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A study of Intelligent Transport Systems (ITS) in Dublin Port in conjunction with the Intelligent Transport for Dynamic Environment (InTraDE) Project

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This research is dedicated to my precious son Colin who passed on the 2nd January 2017. May he rest in peace.

'Say not in grief 'he is no more' but live in thankfulness that he was'

Hebrew proverb

Abstract

In the last four decades the container as an essential part of a unit load-concept has achieved authentic importance in international sea freight transportation. With ever increasing containerization the number of port container terminals and competition among them has become quite remarkable. Port container operations are nowadays unthinkable without effective and efficient use of Intelligent Transport Systems (ITS) (Steenken & Stahlbock, 2004).

The main problem in handling increasing levels of cargo is managing the internal traffic and optimizing space inside smaller and medium sized ports. A gap exists between automated cargo handling equipment that is suitable for use in the larger container terminals such as Rotterdam and its suitability in smaller terminals such as Dublin. A new generation of cargo handling technology has been designed in the form of an Intelligent Autonomous Vehicle (IAV). The IAV is a clean, safe, intelligent vehicle which will contribute to improving the traffic management and space optimization inside confined space by developing a clean, safe and intelligent transport system. This technology has been designed and developed as part of the 'InTraDE' (Intelligent Transport for Dynamic Environment) project to which the research has contributed.

By using ITSs, logistics operations could be improved by enhancing the exchange of information and real-time status updates regarding different business operations in different modes of transportation (Schumacher et al., 2011). Maritime transport has recently gained increased attention, especially in connection to the building and further development of ITS (Pietrzykowski, 2010).

This research looks at the main logistic processes and operations in port container terminals. It discusses the extent to which the terminal shipping operators in Dublin Port currently meet the demands of their customers and whether the introduction of ITS could enhance the efficiency and productivity of such services.

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Finally, I owe a great deal of gratitude to my son Colin and his wife Neva for all their help, encouragement, support and patience.

Declaration

I certify that this thesis, which I now submit for examination for the reward of MPhil thesis, is entirely my own work and has not been taken from the work of others, save and to the extent that such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the regulations for postgraduate study by research of the Dublin Institute of Technology and has not been submitted in whole or in part for another award in any institute.

The work reported on in this thesis conforms to the principles and requirements of the Institutes guidelines for ethics in research.

The Institute has permission to keep, lend or copy this thesis in whole or in part, on condition that any such use of the material of the thesis is duly acknowledged.

Signature ____________________________________ Date ________________

Candidate

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Nomenclature

ABR – Alexander Basin Development

AGV – Automated Guided Vehicle

ARMG – Automated Rail Mounted Gantry

API – Application Programming Interface

ASC – Automatic Stacking Crane

BCT – Belfast Container Terminal

B&I Line – British & Irish Steam Package Company Ltd

DIT – Dublin Institute of Technology

DFT – Dublin Ferryport Terminal

DPC – Dublin Port Company

DSME - Daewoo Shipbuilding and Marine Engineering

ECT – European Container Terminal

ETA – Estimated time of arrival

ETD – Estimated time of departure

EU – European Union

FEU – Forty Foot Equivalent Unit

GDP – Gross Domestic Product

GHP – Green House Gases

GPS – Global Positioning System

HHLA – Hamburgen, Halen and Logistik

IAV – Intelligent Autonomous Vehicle

ICG - Irish Continental Group

ICT – Information and Communication Technology

InTraDE – Intelligent Transport for Dynamic Environment

ISO - International Standard Organisation

ITS – Intelligent Transport System

KPI – Key Performance Indicator

LO/LO – Lift -on / Lift – off

MTL – Marine Terminal Ltd

NPV – Net Present Value

NWE – North West Europe

PRSI – Pay Related Social Insurance

QC – Quay Crane

RMG – Rail Mounted Gantry Crane

ROI – Return on Investment

RO/RO – Roll-on / Roll-off

RTG – Rubber Tyre Gantry Crane

SKEMA – A Maritime Knowledge Platform Project

TEU – Twenty Foot Equivalent Unit

TOS – Terminal Operating Systems

UNCTAD – United Nations Conference on Trade and Development

Chapter One: Introduction

1.0 Introduction

This chapter introduces the research topic and aims to give the reader a brief overview of the changing role of port container terminals and the concept of intelligent transport systems. A rationale for the research is put forward, the research question and research objectives are outlined and chapter outlines are presented.

