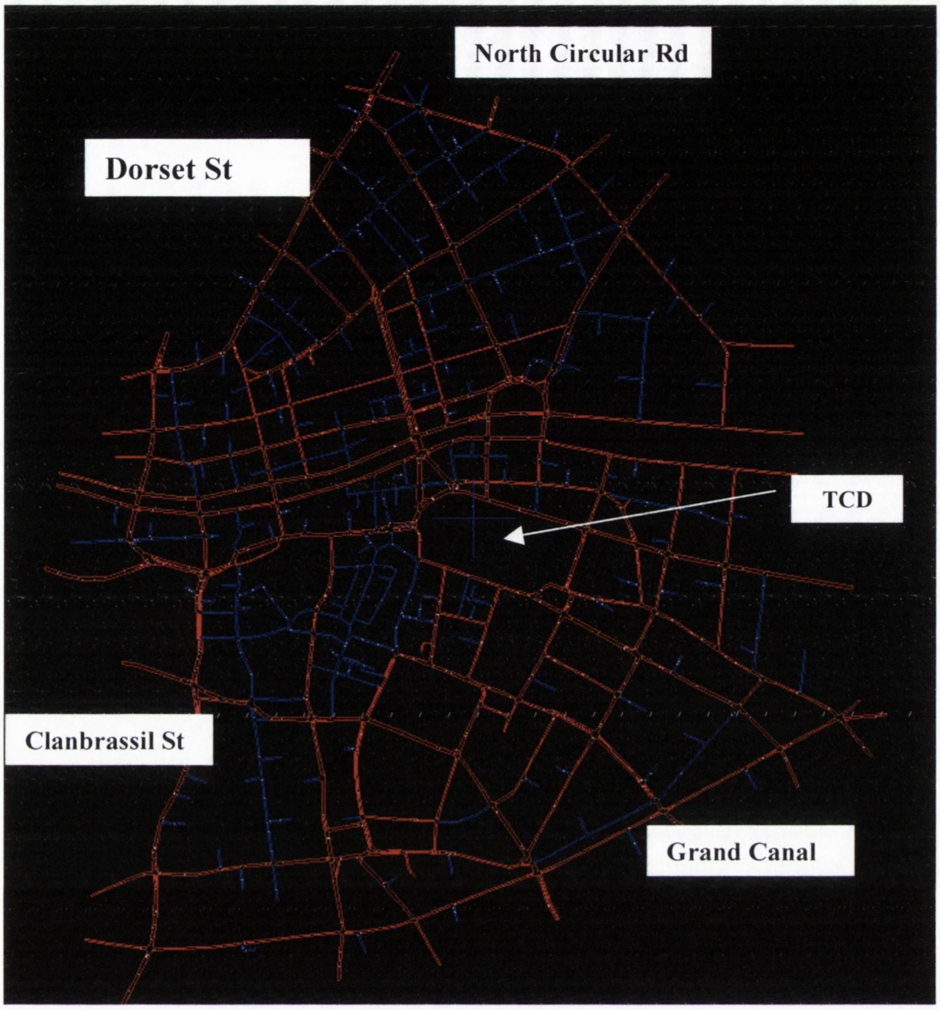


Figure 6.5: Q-Paramics Model Area

A series of link categories were applied to corridors within the study area, ranging from urban major to urban minor links. These categories enabled a road hierarchy to be coded, which allows for sensible, intuitive vehicle routing through the network. All links were coded to the full road width and to the sign-posted speeds. All access restrictions and banned turns have been modelled. A number of minor side roads were added to the model between key junctions to act as sink zones. This allowed for any difference in flows between upstream / downstream surveyed junctions to be balanced. Dublin City Council uses the SCATS system for managing traffic signals in the local authority area. In order to obtain signal timings for the model intersections, SCATS output files were assessed and averages for cycle times and phase times were obtained across the model period. Furthermore, pedestrian crossing locations were identified and the signal timings were coded based on call demand frequency applied by SCATS. A DXF (AutoCAD drawing) overlay was used to define the zoning system for the model. Natural and manmade features such as the River Liffey and major roads enabled a sectional broad zoning system to be established. The zoning system in the model comprises of 162 zones in total.

Vehicles in the model comprise public transport vehicles (buses, trams and taxis) and general traffic. Public transport (PT) is an integral part of traffic movement in the city centre. PT data for the model was gathered from a number of different sources. All buses passing through the model area are accounted for. Timetabled information supplied by Dublin Bus and other bus operators, sourced from published bus timetables and Dublin Bus itself is included in the model. All bus stops in the model area are included. Surveys were carried out to obtain bus dwell times and were input as average dwell times throughout the model period. All bus priority measures such as quality bus corridors in the model area were also included. Public transport vehicles are added into the model as a fixed route in line with their timetabled routes. With regard to general traffic, three separate trip matrices were developed for the following vehicle types for the PM peak period 16:00-19:00:

- Cars/LGVs
- Heavy Goods Vehicles
- Taxis

The trip matrix was developed from manual classified counts provided by a range of transport agencies including the Railway Procurement Agency (RPA), the Quality Bus Network Project Office (QBN) and the Dublin Transportation Office (DTO). Dublin City Council (DCC) supplemented the counts with SCATS detector vehicle flows where necessary. Due to the variety of data sources provided from the various agencies, some of the traffic counts were factored to the base year 2008 using NRA Future Traffic Forecasts 2002-2040 (NRA, 2003). The survey data was processed to produce estimates of traffic generation and cordon volumes by vehicle class for the road network in addition to the generation of profiles for specific zones. Profiles allow a pattern of vehicle movements to be defined based on fifteen minute time periods. An hour pre-load of vehicles is applied to each model run to ensure that the network contains traffic at the beginning of each model analysis period.

The model was validated and calibrated using junction turn flows and queue lengths. The observed data for these flows was obtained from surveys undertaken in 2007. The robustness of the turning count validation ensured that the level of flow and delay on all routes through the network in all directions, north/south and east/west was accurately represented in the operation of the model.

In order to ensure that the Q-Paramics model was robust enough to allow the testing of the UCC scenarios, a number of base model runs were carried out to assess the overall stability of the model. Figure 6.6 below shows the results of the model runs. The base model is considered to be stable as all five runs for the PM model produce consistent results in terms of the vehicles present in the model during fixed time stamps. The variation highlighted in the graph is consistent with daily variation

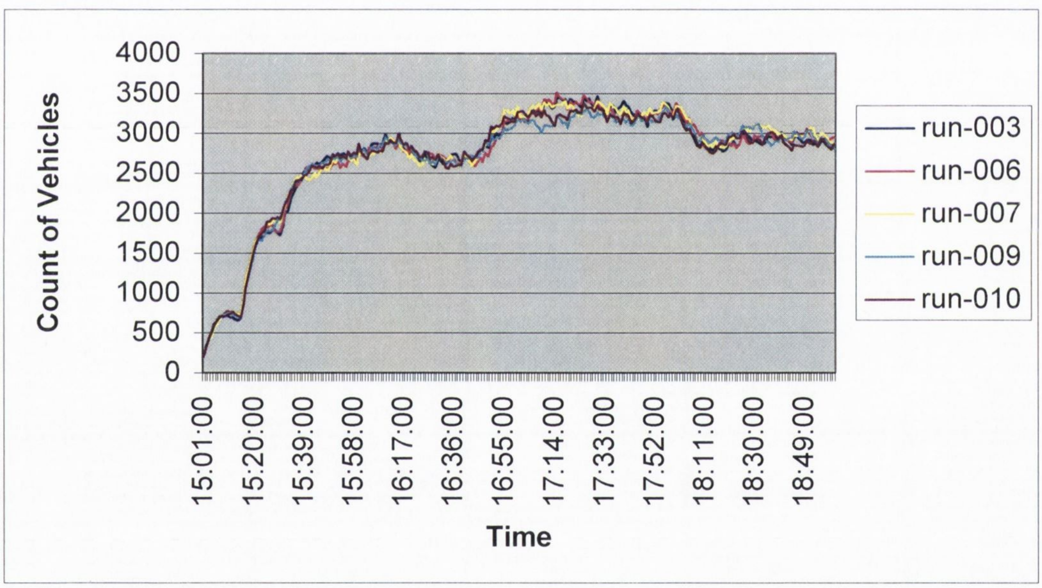


Figure 6.6: Q-Paramics Model Stability

6.7.3 Testing UCC Traffic Scenarios using the Q-Paramics Model

Having assessed that the Q-Paramics model was sufficiently stable and suitable for scenario testing, the next step was to make the adjustments to the matrices in the model to account for the reduced number of HGVs and the corresponding increase in LGVs. In terms of hauling capacity, a medium-sized two-axle truck is the equivalent of five vans and a truck with greater than two axles is comparable to twelve vans (Debauche and Duchateau, 1998). A worst-case view is taken with regard to vehicle transfer coefficients for the analysis of the UCC scenarios and each truck diverted to a UCC is substituted with twelve eco-friendly vans making the delivery to the city centre. In practice, the type of electric vehicles used for a UCC are likely to be of the kind used in the Heathrow Consolidation Centre Case Study and the Bristol Consolidation Centre Case Study. Vehicles used in these case studies are nine-tonne high performance electric vehicles with a driving range of 160 kilometres (DHL, 2009).

In reality, the proportion of trucks using the Distribution Centres compared to the overall number of vehicles in the model network is likely to be very small. In the model, the total number of non-HGVS is 79,786 (consisting of cars, LGVs, taxis and other public transport vehicles). HGVs total 1,180, representing 1% of the overall number of vehicles over the three-hour period of the model. Therefore, if only a small proportion of HGVs are diverted to the UCCs and this proportion is then transferred to multiple vans for city centre deliveries, this will not register as a significant traffic impact with so many other vehicles present in the model. In order to capture significant trends and and likely traffic impacts of UCCs, Scenario 1 was set up to assign 100% of all HGVs passing through the zones, which would be geographically intuitive for HGVs travelling from Dublin Port and from the South West of the city to the UCCs located in each of these respective areas. For the HGVs that are diverted to the UCC, it is assumed that smaller, more eco-friendly vehicles will make the onward trip to the city centre for deliveries. HGVs entering the model zones other than these zones are not diverted to the UCCs. An assumption is made, based on logical routing possibilities for trucks entering the HGV cordon area that HGVs entering the model area from the South West do so via Zone 34. The location for this zone is on the Arran Quay (located along the north quays of the River Liffey to the west of the city) and is illustrated below in Figure 6.7. A second assumption is made, again based on logical routing possibilities for trucks entering the HGV cordon area that HGVS entering the model area from Dublin Port do so via Zone 16. The location for this zone is North Wall Quay (located along the north quays of the River Liffey to the east of the city) and is illustrated by Figure 6.8 below.

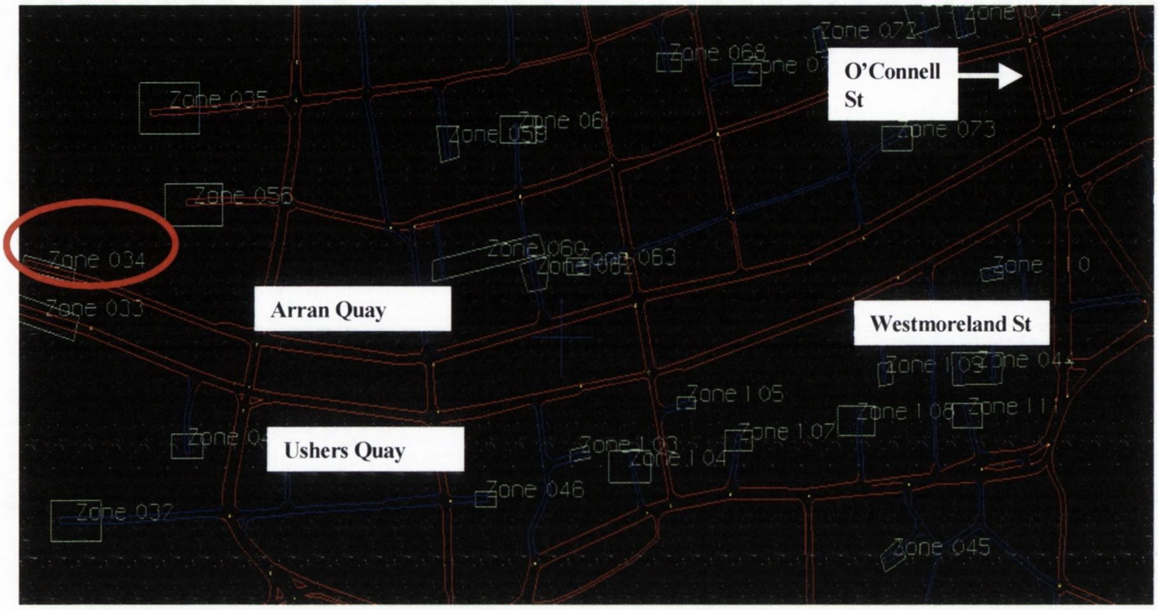


Figure 6.7: Location of Model Zone for HGV Entries From the South West

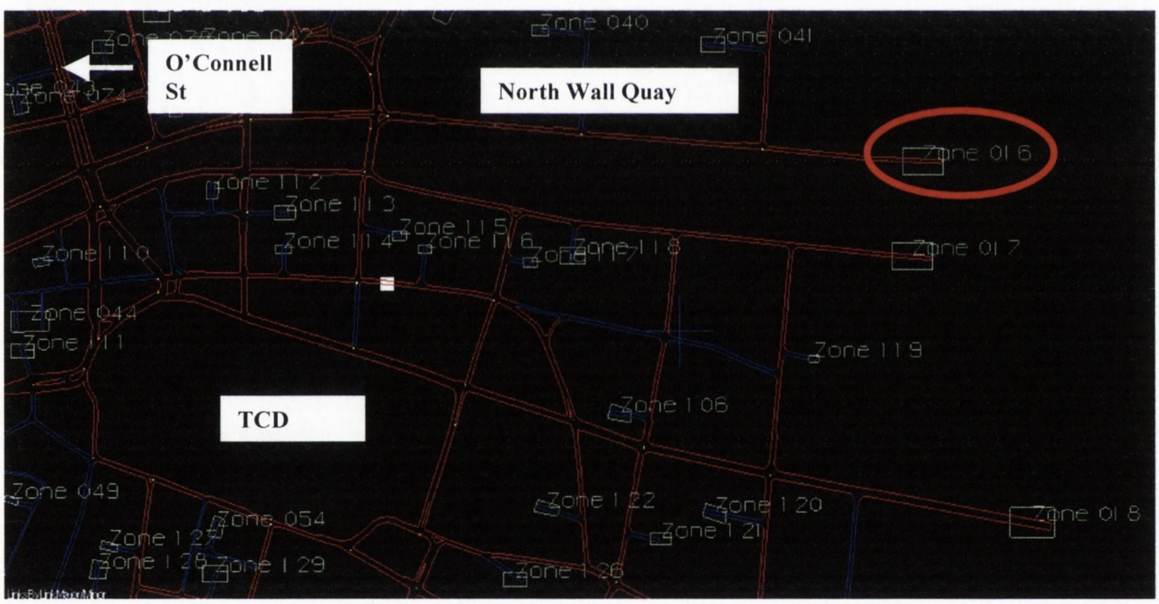


Figure 6.8: Location of Model Zone for HGV Entries From Dublin Port

Scenarios 2 and 3 for modelling are variations on Scenario 1. In Scenario 1, the impact of the implementation of both UCCs is examined. In Scenario 2, the UCC at Dublin Port is examined in isolation. In Scenario 3, the UCC in South West Dublin is examined in isolation. It is assumed in Scenarios 2 and 3 that 100% of HGVs passing through Zone 16 and Zone 34 are diverted to the UCCs at Dublin Port and in the South West of the city. For the HGVs that are diverted to the UCC, it is assumed that smaller more eco-friendly vehicles will make the onward trip to the city centre for deliveries.

Again for Scenarios 2 and 3, HGVs entering the model through zones other than Zones 16 and 34 are not diverted to UCCs.

Two further scenarios are also evaluated. Scenario 4 examines a situation where 50% of the HGVs entering the model area through Zone 16 are assigned to the UCC at Dublin Port. The remaining 50% of HGVs are unaffected and travel to city centre zones as normal. In the case of the HGVs that are diverted to the distribution centre, it is assumed that smaller, more eco-friendly vehicles will make the onward trip to the city centre for deliveries. Scenario 5 examines the situation where 50% of the HGVs entering the model through Zone 34 are assigned to the UCC in the south west of the city. The remaining 50% of HGVs are unaffected and travel onwards to the city centre as normal. Table 6.3 below provides a summary of the five modelling scenarios.

Modelled Scenario	UCC at Dublin Port	% OF HGVS DIVERTED	UCC in South West Dublin	% OF HGVS DIVERTED
Base Case	NO	0%	NO	0%
Scenario 1	YES	100% from Zone 16	YES	100% from Zone 34
Scenario 2	YES	100% from Zone 16	NO	0%
Scenario 3	NO	0%	YES	100% from Zone 16
Scenario 4	YES	50% from Zone 16	NO	0%
Scenario 5	NO	0%	YES	50% from Zone 16

Table 6.3: Summary of Modelled Scenarios

In practical terms, since the model has three separate matrices for cars/LGVs, HGVs and taxis, it is possible to carry out matrix manipulation for each scenario to remove the required proportion of vehicles for each scenario from the HGV matrix. So for example in the case of Scenario 1, 100% of HGVs originating from Zones 16 and 34 are removed from the HGV matrix. The car/LGV matrix is then adjusted to take account of the increased number of LGVs as a result of the multiple (12) vehicles travelling in their place from the UCC to the city centre for deliveries. Each model has three matrices and each individual matrix for the model is of a size of the order of 162 X 162 zones. In total the evaluation of the five scenarios required the manipulation of 10 matrices in total. Each model run takes approximately 3 hours to complete and Q-Paramics produces a number of log run files, which provide traffic network performance information.

6.7.4 Results from the Five Scenarios Modelled

Five model runs for each scenario were carried out. Results focused on speeds in the network, vehicle hours travelled and vehicle kilometres travelled. The results from the five scenarios are described in terms of general traffic and public transport. Results for both categories can be seen in Tables 6.4 and 6.5 below.

Results for both general traffic and public transport were relatively consistent. As expected, Scenario 1 (where both UCCs are implemented) performs the worst overall in terms of the impact on general traffic and on public transport. A 32% reduction in speed of general traffic and a 26% reduction the speed of public transport in the network is obtained. The fact that public transport was not as badly affected as general traffic is likely to be attributable to the mitigation impacts of bus lanes in the city centre. Furthermore, for Scenario 1, the total time spent in the network increases by 38% for general traffic and 18% for public transport. As a consequence of the increased congestion on the network, there is also a reduction in the kilometres travelled during the model period of 11% and 5% respectively for general traffic and public transport.

Scenario 4 (50% of HGVs using Zone 16 diverted to UCC) performs best overall with a 12% reduction in speeds for general traffic and 8% reduction in speed for public transport. The scenario results in additional increases in vehicle hours of 10% for general traffic and 8% for public transport. It also results in a decrease in kilometres travelled of 3% for general traffic and 5% for public transport.

Scenario 5 (50% of HGVs using Zone 34 diverted to a UCC) performs next best. With this scenario, decreases in speeds of 16% and 14% were found for general traffic and public transport respectively. Furthermore, an increase in vehicle hours of 11% for general traffic and 12% for public transport is observed. For both general traffic and public transport, an increase of 8% in vehicle kilometres travelled is observed.