1.1 The Changing Role of Port Container Terminals

The shipping industry is one which is constantly evolving in order to better service customers. At the Nor-Shipping Conference in June 2011, the then IMO Secretary-General, Mr Mitropoulos, stated ''A*lthough the economic outlook for shipping may, in the prevailing circumstances, be uncertain, the march of technology seems inexorable, as the industry seeks constantly to improve its efficiency and improve performance – both from the commercial and environmental viewpoints.''*

According to Yamin & Depledge, (2004) climate change is the result of complex and dynamic interactions between the Earth's atmospheric biosphere and oceans causing greenhouse gases (GHG's) to rise considerably which is due to fossil fuel burning, deforestation, livestock farming and other human activities. These impacts are effecting the environment as well as social and vital economic interests that will have profound consequences for every aspect of society.

Globalisation, sustainable energy and consumption needs, together with climate change have had dramatic effects on our environment and are at the forefront of the international maritime agenda. The benefits that shipping operators can obtain from practising environmental management and implementing the underlying green shipping practices (GSP's) are increasingly being recognised (Lun et al., 2010).

International trade and its integral activities of importing and exporting constitute the fundamental aspects of globalisation (Wang et al., 2005). Today, maritime cargo transportation has become the predominant transport mode in international trade (Grunow et al, 2006). Maritime transportation plays a major role in the national and international trade as well as the economic growth of a country. Seaborne trade represents more than 90% of international world trade (UNCTAD, 2013).

It is expected that global container port throughput will exceed 840 million TEU by 2018, with the fastest growing regions projected to be Africa and Greater China. This represents an average annual growth rate of 5.6% over the next five years, an improvement on the 3.4% recorded in 2013. The overall growth in trade will boost average terminal utilisation from 67% today to 75% in 2018 (Drewry Maritime Research, 2014).

The operators of terminals and ports are obliged to take a more responsible stand with regard to the environment. Environmental issues and related laws and regulations give effect to European Commission EC Directive 2001/42/EC which assesses the effects of certain plans and programmes on the environment; for example land use, transport and energy. Also to be considered is EU Directive 2002/49/EC; relating to the assessment and management of environmental noise. As a result, greater emphasis is being placed on the design and sustainable development of technology in ports (European Commission, 2004).

These developments have brought attention to bear on cargo-handling equipment using low-energy consumption, environmentally aware technologies to reduce emissions and noise and to optimise the use of limited land space, particularly in small to medium sized ports. It is important that the shipping industry uses equipment that is both economical and environmentally compatible.

Most ports today are competing with one another on a global scale and are now perceived to be the remaining controllable component in improving the efficiency of ocean transport logistics (World Port, 2007). This has generated the drive to improve port efficiency, lower cargo handling costs and integrate port services with other components of the global distribution network with regard to lowering emissions, reducing noise, safety and security (ibid).

Dublin is the largest of the three main ports in Ireland, the others being Belfast and Cork. These ports offer multi-modal services with connections to ports such as Rotterdam, Antwerp, Le Havre, Felixstowe, Hamburg, Southampton and Liverpool, which are important strategic trading hubs. Dublin Port handles over €35 billion worth of trade every year and supports some 4,000 jobs locally. Ninety per cent of Irelands Gross Domestic Product (GDP) is exported with 42% handled through Dublin Port. Volumes through the Port grew for the third year in a row, ensuring that a record throughput of 32.8m tonnes was handled in 2015, representing a 6.4% increase on the previous year (Dublin Port Company, 2015).

The current decade has witnessed a remarkable growth in container transportation and vessel size. This has brought an increasing need for optimisation in container terminals. Port container terminals, as the linking nodes, are facing greater challenges in handling, stacking, and transferring large numbers of containers, and high productivity is the key factor in maintaining terminal competitiveness (Sciomachen et al., 2009)

At the same time, container terminals' major customers demand reliability and efficiency at low costs. The changes that have taken place require shipping operators to continuously improve their performances and guarantee seamless operations (ibid).

With this in mind, port technology is facing many challenges due to ever increasing complexity and physical infrastructure. Some of the problems that have received widespread attention are emissions and noise. The lack of new generation facilities and over exploitation of existing facilities, together with the increase in load demand has increased such issues.

The use of Automated Guided Vehicles (AGVs) in some of the major ports such as Rotterdam, Dusseldorf and Hamburg has resolved some of the internal traffic issues but has highlighted others. A new generation of cargo handling technology such as the IAV has been designed in the framework of Intelligent Transport for Dynamic Environment (InTraDE), an EU funded project to which Dublin Institute of Technology (DIT) has been a partner, with Dublin Port Company as a sub-partner. Participation in the project will contribute to improving the traffic management and space optimization inside confined space by developing a clean, safe and intelligent transport system such as the IAV.

1.2 Researcher Profile

The experience gained from over thirty years in the shipping industry has provided the author with a basis for this research. Extensive work experience was gained in the maritime environment and this resulted in various skills being developed as well as the ability to interact with different types of people in a number of shipping roles.

Responsibilities involved dealing with customers regarding bookings and documentation. It also involved liaising with Customs & Excise, Health & Safety and other government agencies such as the Irish Department of the Marine. There was also collaboration with international offices to improve efficiency, productivity and processes of logistic flows. This experience was enhanced as a result of a role as office/terminal supervisor in the lift/on-lift/off (LO/LO) freight division, providing strategic and tactical support to the container terminal manager.

The combination of a BA (Hons) in Port Management and a lecturing post (part-time) in DIT has also provided a basis in terms of the skills required to undertake academic research, using initiative and self-motivation. The researcher has been the Principal Coordinator on the InTraDE project and was accountable to the project manager Professor Rochdi Merzouki for delivering the DIT packages as planned. This involved travelling to the other partners' locations as well as presenting at conferences in Hong Kong, Rome and Belfast (see Appendix XII). Other responsibilities included all the necessary skills to achieve the project outputs. This involved integrating the goals and activities of the other partners involved with the project. The functional units, such as finance, human resources and procurement, were also coordinated by the researcher in a way that benefited the project. Other responsibilities were to ensure that changes were beneficial and contributed to the success of the project. This was achieved by influencing factors that created change and by making trade-offs among the project constraints such as scope, schedule, budget and quality. She is currently lecturing in Maritime Operations on the BSc in Transport Operations and Technology at DIT.

1.3 Research Rationale

Due to globalization and the development of emerging countries, world seaborne trade has been evolving rapidly since the 1960's. This growth has a significant influence on the development of ports and terminals worldwide, and as a result many container terminals have become over utilized. Despite the importance of the North West Europe (NWE) coastal area stretching from Ireland to the Netherlands, several of its smaller and medium sized ports are unable to keep pace with this expansion (InTraDE, 2010). This research presents facts aimed at investigating ITS in port container terminals suitable for use in small-to-medium sized ports.