Results from Scenarios 2 and 3 show broadly similar performance levels across the three different network performance indicators. For general traffic, reduction in speeds of 19% and 23% is observed for Scenarios 2 and 3 respectively. Patterns of increase with regard to vehicle hours travelled are similar with increases of 21% for Scenario 2 and 22% for Scenario 3 observed. Furthermore, decreases in network kilometres travelled of 8% and 9% are noted for Scenarios 2 and 3 respectively indicating similar levels of congestion in both networks. Public transport results for Scenarios 2 and 3 are also broadly in line. Reductions in speed for public transport of 18% for Scenario 2 and 21% for Scenario 3 are observed. Increases in vehicle hours of 15% for Scenario 2 and 13% for Scenario 3 are noted. Finally, decreases in vehicle kilometres travelled of 9% for Scenario 2 and 10% for Scenario 3 are observed.

Overall, all five scenarios result in negative impacts for both general traffic and public transport in terms of reductions in speeds within the modelled area, increased travel times and reduced kilometres travelled due to congestion in the network. When UCC options are tested in isolation, the Dublin Port UCC outperforms the Dublin South West UCC. In order to ascertain if this is simply due to the volumes involved, the number of HGVs passing through each zone was compared. 54 HGVs enter the model via Zone 16 (for Dublin Port UCC) and 77 HGVs enter the model via Zone 34 (for South West UCC). For Scenarios 2 and 3 this corresponds to a difference of 276 LGVs on the network over a three-hour period. For Scenarios 4 and 5, this corresponds to a difference of 144 LGVs on the network over the three-hour period. Given that the total number of vehicles present on the network between 16:00 and 19:00 is approximately 80,000, it is unlikely that the difference of 23 HGVs between the two zones is responsible for the improved performance levels of Scenarios 2 and 4.

It is also interesting to note that across the board, the impacts of all of the scenarios are not as severe on public transport as on general traffic. This is likely to be attributable to the bus lane facilities within the city centre that provide segregation on certain routes from general traffic for buses. However, it is contrary to local and national policy (Department of Transport, 2009b) to introduce permanent traffic management measures that adversely affect public transport operations. Therefore, it is not a viable option to implement a UCC scenario for deliveries to the city centre with the current transport network arrangement in the city. This argument is strengthened by the fact that impacts observed in the model are caused by a minority of HGVs. Vehicles entering the cordon via Zones 16 and 34 comprise just 11% (131) of the overall total of HGVs. Furthermore, Scenarios 4 and 5, which only re-assign half of this total to UCCs still have significant negative impacts on the performance of public transport in the modelled area. From an environmental perspective, the benefits of using zero emission electric vehicles for deliveries to the city centre is likely to be counteracted by increased congestion levels resulting in increased vehicle hours in the network.

However, in the future, a UCC scenario may become more appropriate if more dedicated road space is provided for public transport movement in the city centre through the provision of additional bus lanes. This may also require the imposition of stringent demand management measures to free up road space currently used by general traffic. The output from the Q-Paramics model scenarios suggests that public transport operation levels can be protected by providing increased levels of segregated bus priority facilities.

General Traffic Indicator	Base Model	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Speed K/Hr	18.56	12.7	15.1	14.2	16.3	15.5
Vehicle Hrs Travelled	9932	13697	11976	12121	10936	11030
Vehicle KM Travelled	195707	174131	180432	178636	189141	180047

Table 6.4: General Traffic Results from the Five Scenarios Modelled

Public Transport Indicator	Base Model	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Speed K/Hr	14.2	10.5	11.6	11.2	13	12.2
Vehicle Hrs Travelled	501	589	568	576	543	562
Vehicle KM Travelled	6506	6190	5897	5830	6204	5998

Table 6.5: Public Transport Results from the Five Scenarios Modelled

6.8 DISCUSSION

The overall purpose of this chapter is to develop a qualitative and quantitative framework to assess whether an Urban Consolidation Centre scenario is appropriate in a Dublin context. This assessment is done with reference to international case studies of UCCs, a domestic example of a privately operated UCC and a traffic microsimulation model testing the traffic implications of UCC scenarios.

There are numerous examples of UCCs, which have experienced varying degrees of success. In the UK, there has been some positive experience with projects such as the Bristol Consolidation Centre, Meadowhall Consolidation Centre and the Heathrow Consolidation Centre. These examples of UCCs tend to emphasise the value-adding aspects of the initiatives in order to enable their long-term viability. In an Irish context, a case study of the Musgrave Distribution Centre in Kilcock is described in the chapter. By operating a UCC, the Musgrave Group has streamlined deliveries thereby reducing the number of deliveries to the Dublin area by 500 per week. However, in Leiden and LaRochelle, experience has been negative with high levels of public opposition, severe traffic impacts and difficulties in relation to enforcement.

Two potential locations for UCCs are proposed at Dublin Port and in the South West of the City. These locations emerged from the survey of city centre deliveries described and analysed in Chapter 3 and also from the assessment of HGV Permit Data in Chapter 4.

Both options for UCCs benefit from good surrounding road networks. In particular, the location at Dublin Port is close to the Dublin Port Tunnel, which provides rapid access to the wider road network from the Port. A number of critical success factors (CSFs) are used to assess the potential for the two proposed UCCs. Using the CSF framework, a gap in local knowledge regarding the potential traffic impacts of using smaller vehicles to make city centre deliveries is identified. In particular, the potential impacts of the use of these smaller delivery vehicles on the operational performance of public transport vehicles is of interest. In order to address this gap in knowledge a series of UCC scenarios are tested using a Q-Paramics traffic microsimulation model of an extended city centre traffic network.

In total, five scenarios requiring five different models, each with different demand levels are tested. The two UCC locations are tested in the same scenario and also in isolation in order to identify subtle performance issues. Performance indicators for each scenario are classified in terms of impacts on general traffic and impacts on public transport. Indicators used include average speed, vehicle hours travelled and vehicle distance travelled. Assessment of these indicators across all five scenarios shows that while the UCC at Dublin Port performs best, there are serious impacts on traffic in the model area as a result of the UCCs. The impacts on public transport are of particular concern and the point is made that the HGVs diverted to UCCs in the model only comprise 5.5% or 11% (depending on the scenario) of the total of HGVs entering the model area. The point is also made that impacts on public transport are less severe than on general traffic. This suggests that segregated bus lane provision in the city centre protects buses from increases in the levels of general traffic to a certain extent.

6.9 CONCLUSIONS AND CONTRIBUTION TO KNOWLEDGE

Given that it is Government Policy to promote public transport (Department of Transport, 2009b), the implementation of UCCs at this point in time would be in conflict with National Transport Policy given the likely associated adverse impacts on public transport. However, this may not always be the case and over the next number of years, a UCC scenario will be more appropriate if more bus lanes are provided in the city centre to protect the operations and general performance of public transport. In addition, the Q-Paramics model assesses traffic conditions in the city at peak time in the PM period. There is scope for deliveries from a UCC during off-peak periods or out of hours between 19:00

and 07:00. Chapter 4 notes that 46% of premises receiving deliveries from five plus axle vehicles state that they can receive deliveries out of hours.

Furthermore, given the recent drop in property values, the acquisition of UCC facilities by local authorities becomes a more affordable option. Finally, it is important that local authorities in Dublin have a structured framework of consultation in place for developing and implementing urban freight plans. A freight consultation forum should form part of this framework and would serve be a vital component to a partnership approach to any future UCC initiative.

Contributions to knowledge in this chapter consist of the following:

1. Qualitative assessment of the potential for a UCC in Dublin using a case study approach and critical success factors.
2. Use of traffic microsimulation model to assess the quantitative aspects of potential UCCs in a Dublin context.

CHAPTER 7: DISCUSSION OF FINDINGS AND CONCLUSIONS

7.1 INTRODUCTION

Throughout this thesis, the importance of urban freight transport for the economic and social prosperity of cities is highlighted. Urban freight plays a major role in ensuring that goods and services are available when required. However the evaluation of urban freight to date has been presented in terms of the negative impacts for the environment and society. This thesis presents a broader paradigm for the evaluation of freight, namely an integrated transport policy framework. In seeking to establish this broader policy framework, a number of research objectives are addressed, each of which is discussed below.

7.2 SYNOPSIS OF KEY ISSUES AND THEMES CONTAINED IN THE LITERATURE ON URBAN FREIGHT

The development of the field of urban freight is discussed in Chapter 2. The availability of urban freight data is assessed and a gap in knowledge regarding the micro-detail of goods deliveries in cities generally and particularly for Dublin is noted. Chapter 2 also evaluates various international policies for urban goods movement in the United Kingdom, Germany, France, the Netherlands and Japan. Various examples of Urban Consolidation Centres (UCCs) with limited levels of success in France and the Netherlands are discussed. However, more recent examples in the United Kingdom have shown more promising results and point to the importance of the provision of value added services as an additional revenue stream for UCCs.

Another relevant issue is time of day pricing for urban freight delivery traffic. Research available indicates that road pricing alone is not successful for moving freight transport from peak to off-peak periods. The nature of the response to road pricing is determined by the balance of power between the carrier and the receiver. In many cases, carriers are not in a position to react to urban freight charge increases by changing delivery times because the receivers of goods dictate the delivery schedule.

7.3 DISCUSSION OF RESEARCH FINDINGS AND CONCLUSIONS

Research findings and conclusions are discussed in terms of the four overarching research objectives of the thesis:

1. **To address the gap in knowledge that exists regarding urban freight data in European cities by carrying out a comprehensive goods delivery survey in Dublin and analysing the survey data.**

In order to develop a comprehensive understanding of urban freight in Dublin City Centre, a survey of goods deliveries to Dublin City Centre was carried out. In broad terms, the objectives of the survey were to obtain information on the vehicles used, the types of organisations receiving deliveries, types of goods delivered, loading facilities used, delivery time profiles and dwell times. Prior to implementing the overall survey, a pilot survey of deliveries to the Trinity College Campus was carried out.