The growth rate of containership size has accelerated over the last decade. It took one decade to double the average container ship capacity from 1,500 to 3,000 TEU, but almost 30 years to get to 1,500 TEU. This has been driven by large increases in the maximum capacity of container ships, especially in the last decade. These increases in maximum capacity have accelerated the growth of the average ship capacity. The average age of newly built container vessels had been oscillating around approximately 3,400 TEU between 2001 and 2008, but has increased significantly since then reaching a mean of 5,800 between 2009 and 2013. The average size of a newly built containership has soared to approximately 8,000 TEUs in 2015 (International Transport Forum, 2006)

With the arrival of the new generation ultra–large Triple-E vessels carrying 18,270 TEU it is important to investigate the opportunities to introduce innovation in the development of port container terminal operations. Growth has led to severe pressure on ports and terminals to find more efficient ways of handling containers and increasing terminal capacity whilst ensuring safety. A traditional method, such as expanding the port, is not feasible because many ports such as Dublin are located inside major cities where land is restricted. Dublin Port infrastructure consists of 260 hectares of reclaimed land. All of this land comes from reclamation works carried out over the last 200 years. The last phase of this work ended in the 1970's. If the port is to expand, it is clear that additional land will be required. There is a limit to the amount of traffic the port's existing estate can handle, so to cater for future expansion another 30 to 40 hectares will be required for this growth (Dublin Port Company, 2011). As this land is not available at this point in time (2015), Dublin Port and its terminals is constantly searching for better solutions to cargo handling technology

Not every review of terminal operations and cargo handling technology will result in improved terminal operations. Therefore, this research examines ITS, in port container terminals as demand is largely driven by the ever changing demands of customers. As a result, this research should be able to be utilised by industry professionals to determine what today's customer demands are and to see if their organisation is able to meet those demands.

1.4 Research Objectives

The objectives to be reached in order to achieve are:

i. *Identify the current intelligent transport systems offered by container terminal operators in Dublin Port and investigate the possibility of introducing new ITS.*
ii. *Explore the factors that influence the customer satisfaction of freight operators provided by container terminal operators in Dublin Port and analyse their views.*
iii. *Determine if container terminal operators are currently meeting the intelligent transport systems demands of consumers and explore their plans for the introduction of ITS in the future.*

1.5 Research Question

The research question is the signle question or hypothesis that best states the research objectives (Cooper & Emory, 1995). From the above research objectives the research question is defined as;

Could Dublin Port container terminal operators improve their productivity and efficiency by implementing new ITS for example the IAV?

1.6 Organisation of the thesis

This research consists of 7 chapters including 12 appendices and is summarised and structured as follows:

Chapter One: Introduces the research undertaken by stating the main question addressed and the objectives of the research before putting it in its wider context and summarising the remainder of the research and the work presented in it.

Chapter Two: Provides an overview of cargo handling technology and a literature review that references the work of relevant researchers in the field of intelligent transport systems used in container ports. The impact of operations in Dublin Ferryport Terminals is also discussed.

Chapter Three: This chapter portrays the services operated in Dublin Port. Port and terminal operations are explained. Future plans for growth and prosperity in the Port are discussed. DFT one of the three container terminals in Dublin Port was also discussed. Containerisation and cargo handling equipment are explained.

Chapter Four: Explains the InTraDE project, its aims and objectives. The project work packages are discussed and the IAV is introduced.

Chapter Five: The Methodology chapter gives an overview of the research methods that are used to undertake the research. It also provides a justification for the research methods that are used to answer the research question.

Chapter Six: This chapter illustrates the key findings of the primary research in the form of figures, tables and text by revealing the results of both the on-line questionnaire and key informant interviews.

Chapter Seven: The final chapter draws conclusions of the research and discusses future research. It also contains a summary and recommendations. The overall aim was to examine the potential impact of new ITS in Dublin Port, and to advance an understanding of actual benefits and issues encountered.

1.7 Conclusion

This chapter provides an overview of the research topic of the research. The background for container terminals is reviewed and a rationale for undertaking the research was put forward. The research question is highlighted and the objectives of the study, which will enable the research question to be answered, are presented.