Analysis of the survey of goods deliveries showed that:

- High delivery generating zones occur in the south west of the city, the south of the city, the north west of the city and in the city centre
- The busiest time for deliveries occurs between 10:00 and 11:00 with 16% of the total arriving during this period
- The number of night-time deliveries is extremely small. Only 2% of deliveries occurred between 17:00 and 23:00 with no deliveries observed between 23:00 and 05:00
- Vans were the most prevalent type of delivery vehicles used, accounting for 55% of the total
- Trucks were used in 40% of deliveries
- Average dwell time for deliveries was 14 minutes
- 49% of deliveries used on-street parking for unloading goods, while 39% and 12% used dedicated and shared loading bays respectively.

Overall, the survey provides preliminary analysis regarding urban goods movement in Dublin City Centre. However the results of the survey need to be interpreted with caution for a number of reasons. Firstly, there are issues regarding how representative the survey is of the overall population. The survey gathers data from 125 organisations and ideally a much larger sample size should be used if at all possible. The approach of specifically targeting representative business groups was taken in order to boost the response rate of the survey. However, this approach inevitably introduces a degree of bias in the data gathered by bringing about an over-representation of some categories of businesses, e.g. pubs and restaurants. Secondly, the overall response rate to the survey of 10% is low and presents difficulties in terms of the capacity to accurately analyse the data and reach definitive and robust conclusions. Ultimately, considerable resources are required to implement a large survey of deliveries to organisations. However, even with such resources, the challenge of securing a high response rate remains.

2. **To evaluate a two-tiered approach to the management of urban freight in a European city by firstly assessing the impacts of the implementation of the Dublin Port Tunnel and the HGV Management Strategy in Dublin through the identification of key trends in relation to the urban HGV fleet and permits; and secondly to examine possible statistical indicators and relationships that may be used to predict the volume of permits on an annual basis**

The implementation of a two-tiered approach for managing HGVs in Dublin via the Dublin Port Tunnel and the HGV Management Strategy represents an innovative step in the field of urban freight. The HGV Management Strategy represents the control mechanism to optimise the use of Port Tunnel while simultaneously managing how deliveries to the city centre using five axle plus vehicles are made.

A full dataset comprising two year's permit information has been analysed in this thesis. The dataset is a useful resource for urban freight data and key trends. In total over 94,000 permits and 160,000 journeys are analysed firstly by setting up a new ACCESS database and secondly by importing full tables and a series of SQL queries into SPSS. A full assessment of permits has shown that:

- 85% of permits are used for deliveries, while the remaining 15% are used to allow access to the cordon area for HGVs that cannot use the Port Tunnel
- 88% of permits are acquired either on the day they are needed or just one day in advance

- Dominant organisational types for permit applications are retail companies, construction firms, and wholesale companies
- The most frequently used cordon entry and exit points are at North Wall Quay, South Circular Road/St. John's Road, North Strand Road, Navan Road and East Wall Road.

Output from the Permit System is also presented in the context of other relevant traffic datasets. Overall, the decrease in the number of HGVs with five or more axles has been in the range of 78%-91% across the cordon area. This substantial decrease is replicated across all time periods. The HGV Management Strategy has not resulted in a switch to night-time deliveries. It is also observed from classified traffic counts that there has been an increase in car traffic since the implementation of the HGV ban. This points to a missed opportunity by Dublin City Council to capitalise on the increased road capacity in the network as a result of the reduced number of HGVs present on the city's streets.

While the data provided by the Permit System is an extremely useful source of information, there are a number of underlying concerns regarding the accuracy of the information contained within it. In the first instance, it is likely that in many circumstances the individual applying for the permit is not the individual making the delivery. Secondly, the data from the permits is based on what hauliers planned to do, rather than what they actually do. This could result in a situation where cordon entry and exit points used are completely different to those listed in the permit. The key issue for Dublin City Council is to ensure that hauliers apply for a permit to deliver to the city centre. Therefore, no resources are dedicated to ensuring that permit details are correct.

In addition to the statistical analysis of the Permit System, consideration in the thesis is also given to operational aspects of the HGV Management Strategy. One area of concern is the informal structure in place by Dublin City Council to monitor compliance levels. Monitoring is done on an ad-hoc basis and in response to queries from members of the public. While compliance levels to date have been high, there is no guarantee that this will continue to be the case in the future. Therefore, more formal monitoring procedures are required by Dublin City Council involving periodic surveys of HGVs in the cordon area and crosschecks with permit data.

A further source of concern from an operational perspective is the cost of the Eastlink Rebate Toll Scheme. Dublin City Council now face considerable monthly rebate costs. The cumulative cost of rebates from March 2007 to September 2009 is €1,567,405. As local authority finances become more constrained, the ability of the Council to continue to meet this cost will be called into question.

The second strand of this research objective is to examine possible statistical indicators and relationships that may be used to predict the volume of permits on an annual basis. The volume of permits produced in future years is of interest from a traffic management and a financial perspective. Chapter 5 of the thesis analyses the relationship of three key factors with the number of permits produced on an annual basis. These factors are construction employment levels, gross domestic product (GDP) and the retail sales index (RSI). The RSI shows tentative potential as a suitable measure of future year permits numbers. It is worth noting that while the RSI performs well in tests as a predictor of permit numbers, an ongoing evaluation of RSI and permit numbers on a quarterly basis over a five to ten year period would be required in order to establish definitively that RSI is an accurate long term prediction indicator.

3. **To develop a coherent framework for integrating urban freight solutions in a broader transport policy context.**

Pricing is a complex activity in any discipline. In the case of the Permit System, this thesis proposes a PDVPM based on a 75% cost recovery of the breakeven point. However, based on research elsewhere and delivery patterns to date in Dublin, it is unlikely that a PDVPM will affect a significant shift in behaviour unless other external factors are addressed in conjunction with a revised pricing scheme. These factors are discussed briefly below and the PDVPM is presented together with some overall conclusions.

External factors contributing to a change in haulier behaviour primarily relate to the demands of the organisation receiving the goods. The experience of the HGV Management System to date shows that a movement towards night-time or off-peak deliveries has not occurred. This suggests that the current cost of the permits is not sufficient to bring about a change in the pattern of deliveries. Therefore, a separate policy response is required by local authorities to address this. Policies could include planning conditions for new developments and favourable adjustments in commercial rates to encourage the receipt of deliveries outside of peak times.

Another influencing factor is the potential additional operating cost incurred by hauliers as a result of changes in their delivery patterns. An assessment of HGV operating costs suggests that the financial impact of variable priced permits on hauliers is actually quite small when measured in the context of the total operating costs of the vehicle. Potentially hauliers could absorb the extra cost into their margins and continue with existing delivery patterns.

These two factors have the following implications for the introduction of a variable pricing model for permits:

1. There is a need to for policy measures for organisations who receive goods to do so at off-peak times
2. The scale of the pricing proposed under the variable pricing model must be of sufficient magnitude to force hauliers to change their behaviour

The Permit System as originally conceived uses an arbitrary flat price per permit. However, this pricing structure has no bearing on the actual cost of operating the Permit System on an annual basis. Therefore, one of the research objectives was to establish a methodology, which would produce a price for each permit having regard to the annual cost and more importantly to wider transport policy imperatives.

A breakeven cost for the permit system is obtained based on the annual cost of the system divided by the number of permits. A breakeven cost per cordon crossing is also obtained. The assessment is made that a charge per cordon crossing is more appropriate than an overall permit cost because it allows the implementation of a pricing model that can discriminate between cordons based on price. For transport policy reasons, the concept of a breakeven cost per cordon is introduced as part of the development of a Policy Driven Variable Pricing Model (PDVPM). The application of a PDVPM is applied to three different transport policies. The national transport policies analysed are the promotion of cycling and the promotion of bus priority measures. The PDVPM is also applied to a local transport policy imperative involving a movement towards creating a more pedestrian friendly environment along the quays of the River Liffey. In essence the PDVPM allows for the possibility of directing five plus axle vehicles to certain "encouraged" cordon points by applying a discount to the breakeven cordon cost and away from "discouraged" cordon point by adding a premium to the breakeven cost on the basis of selected transport policies. Given that there is a dearth of data currently available regarding how hauliers react to a range of pricing initiatives in an urban environment, a number of assumptions are made. Firstly, findings from the Chapter 4 indicate that a shift to deliveries outside of cordon hours has not occurred with the introduction of the HGV Management Strategy. This is likely to be a reflection of the customer driven nature of deliveries in Dublin, whereby the customer dictates delivery times. As an initial estimation of shift in behaviour, each of the three policies estimate a diversion of 15% of the total number of HGVs using a particular cordon point. This figure is based on a study carried out in New York and is a conservative estimate of HGV diversion rates. Premium and discount cordon costs are set with reference to the New York model and represent a 33% surcharge and reduction respectively.

The application of the PDVPM on each of the three policies is tested on 2008 permit data using a random sample of 100 permits. New average costs per permit of €16.42, €14.71 and €16.43 are obtained for Policy 1(promotion of cycling), Policy 2 (promotion of bus priority) and Policy 3 (promoting a more pedestrian friendly environment) respectively. However the cordon prices used are based on a breakeven cordon charge. The point is made in the thesis that the ongoing costs of the HGV Management Strategy are determined by the amount paid out in Eastlink toll rebates. The loophole in the system, which allows all five plus axle HGV traffic to claim a rebate as opposed to just the five plus HGVs moving between the North and South Ports (the original intention) increases the overall cost.

This thesis discusses a PDVPM based on a 75% cost recovery of the breakeven point. Using this methodology, average costs per permit of €12, €11, and €12 are obtained for Polices 1, 2 and 3 respectively.

While all three transport policies are assessed individually, it is noted that since there is no conflict between the "encouraged" cordon points and the "discouraged" cordon points selected, it would be possible for Dublin City Council to implement a PDVPM that takes into account all three transport imperatives. Furthermore, other local and national transport polices can be incorporated in a variable pricing model depending on the priorities and objectives for Dublin.

4. To test the impacts of an Urban Consolidation Centre on the speed, journey time and distance travelled by general traffic and public transport in a city where cars are the predominant mode of transport and to apply critical success factors to potential UCC location scenarios in Dublin

This research objective is addressed qualitatively through a set of proposed critical success factors based on international examples of UCCs and an Irish example of a privately operated UCC. It is addressed quantitatively through scenarios tested using a traffic microsimulation model.

International experience of UCCs has produced mixed results to date. UCCs such as those located in La Rochelle and Leiden have experienced difficulties in relation to enforcement, increases in traffic congestion and public opposition to the initiatives. More recent examples of UCCs in the U.K. have shown reasonable levels of success. UCCs such as the Bristol Consolidation Centre and Heathrow Airport Consolidation Centre have had modest success in terms of the number of trips reduced. In the case of the Musgrave Group, deliveries to the various Centra and SuperValu shops in the Dublin Area have been reduced by 500 by the company's operation of a UCC in Kilcock County Kildare. A set of critical success factors (CSFs) for UCCs based on case studies evaluated is presented in the thesis. CSFs include:

- Presence of a freight forum
- High levels of technology
- Local knowledge and appreciation for local conditions
- Location close to key target market and good transport network
- High proportion of own-account transport
- Provision of value added services as an additional revenue stream

Two potential locations for UCCs are proposed at Dublin Port and in the South West of the City. These locations emerged from the survey of city centre deliveries described in Chapter 3 and also from the assessment of Permit System data in Chapter 4. Using the set of CSF framework, a gap in knowledge is identified regarding the potential traffic impacts of using smaller vehicles to make city centre deliveries. In order to address this critical gap in knowledge, a number of UCC scenarios are tested using a Q-Paramics microsimulation traffic model. In total five scenarios, requiring five different models are tested. In each scenario, smaller, more eco-friendly vans are used to deliver goods from the UCC to the city centre. The two UCC locations are tested in the same scenario and also separately in order to identify subtle network performance issues.

Overall, it was found that while the option of a UCC at Dublin Port performs best, there are serious impacts on traffic in the model area as a result of both of the UCC options. For both general traffic and public transport, there are impacts in terms of reduction in speeds, increased travel times and reduced kilometres travelled due to increase levels of congestion in the network. The impact of the scenarios tested is not as severe on public transport as on general traffic. This is likely to be attributable to the protection that segregated bus lanes provide in parts of the city. However, given that it is national policy to promote the use of public transport (Department of Transport, 2009a), it is unacceptable at this point in time with current network conditions and capacity to introduce a HGV traffic management measure such as a UCC that has negative impacts for bus routes travelling to and from the city centre.

However, there are two measures, which may contribute to the viability of UCCs as a scenario for managing HGV deliveries in the future. The first measure is the extensive roll-out of additional segregated bus lanes in the HGV cordon area. An increase in bus lanes would provide higher levels of segregation from general traffic. Secondly, the Q-Paramics model represents a peak hour traffic situation. If deliveries from the UCC occurred out of cordon operation hours (19:00-07:00) or in off-peak times, the impact on public transport operations is likely to be mitigated considerably.

7.4 POTENTIAL AREAS FOR FURTHER WORK AND RESEARCH

Dublin Port Tunnel has been open to traffic since December 2006 and the HGV Management Strategy has been in operation since February 2007. While the two-tiered approach for managing urban freight has been successful, there are a number of areas that require further work and research in order to optimise existing functions and provide for enhanced functionality, especially if a similar approach is to be applied in a European context. Firstly, there is scope for extending the functionality of the Permit System to cater for the scheduling of permits. Essentially, this would involve developing a real-time Permit System that allocates a time window for deliveries based on a maximum number of deliveries to certain zones or based on maximum number of crossings of particular cordons within a given time period. This would involve working closely with heavy users of the permit system such as Diageo and Total Produce. There is further potential for the integration of a delivery trip scheduling system involving UCCs with the Permit System. This would create an overarching control system to manage the flow of vehicles from the UCCs into the city centre, and would be transferable to any European city with a network of UCCs.

Secondly, while the survey of goods deliveries to Dublin City Centre provides data on urban goods movement in the city, an annual survey of this kind is needed to monitor trends in the long term. Also, given the European dimension to urban freight distribution it would be worthwhile to undertake such surveys in a range of European cities in order to identify emerging issues and common trends.

Thirdly with regard to the Variable Pricing Policy Driven Model proposed in this thesis, a stated preference survey of hauliers focusing on reactions to variable pricing signals at cordon points would be a worthwhile piece of work.

Finally, there is a need to address the Eastlink loophole issue. One option for Dublin City Council is to implement a system of ANPR cameras at the North and South Port Areas and to crosscheck registration plate details with rebate claim applications. Reducing the amount of cost of rebates would provide Dublin City Council with more scope to introduce policy based pricing mechanisms, such as those referred to in this thesis.

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APPENDIX A
LETTERS OF SUPPORT FROM TRADE ASSOCIATIONS FOR DELIVEY SURVEY, DELIVERY DIARY AND SAMPLE COMPLETED FORMS

DUBLIN CITY BUSINESS ASSOCIATION

DCCBA Ltd.
21 Dawson Street
Dublin 2
Tel: 01 - 662 2995
Fax: 01 - 662 2284
Email: info@dcba.ie
Website: www.dcba.ie

February 27, 2003

«Title» «Initials» «Last_Name»
«Company»
«Address1»
«Address2»
«Address3»

Dear «First_Name»,

I would be very grateful if you would kindly facilitate a team from Trinity College (Clare Finnegan and Hugh Finlay) to compile data for an important new project on sustainable transport, which is of interest to members.

This involves a survey of deliveries to city centre business premises within the canal cordons on *a typical day during the week of 10th to 16th March.*

This exercise, which is being sponsored by the Department of Transport, will fill a crucial gap in the association's current understanding of the movements and behaviour of goods vehicles on our busy streets.

As you may be aware, our association sees an urgent need to persuade all the parties concerned to begin to manage deliveries in a way that will accommodate and maximise customer access. Indeed this concern will feature in the association's new "Mobility Plan for the City", currently under discussion.

Attached you will find diary sheets to be completed and returned by fax or by post to the address below for *a typical day, (preferably the 12th March)* in the week beginning the 10th March.

The completed diaries should be returned to following address or fax number before March 19th:
Clare Finnegan
TSRG
Department of Civil, Structural & Environmental Engineering
Trinity College, Dublin 2
Fax: 01 6773072; Tel: 01 6082537

If you have more than one outlet, please copy the diary sheet and circulate to each premises in the group.

A summary of the survey will be e-mailed back to respondents and I hope that this will provide useful feedback to members. Individual respondents will not be identified.

Thanking you for your kind co-operation.

Yours sincerely

Tom Coffey
Chief Executive

95

Anglesea House,
Anglesea Road,
Ballsbridge,
Dublin 4

Tel: 668 0215.
Fax: 668 0448.

Chief Executive Frank Fell.

27 March 2003

TO ALL MEMBERS OF THE ASSOCIATION

Dear Member

I would be very grateful if you would facilitate a team from Trinity College (Clare Finnegan and Hugh Finlay) to compile data for an important new project on sustainable transport (particularly in relation to deliveries) of interest to members.

This involves a survey of deliveries to city centre business premises within the canal cordons during *a typical day during the week of 7th to 12th April.*

This exercise, which is being sponsored by the Department of Transport, will help to fill a crucial gap in the LVA's current understanding of the movements and behaviour of goods vehicles on our busy streets.

Attached you will find diary sheets to be completed and returned to the address below for *a typical day (say Wednesday the 9th April)* in the week beginning the 7th April.

The completed diaries should be returned to the following address or fax number, by the 16th April if possible.

Clare Finnegan
TSRG, Department of Civil, Structural & Environmental Engineering
Trinity College
Dublin 2
Fax: 677 3072
Tel: 608 2537/608 2534

A summary of the survey results will be made available to respondents and I hope that this will provide useful feedback. Individual respondents will not be identified.

Thanking our for your kind co-operation,

Yours sincerely,

FRANK FELL
CHIEF EXECUTIVE

TCD Daily Delivery Survey

Company Name ______________ **Contact Person** **Type of Business** ______________ **Business Address**

Phone Number

Fax Number

Day of the Week ______________ **Date** ______________

Time of Delivery Arrival	Time of Delivery Departure	Type of Goods	How Packaged (pallets, boxes parcels, loose, etc)	Quantity of Packages	Type of Delivery Vehicle (truck, van, car motorbike)	Who supplied the Goods	Where is your Supplier Located	Where does loading/unloading occur? (on-street parking, shared loading bay, dedicated loading bay, other)

Please answer the following questions when you have completed the delivery diary

1.) Would you consider the number of deliveries today

- Less than usual ☐
- Greater than usual ☐
- Typical of an average day ☐

2.) If the number of deliveries is more or less than usual, please indicate whether there were

1 to 5 less ☐	1 to 5 more ☐
6 to 10 less ☐	6 to 10 more ☐
11 to 15 less ☐	11 to 15 more ☐
greater than 15 less ☐	greater than 15 more ☐

3.) Please provide details of deliveries which are normally scheduled for today and did not arrive

Name of Supplier	Type of Goods	Expected Delivery Date

Please return this form to Clare Finnegan by fax (6773072) or by post to TSRG, Dept of Civil Structural &Environmental Engineering, TCD, Dublin 2