Chapter Two: Literature Review

2.0 Introduction

The purpose of this chapter is to review and critically analyse the pertinent literature with a view to obtaining an in-depth understanding of cargo handling equipment and new ITS used in the constantly changing ports of today as well as the impact on container operations.

2.1 A Vision for the Future in Port Container Terminals.

Maritime transport is composed of maritime shipping and port dimensions. Areas of focus include establishing a vision for the future of maritime transport, identifying the innovative technologies, business modes and policies that will drive change, overcoming barriers to innovation and establishing governance structures at the global and national levels to foster the innovations that our societies will need for a more sustainable and better performing future transport system (Rodrigue, 2010).

The field of intelligent autonomous vehicles is rapidly growing worldwide, both in the diversity of applications and in increasing interest in the automotive, truck, public transport, industrial, and military sectors. These systems offer the potential for significant enhancements in safety and operational efficiency (Bishop, 2000).

Most ports today are competing with one another on a global scale and, with the tremendous gains in productivity in ocean transport achieved over the past decades, ports are now perceived to be the remaining controllable component in improving the efficiency of ocean transport logistics. This has generated the drive to improve port efficiency, lower cargo handling costs and integrate port services with other components of the global distribution network with regard to lowering emissions, safety and security (World Bank, 2007)

Ports no longer operate in an insulated or isolated environment. They face the same competitive forces that companies in other industries experience. There is rivalry among existing competitors, the continuing threat of new entrants; and potential for global substitutes, the presence of powerful customers and powerful supplies, and regulative and legislative boundaries that must be adhered to (ibid).

2.2 Intelligent Transport Systems (ITS)

Logistics has become a major economic activity comprising the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services and related information from point of origin to point of consumption for the purpose of conforming to customer requirements (Stock, J. R. 1998) The use of ITS has been encouraged by government directives and initiatives aiming at making operations more efficient and environmentally friendly. For example, in recent years the European Commission has released a series of calls aiming at the development of short-sea shipping as a sustainable part of the logistics chain as European roads suffer from major congestion problems (Aperte and Baird, 2013). International logistics requires ITS, that satisfy a diversity of needs as it has been agreed that international logistics is practically mostly multimodal and involves a number of different players that underline the challenge of implementing information services that work to serve the needs of the whole logistics chain (Leviakangas et al., 2007). In order to cope with the increased level of cargo passing through ports, significant investments in ITS have been taking place in recent years. Ports today are becoming more technologically advanced with the adoption of ITS such as GPS systems, ITS support for quay planning, routing of automated guided vehicles such as the IAV (see Chapter 4) as well as equipment used for stacking of containers and invoicing (Neade, 2008). The attention to port container terminals using ITS is not recent. For example (Kia et al., 2000) investigated the importance of information technology and its role in improving cargo handling operational systems. In recent years, ITS have emerged as an initiative that will not only transform transportation by enabling Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications but also the overall efficiency of port container terminals. According to Wiegmans et al, (2001), (see Section 2.9) it is important for the terminal operator to provide services that deliver excellent quality therefore ITS relying on wireless vehicular networks have the potential to be the platform that overcomes problems related to technology proliferation such as reliability, accessibility, reliability, speed, efficiency, security and cost. (Ibid) states that reliability and costs are the most important elements for container terminal quality. This research shows that in the maritime environment we operate in today this is not entirely true. As discussed in Chapter 6 (see Figure 21) freight operators regard speed as the most important element with reliability second and cost coming in last. This proves that freight operators are more concerned with just-in-time (JIT) deliveries which will result in excellent quality and fit into the value chain of their customers.

2.3 Port Operations and Technology

Automation in ports will probably be as hard to accept as the ending of the UK's National Dock Labour Scheme in October 1990. It saw the country's dock work force reduced to 4,000 from a total of just over 9,000 in April 1989, because the workforce stood in the way of a modern and efficient port industry. However, no one can argue that the ending of this scheme together with the arrival of port privatisation brought in a new era of growth in the UK ports sector (Portstrategy, 2014).