DCCBA/TCD Daily Delivery Diary 12/3/03

Company Name Eason
Day of the Week Wednesday
Date 12-3-03

Contact Person
Phone Number
Fax Number

Business Address Eason + Son Ltd, Ilac Centre, Dublin

Time of Delivery Arrival	Time of Delivery Departure	Type of Goods	How Packaged (pallets, boxes, parcels, loose, other)	Quantity of Packages	Type of Delivery Vehicle (truck, van, car, motorbike)	Who Supplied the Goods	Where is your Supplier Located	Where does Loading/Unloading Occur? (on-street parking, shared loading bay, dedicated loading bay, other)
07.00	07.10	Newspapers + Magazines	Parcels	47 Parcels	Van	Eason Wholesale [illegible] Hoban	Clonshaugh 17	on street Parking
07.30	07.35	Stationery	1 Pallet	1 Pallet (17 boxes)	Truck	Deliverance	Brickfield Drive Crumlin D12	on-street Parking
08.15	08.20	Books	1 Pallet [illegible] 22 boxes	1 pallet (22 boxes)	Truck	Eason (Dromgoe) Wholesale	Santry	on street Parking
09.00	09.25	Batteries	boxes	[illegible] small boxes	VAN	Powerline	Alban Road	on street Parking
10.15	10.17	Bcs	Box	1 Sm Box	VAN	SDS	NAAS RD.	on Street Park
10.27	10.30	CARDS	Boxed	8 Large	VAN	Omega	Ballymount Rd.	ON ST.
11.25	11.25	News (Irish [illegible])	Boxes	2	VAN.	[illegible]	Clonshaugh 17	on st Parking
1.00	1.05	Art [illegible]	Box	1	VAN	Frans Maas	Swords	on ST. Park

Please answer the following questions when you have completed the delivery diary

1.) Would you consider the number of deliveries today

- Less than usual ☐
- Greater than usual ☐
- Typical of an average day ☑

2.) If the number of deliveries is more or less than usual, please indicate whether there were

1 to 5 less	☐	1 to 5 more	☐
6 to 10 less	☐	6 to 10 more	☐
11 to 15 less	☐	10 to 15 more	☐
greater than 15 less	☐	greater than 15 more	☐

3.) Please provide details of deliveries which are normally scheduled for today and did not arrive.

Name of Supplier	Type of Goods	Expected Delivery Date
N/A		

Please return the completed form to Clare Finnegan by fax (6773072) or by post to TSRG, Dept. of Civil, Structural Environmental Engineering, TCD, D2

DCCBA/TCD Daily Delivery Diary

Company Name

Contact Person
Phone Number
Fax Number

Business Address: Marks & Spencer (Irl) Ltd, 24-29 Mary St., Dublin 1

Day of the Week: Wednesday

Date: 12-3-03

Time of Delivery Arrival	Time of Delivery Departure	Type of Goods	How Packaged (pallets,boxes parcels,loose,other)	Quantity of Packages	Type of Delivery Vehicle (truck,van,car motorbike)	Who supplied the Goods	Where is your Supplier Located	Where does loading/unloading occur? (on-street parking, shared loading bay, dedicated loading bay,other)
0600	06:15	Catering/Food	Loose	50	Van	Country Foods.	Dublin 13	Loading Bay
06:50	07:00	Chilled Foods	Pallets	4	24' Truck	Bradford Meats	Monaghan	Loading Bay
07:00	09:45	Chilled Foods	Pallets	53	40' Truck	B.O.C.	Crewe, U.K.	Loading Bay
07:05	09:30	Chilled/Ambient Foods	Pallets	53	40' Truck	B.O.C.	Crewe, U.K.	Loading Bay
07:10	07:45	Textiles/Chilled/Ambient Foods	Rails and Pallets	3 Rails + 1 Pallet of Textiles 18 Pallets Foods	Double Decker Truck	Distribution Centre	Mallusk, Northern Ireland	Loading Bay
10:15	10:27	Staff Uniforms	Box	1	Van	Silver Safety Products	Dublin 4	Back Door
12:00	12:20	Chilled Foods	Pallets	6 Pallets - Mary St. 7 Pallets Grafton St	40' Truck	B.O.C.	Crewe, U.K.	Loading Bay
12:00	12:55	Chilled & Ambient Foods	Pallets	53	40' Truck	B.O.C.	Crewe, U.K.	Loading Bay
12:10	12:15	Stationery	Boxes	2	Van	Cobay	Dublin 4	Back Door
17:50	19:10	Textiles	Rails & Pallets	54 Rails 20 Pallets	Double Decker Truck	Distribution Centre	Mallusk, Northern Ireland	Loading Bay

Please answer the following questions when you have completed the delivery diary

1.) Would you consider the number of deliveries today

- Less than usual ☑
- Greater than usual ☐
- Typical of an average day ☐

2.) If the number of deliveries is more or less than usual, please indicate whether there were

- 1 to 5 less ☑ — 1 to 5 more ☐
- 6 to 10 less ☐ — 6 to 10 more ☐
- 11 to 15 less ☐ — 11 to 15 more ☐
- greater than 15 less ☐ — greater than 15 more ☐

3.) Please provide details of deliveries which are normally scheduled for today and did not arrive

Name of Supplier	Type of Goods	Expected Delivery Date
	None	

DCCBA/TCD Daily Delivery Diary

Company Name [illegible] Contact Person [illegible] Business Address [illegible] Street (upstairs) Dublin 1

Phone Number [illegible]

Fax Number [illegible]

Day of the Week Tuesday 13th May Date [illegible] May 13th

Time of Delivery Arrival	Time of Delivery Departure	Type of Goods	How Packaged (pallets boxes parcels/loose other)	Quantity of Packages	Type of Delivery Vehicle (truck van car motorbike)	Who supplied the Goods	Where is your Supplier Located	Where does loading/unloading occur? (on-street parking, shared loading bay, dedicated loading bay, other)
7.45	7.50	[illegible]	LOOSE	8	[illegible]	[illegible]	[illegible]	Shared loading bay
8.15	8.35	Vegetables	BAGS / LOOSE	17	VAN	[illegible]	[illegible]	[illegible]
9.30	9.35	[illegible]	BOXES	4	VAN	[illegible]	[illegible]	Shared loading bay
9.30	9.35	FISH	BAG	1	VAN	[illegible] FISH	[illegible]	[illegible]
11.40	11.55	DRY GOODS	BOXES	9	VAN	[illegible]	[illegible]	LOADING BAY
11.55	12.05	CHEESE	"	3	VAN	[illegible]	[illegible]	[illegible]
12.15	12.30	MEAT	[illegible]	1	VAN	SKJ	[illegible]	LOADING BAY
2.00	2.10	MEAT	BAG	1	VAN	[illegible] BUTCHER	[illegible]	LOADING BAY
2.30	2.40	BEER	GUINNESS BARREL	1	TRUCK	GUINNESS	JAMES GATE	LOADING BAY
2.40	2.50	BEER	[illegible] BARREL	1	TRUCK	"	"	"

Please answer the following questions when you have completed the delivery diary

1.) Would you consider the number of deliveries today

- Less than usual ☐
- Greater than usual ☐
- Typical of an average day ☑

2.) If the number of deliveries is more or less than usual, please indicate whether there were

1 to 5 less	☐	1 to 5 more	☐
6 to 10 less	☐	6 to 10 more	☐
11 to 15 less	☐	11 to 15 more	☐
greater than 15 less	☐	greater than 15 more	☐

3.) Please provide details of deliveries which are normally scheduled for today and did not arrive

Name of Supplier	Type of Goods	Expected Delivery Date

APPENDIX B
RESIDUAL VALUES FOR CHI SQUARE TEST: (CORDON ENTRIES AND DELIVERY ZONE ID)

			zone_id							
			1	1: Northside West	2: NorthsideCore	3: Northside East	4: Southside West	5a: Southside Core	6: Southside East	Total
cordon entry	1	Count	1310	7	492	128	731	420	550	3638
		Expected Count	270.9	137	763.8	511.3	1632.3	127.3	195.3	3638
		% within zone_id	12.80%	0.10%	1.70%	0.70%	1.20%	8.70%	7.40%	2.60%
		Residual	1039.1	-130	-271.8	-383.3	-901.3	292.7	354.7	
		Std. Residual	63.1	-11.1	-9.8	-17	-22.3	25.9	25.4	
	2	Count	958	66	179	176	178	94	511	2162
		Expected Count	161	81.4	453.9	303.9	970.1	75.6	116.1	2162
		% within zone_id	9.30%	1.30%	0.60%	0.90%	0.30%	2.00%	6.90%	1.60%
		Residual	797	-15.4	-274.9	-127.9	-792.1	18.4	394.9	
		Std. Residual	62.8	-1.7	-12.9	-7.3	-25.4	2.1	36.7	
	3	Count	221	7	26	7	32	82	805	1180
		Expected Count	87.9	44.4	247.8	165.9	529.5	41.3	63.3	1180
		% within zone_id	2.20%	0.10%	0.10%	0.00%	0.10%	1.70%	10.90%	0.90%
		Residual	133.1	-37.4	-221.8	-158.9	-497.5	40.7	741.7	
		Std. Residual	14.2	-5.6	-14.1	-12.3	-21.6	6.3	93.2	
	4	Count	135	103	30	11	24	19	388	710
		Expected Count	52.9	26.7	149.1	99.8	318.6	24.8	38.1	710
		% within zone_id	1.30%	2.00%	0.10%	0.10%	0.00%	0.40%	5.30%	0.50%
		Residual	82.1	76.3	-119.1	-88.8	-294.6	-5.8	349.9	
		Std. Residual	11.3	14.7	-9.8	-8.9	-16.5	-1.2	56.7	
	5	Count	146	26	169	22	683	46	58	1150
		Expected Count	85.6	43.3	241.5	161.6	516	40.2	61.7	1150
		% within zone_id	1.40%	0.50%	0.60%	0.10%	1.10%	1.00%	0.80%	0.80%
		Residual	60.4	-17.3	-72.5	-139.6	167	5.8	-3.7	
		Std. Residual	6.5	-2.6	-4.7	-11	7.4	0.9	-0.5	
	6	Count	18	5	15	2	34	11	90	175
		Expected Count	13	6.6	36.7	24.6	78.5	6.1	9.4	175
		% within zone_id	0.20%	0.10%	0.10%	0.00%	0.10%	0.20%	1.20%	0.10%
		Residual	5	-1.6	-21.7	-22.6	-44.5	4.9	80.6	

	Std. Residual	1.4	-0.6	-3.6	-4.6	-5	2	26.3	
7	Count	20	7	29	6	16	15	39	132
	Expected Count	9.8	5	27.7	18.6	59.2	4.6	7.1	132
	% within zone_id	0.20%	0.10%	0.10%	0.00%	0.00%	0.30%	0.50%	0.10%
	Residual	10.2	2	1.3	-12.6	-43.2	10.4	31.9	
	Std. Residual	3.2	0.9	0.2	-2.9	-5.6	4.8	12	
8	Count	20	18	26	12	323	39	21	459
	Expected Count	34.2	17.3	96.4	64.5	205.9	16.1	24.6	459
	% within zone_id	0.20%	0.30%	0.10%	0.10%	0.50%	0.80%	0.30%	0.30%
	Residual	-14.2	0.7	-70.4	-52.5	117.1	22.9	-3.6	
	Std. Residual	-2.4	0.2	-7.2	-6.5	8.2	5.7	-0.7	
9	Count	314	112	292	70	4790	370	300	6248
	Expected Count	465.3	235.3	1311.8	878.2	2803.4	218.6	335.4	6248
	% within zone_id	3.10%	2.20%	1.00%	0.40%	7.80%	7.70%	4.10%	4.50%
	Residual	-151.3	-123.3	-1019.8	-808.2	1986.6	151.4	-35.4	
	Std. Residual	-7	-8	-28.2	-27.3	37.5	10.2	-1.9	
10	Count	59	121	42	10	1442	83	37	1794
	Expected Count	133.6	67.6	376.7	252.2	805	62.8	96.3	1794
	% within zone_id	0.60%	2.30%	0.10%	0.10%	2.30%	1.70%	0.50%	1.30%
	Residual	-74.6	53.4	-334.7	-242.2	637	20.2	-59.3	
	Std. Residual	-6.5	6.5	-17.2	-15.2	22.5	2.6	-6	
11	Count	129	43	309	32	941	35	92	1581
	Expected Count	117.7	59.5	331.9	222.2	709.4	55.3	84.9	1581
	% within zone_id	1.30%	0.80%	1.10%	0.20%	1.50%	0.70%	1.20%	1.10%
	Residual	11.3	-16.5	-22.9	-190.2	231.6	-20.3	7.1	
	Std. Residual	1	-2.1	-1.3	-12.8	8.7	-2.7	0.8	
12	Count	2012	216	6318	496	10278	344	980	20644
	Expected Count	1537.3	777.5	4334.4	2901.6	9262.8	722.3	1108.2	20644
	% within zone_id	19.60%	4.20%	21.90%	2.60%	16.60%	7.10%	13.30%	15.00%
	Residual	474.7	-561.5	1983.6	-2405.6	1015.2	-378.3	-128.2	
	Std. Residual	12.1	-20.1	30.1	-44.7	10.5	-14.1	-3.9	
13	Count	394	127	477	57	495	101	99	1750
	Expected Count	130.3	65.9	367.4	246	785.2	61.2	93.9	1750
	% within zone_id	3.80%	2.40%	1.70%	0.30%	0.80%	2.10%	1.30%	1.30%
	Residual	263.7	61.1	109.6	-189	-290.2	39.8	5.1	

	Std. Residual	23.1	7.5	5.7	-12	-10.4	5.1	0.5	
14	Count	776	1208	843	214	6203	267	248	9759
	Expected Count	726.7	367.5	2049	1371.7	4378.8	341.4	523.9	9759
	% within zone_id	7.60%	23.30%	2.90%	1.10%	10.00%	5.50%	3.40%	7.10%
	Residual	49.3	840.5	-1206	-1157.7	1824.2	-74.4	-275.9	
	Std. Residual	1.8	43.8	-26.6	-31.3	27.6	-4	-12.1	
15	Count	171	142	5140	119	1301	215	261	7349
	Expected Count	547.2	276.8	1543	1032.9	3297.4	257.1	394.5	7349
	% within zone_id	1.70%	2.70%	17.80%	0.60%	2.10%	4.50%	3.50%	5.30%
	Residual	-376.2	-134.8	3597	-913.9	-1996.4	-42.1	-133.5	
	Std. Residual	-16.1	-8.1	91.6	-28.4	-34.8	-2.6	-6.7	
16	Count	752	87	3276	257	3072	174	158	7776
	Expected Count	579	292.9	1632.7	1092.9	3489	272.1	417.4	7776
	% within zone_id	7.30%	1.70%	11.30%	1.30%	5.00%	3.60%	2.10%	5.60%
	Residual	173	-205.9	1643.3	-835.9	-417	-98.1	-259.4	
	Std. Residual	7.2	-12	40.7	-25.3	-7.1	-5.9	-12.7	
17	Count	12	55	76	23	91	32	16	305
	Expected Count	22.7	11.5	64	42.9	136.9	10.7	16.4	305
	% within zone_id	0.10%	1.10%	0.30%	0.10%	0.10%	0.70%	0.20%	0.20%
	Residual	-10.7	43.5	12	-19.9	-45.9	21.3	-0.4	
	Std. Residual	-2.2	12.8	1.5	-3	-3.9	6.5	0	
18	Count	276	172	83	14390	336	195	29	15481
	Expected Count	1152.8	583	3250.4	2175.9	6946.2	541.6	831	15481
	% within zone_id	2.70%	3.30%	0.30%	74.40%	0.50%	4.00%	0.40%	11.20%
	Residual	-876.8	-411	-3167.4	12214.1	-6610.2	-346.6	-802	
	Std. Residual	-25.8	-17	-55.6	261.8	-79.3	-14.9	-27.8	
19	Count	431	89	1308	125	957	137	353	3400
	Expected Count	253.2	128	713.9	477.9	1525.6	119	182.5	3400
	% within zone_id	4.20%	1.70%	4.50%	0.60%	1.50%	2.80%	4.80%	2.50%
	Residual	177.8	-39	594.1	-352.9	-568.6	18	170.5	
	Std. Residual	11.2	-3.5	22.2	-16.1	-14.6	1.7	12.6	
20	Count	646	443	2602	1112	3022	1560	1090	10475
	Expected Count	780	394.5	2199.3	1472.3	4700	366.5	562.3	10475
	% within zone_id	6.30%	8.50%	9.00%	5.70%	4.90%	32.40%	14.80%	7.60%
	Residual	-134	48.5	402.7	-360.3	-1678	1193.5	527.7	

	Std. Residual	-4.8	2.4	8.6	-9.4	-24.5	62.3	22.3	
21	Count	1450	2130	7169	2078	26813	577	1264	41481
	Expected Count	3088.9	1562.2	8709.4	5830.3	18612.2	1451.3	2226.7	41481
	% within zone_id	14.10%	41.10%	24.80%	10.70%	43.40%	12.00%	17.10%	30.10%
	Residual	-1638.9	567.8	-1540.4	-3752.3	8200.8	-874.3	-962.7	
	Std. Residual	-29.5	14.4	-16.5	-49.1	60.1	-23	-20.4	
Total	Count	10250	5184	28901	19347	61762	4816	7389	137649
	Expected Count	10250	5184	28901	19347	61762	4816	7389	137649
	% within zone_id	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

RESIDUAL VALUES FOR CHI SQUARE TEST: (CORDON EXITS AND DELIVERY ZONE ID)

		zone_id							
		1	1: Northside West	2: Northside Core	3: Northside East	4: SouthsideWest	5a: Southside Core	6: Southside East	Total
CORDON EXIT	1 Count	1318	23	492	124	533	434	585	
	Expected Count	267.4	136.4	774	510.9	1506.4	116.6	197.4	3509
	% within zone_id	13.10%	0.40%	1.70%	0.60%	0.90%	9.90%	7.90%	2.70%
	Residual	1050.6	-113.4	-282	-386.9	-973.4	317.4	387.6	
	Std. Residual	64.2	-9.7	-10.1	-17.1	-25.1	29.4	27.6	
	2 Count	1078	80	137	276	340	142	456	2509
	Expected Count	191.2	97.5	553.4	365.3	1077.1	83.4	141.1	2509
	% within zone_id	10.70%	1.60%	0.50%	1.40%	0.60%	3.20%	6.20%	1.90%
	Residual	886.8	-17.5	-416.4	-89.3	-737.1	58.6	314.9	
	Std. Residual	64.1	-1.8	-17.7	-4.7	-22.5	6.4	26.5	
	3 Count	260	6	23	15	32	88	820	1244
	Expected Count	94.8	48.4	274.4	181.1	534	41.3	70	1244
	% within zone_id	2.60%	0.10%	0.10%	0.10%	0.10%	2.00%	11.10%	0.90%
	Residual	165.2	-42.4	-251.4	-166.1	-502	46.7	750	
	Std. Residual	17	-6.1	-15.2	-12.3	-21.7	7.3	89.7	
	4 Count	102	16	33	12	26	24	196	409
	Expected Count	31.2	15.9	90.2	59.5	175.6	13.6	23	409
	% within zone_id	1.00%	0.30%	0.10%	0.10%	0.00%	0.50%	2.60%	0.30%
	Residual	70.8	0.1	-57.2	-47.5	-149.6	10.4	173	
	Std. Residual	12.7	0	-6	-6.2	-11.3	2.8	36.1	
	5 Count	77	14	102	22	379	55	82	731
	Expected Count	55.7	28.4	161.2	106.4	313.8	24.3	41.1	731
	% within zone_id	0.80%	0.30%	0.40%	0.10%	0.70%	1.30%	1.10%	0.60%
	Residual	21.3	-14.4	-59.2	-84.4	65.2	30.7	40.9	
	Std. Residual	2.9	-2.7	-4.7	-8.2	3.7	6.2	6.4	
	6 Count	12	2	4	5	26	8	17	74
	Expected Count	5.6	2.9	16.3	10.8	31.8	2.5	4.2	74
	% within zone_id	0.10%	0.00%	0.00%	0.00%	0.00%	0.20%	0.20%	0.10%
	Residual	6.4	-0.9	-12.3	-5.8	-5.8	5.5	12.8	
	Std. Residual	2.7	-0.5	-3	-1.8	-1	3.5	6.3	

7	Count	12	3	17	9	25	13	36	115
	Expected Count	8.8	4.5	25.4	16.7	49.4	3.8	6.5	115
	% within zone_id	0.10%	0.10%	0.10%	0.00%	0.00%	0.30%	0.50%	0.10%
	Residual	3.2	-1.5	-8.4	-7.7	-24.4	9.2	29.5	
	Std. Residual	1.1	-0.7	-1.7	-1.9	-3.5	4.7	11.6	
8	Count	27	12	28	12	220	39	18	356
	Expected Count	27.1	13.8	78.5	51.8	152.8	11.8	20	356
	% within zone_id	0.30%	0.20%	0.10%	0.10%	0.40%	0.90%	0.20%	0.30%
	Residual	-0.1	-1.8	-50.5	-39.8	67.2	27.2	-2	
	Std. Residual	0	-0.5	-5.7	-5.5	5.4	7.9	-0.5	
9	Count	326	98	267	68	3806	409	320	5294
	Expected Count	403.5	205.8	1167.7	770.7	2272.6	175.9	297.8	5294
	% within zone_id	3.20%	1.90%	0.90%	0.40%	6.70%	9.40%	4.30%	4.00%
	Residual	-77.5	-107.8	-900.7	-702.7	1533.4	233.1	22.2	
	Std. Residual	-3.9	-7.5	-26.4	-25.3	32.2	17.6	1.3	
10	Count	62	121	53	25	1535	65	36	1897
	Expected Count	144.6	73.7	418.4	276.2	814.3	63	106.7	1897
	% within zone_id	0.60%	2.40%	0.20%	0.10%	2.70%	1.50%	0.50%	1.40%
	Residual	-82.6	47.3	-365.4	-251.2	720.7	2	-70.7	
	Std. Residual	-6.9	5.5	-17.9	-15.1	25.3	0.2	-6.8	
11	Count	126	30	519	49	770	37	67	1598
	Expected Count	121.8	62.1	352.5	232.6	686	53.1	89.9	1598
	% within zone_id	1.30%	0.60%	1.80%	0.30%	1.40%	0.80%	0.90%	1.20%
	Residual	4.2	-32.1	166.5	-183.6	84	-16.1	-22.9	
	Std. Residual	0.4	-4.1	8.9	-12	3.2	-2.2	-2.4	
12	Count	1668	192	7768	475	10925	405	901	22334
	Expected Count	1702.2	868.1	4926.2	3251.5	9587.6	742.2	1256.2	22334
	% within zone_id	16.60%	3.80%	26.80%	2.50%	19.30%	9.30%	12.20%	17.00%
	Residual	-34.2	-676.1	2841.8	-2776.5	1337.4	-337.2	-355.2	
	Std. Residual	-0.8	-22.9	40.5	-48.7	13.7	-12.4	-10	
13	Count	431	116	432	70	172	87	75	1383
	Expected Count	105.4	53.8	305	201.3	593.7	46	77.8	1383
	% within zone_id	4.30%	2.30%	1.50%	0.40%	0.30%	2.00%	1.00%	1.10%
	Residual	325.6	62.2	127	-131.3	-421.7	41	-2.8	
	Std. Residual	31.7	8.5	7.3	-9.3	-17.3	6.1	-0.3	

14	Count	1158	1326	1299	237	6087	322	248	10677
	Expected Count	813.7	415	2355	1554.4	4583.4	354.8	600.6	10677
	% within zone_id	11.50%	25.90%	4.50%	1.20%	10.80%	7.40%	3.30%	8.10%
	Residual	344.3	911	-1056	-1317.4	1503.6	-32.8	-352.6	
	Std. Residual	12.1	44.7	-21.8	-33.4	22.2	-1.7	-14.4	
15	Count	279	150	6307	87	1617	168	269	8877
	Expected Count	676.6	345.1	1958	1292.3	3810.7	295	499.3	8877
	% within zone_id	2.80%	2.90%	21.70%	0.50%	2.90%	3.80%	3.60%	6.70%
	Residual	-397.6	-195.1	4349	-1205.3	-2193.7	-127	-230.3	
	Std. Residual	-15.3	-10.5	98.3	-33.5	-35.5	-7.4	-10.3	
16	Count	897	91	4575	252	2946	70	234	9065
	Expected Count	690.9	352.4	1999.4	1319.7	3891.4	301.3	509.9	9065
	% within zone_id	8.90%	1.80%	15.80%	1.30%	5.20%	1.60%	3.20%	6.90%
	Residual	206.1	-261.4	2575.6	-1067.7	-945.4	-231.3	-275.9	
	Std. Residual	7.8	-13.9	57.6	-29.4	-15.2	-13.3	-12.2	
17	Count	15	26	54	36	50	10	56	247
	Expected Count	18.8	9.6	54.5	36	106	8.2	13.9	247
	% within zone_id	0.10%	0.50%	0.20%	0.20%	0.10%	0.20%	0.80%	0.20%
	Residual	-3.8	16.4	-0.5	0	-56	1.8	42.1	
	Std. Residual	-0.9	5.3	0	0	-5.4	0.6	11.3	
18	Count	303	191	80	14369	617	116	25	15701
	Expected Count	1196.6	610.3	3463.1	2285.8	6740.2	521.8	883.1	15701
	% within zone_id	3.00%	3.70%	0.30%	75.00%	1.10%	2.70%	0.30%	11.90%
	Residual	-893.6	-419.3	-3383.1	12083.2	-6123.2	-405.8	-858.1	
	Std. Residual	-25.8	-17	-57.5	252.7	-74.6	-17.8	-28.9	
19	Count	321	78	767	132	834	106	330	2568
	Expected Count	195.7	99.8	566.4	373.9	1102.4	85.3	144.4	2568
	% within zone_id	3.20%	1.50%	2.60%	0.70%	1.50%	2.40%	4.50%	2.00%
	Residual	125.3	-21.8	200.6	-241.9	-268.4	20.7	185.6	
	Std. Residual	9	-2.2	8.4	-12.5	-8.1	2.2	15.4	
20	Count	470	415	2243	867	2980	1205	1312	9492
	Expected Count	723.4	369	2093.6	1381.9	4074.7	315.5	533.9	9492
	% within zone_id	4.70%	8.10%	7.70%	4.50%	5.30%	27.50%	17.70%	7.20%
	Residual	-253.4	46	149.4	-514.9	-1094.7	889.5	778.1	
	Std. Residual	-9.4	2.4	3.3	-13.9	-17.1	50.1	33.7	

21	Count	1089	2126	3830	2019	22580	571	1320	33535
	Expected Count	2555.9	1303.5	7396.7	4882.1	14396	1114.5	1886.3	33535
	% within zone_id	10.90%	41.60%	13.20%	10.50%	40.00%	13.10%	17.80%	25.50%
	Residual	-1466.9	822.5	-3566.7	-2863.1	8184	-543.5	-566.3	
	Std. Residual	-29	22.8	-41.5	-41	68.2	-16.3	-13	
Total	Count	10031	5116	29030	19161	56500	4374	7403	131615
	Expected Count	10031	5116	29030	19161	56500	4374	7403	131615
	% within zone_id	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

APPENDIX C
LETTER FROM DUBLIN CITY COUNCIL TO ORANISATIONS IN BREACH OF THE HGV MANAGEMENT STRATEGY

Dublin City Council
Comhairle Cathrach Bhaile Átha Cliath

Córais Thráchta Cliste,
Roinn Bóithre agus Tráchta,
Oifigína Cathrach,
An Ché Adhmaid,
Baile Átha Cliath 8

Intelligent Transport Systems,
Roads and Traffic Department,
Civic Offices,
Wood Quay,
Dublin 8

T. 01 222 5271
F. 01 222 2760
E. niall.bolger@dublincity.ie

XXXXX Ltd,
Longacre,
Newmarket,
Co Cork.

30th September 2009

RE: HGV Cordon Breach on 25th September 2009

Dear Sir/Madam,

A vehicle registered to your company was sighted within the HGV Cordon Area on the 25th September 2009. On checking, this vehicle did not have the required HGV permit allowing it to be legally inside the cordon.

The vehicle registration number of the vehicle in question is 08C2XXXX
Please contact me as soon as possible to discuss this matter.

Please note that fines for breaching the cordon are: up to €800 for the first offence, €1,500 for second offence within 12 months and €1,500 and possible imprisonment for third offence.

This matter is being dealt with by Niall Bolger and can be contacted at 222 XXXX.

Yours sincerely,

Niall Bolger

Assistant ITS Officer

APPENDIX D
PUBLISHED RESEARCH

Finnegan, C., O'Brien, B., Bolger, N (2008). Implementation of a HGV Management Strategy for Dublin City Centre: One Year On. Transport Practitioners Meeting, Reading

Finnegan, C., O'Brien, B., Traynor, D., (2007). An Initial Evaluation of Dublin Port Tunnel and the HGV Management Strategy for the City, European Transport Conference, Leiden

Finnegan, C., O'Mahony, M., Finlay, H. (2005).Urban Freight in Dublin City Centre: Survey Analysis and Strategy Evaluation. Transport Research Record Number 1906, 2005, pg 33-41

Finnegan, C. O'Mahony, M., Finlay, H., (2005) Urban Freight in Dublin City Centre: Survey Analysis and Strategy Evaluation.. 37th Annual Conference of the University Transport Study Group, Bristol

Finnegan, C O'Mahony, M. (2004).An Analysis of Goods Deliveries in Dublin City Centre. 36th Annual Conference of the University Transport Study Group, Newcastle Upon Tyne

Finnegan, C., O'Mahony, M., Finlay H.,, (2004). An Initial Assessment of the Potential for an Urban Freight Distribution Centre in Dublin. 83rd Meeting of the Transportation Research Board, Washington D.C.

Finnegan C., O'Mahony, M. (2003) Patterns of Freight Distribution for a Historic Urban Centre. European Transport Conference, Strasbourg