Today's concerns are being expressed by industrialised unions in ports such as Rotterdam because of the introduction of two new highly automated container terminals. Their argument is that the company did not engage in talks with the union or move to sign a collective bargaining agreement (Ibid).

The increased role of automation on container ports in developed countries, where labour costs are high, is inevitable. In most container terminals labour is usually the highest element of operational costs and it is through reducing these costs that development can be achieved. Researchers such as Cullinane and Song, (2006) and Liu et al, (2002) have stated that automation has improved terminal capacity and efficiency in container terminals. Due to the boom in world trade, port container terminals are examining ways of making existing facilities more efficient. According to Liu et al, (2010) one way to improve efficiency, increase capacity and meet future demand is to use advanced technologies and automation in order to speed up terminal operations.

The way forward is to look to replace manpower with automation in key aspects in a container terminal operation that has automated processes in transporting containers from ship to stacks, and vice versa. The most up-to-date advancements can be sourced from periodicals such as Port Strategy Newsletter and World Cargo News. General information about technical equipment for container terminals can be found in engineering oriented journals, as well as specialized outlets such as porttechnology.org. There is a wide consensus that demands for cargo handling in ports will outpace the development of port infrastructure. Once the economic crisis is over, the impact on port handling capacity will increase significantly.

Many experts and scholars have focused on automated terminal handling technology research, such as He et al, (2014) and Zhen et al, (2012) who introduce a new automated container transfer system using frame bridges and rail mounted trolleys to transport containers around a container terminal. In recent decades the ever increasing importance of maritime container transportation has become quite remarkable. The container has achieved huge importance in the international sea freight transportation as discussed by Lee and Cullinane, (2005) and Steenken et al, (2004) who investigate efficiency of port container terminals within the area of logistic strategy. They also discuss the main processes and operations carried out in container terminals.

2.4 Container Terminal Operations, Procedures and Practices

Container terminals are designed for the handling, storage, loading and unloading of international standard organisation (ISO) containers. The also constitute the facility where containers can be picked up, dropped off and transported from ships, trucks, trains and barges. Container terminals facilitate both full and empty containers. Full containers are stored for a relatively short time, while waiting for onward transportation. Empty containers are stored for longer periods while waiting for space on the next outward vessel; or in some cases go back on the road for their next load.

According to Kozan (1997), a container terminal represents a point where containers are moved from one mode of transport to another. Kozan & Preston (1999) use genetic algorithms in a study to reduce container transfer and handling times and also the berthing times of vessels. Vis and Koster (2003) add that in the container terminal, different types of container handling equipment are used to tranship containers from ships to barges, trucks and train, and vice versa.

2.5 Operating Equipment in Container Terminals

The overall task of a container terminal is to manage the container operations as efficiently as possible. The right selection of operating equipment is a key factor in operating a successful terminal. Cargo handling systems for terminal transport have been described by Meersmans and Dekker (2001) by giving an account of the use of operating equipment in container terminals. They also state activities that take place in the container terminal give an overall account of the relevant problems that occur both at tactical, operational and strategic levels. Ilmer (2004) address what the key performance conditions are for a container terminal and how they can help the terminal operator.

2.6 The Impact of Terminal Expansion

It is a challenging task to operate a successful container terminal. A port container terminal is a complex system that will only function efficiently if loading/unloading is running smoothly (Brinkmann, 2011). The larger vessels coming on stream will challenge the terminal operator to increase efficiency and performance. Land is scarce, particularly in the smaller to medium sized ports such as Dublin, Ostend and Le Havre, so the correct allocation of containers is vital to the overall terminal operation. Vis and Koster (2003) examine the daily requirements needed in a terminal and, based on these, the required technical operations to be planned. For example, the location where a particular container is stored is vital. The size of container vessels has increased dramatically, up to 13,000 TEU (twenty foot unit) over the past decade, which means vast amounts of containers have to be unloaded / loaded (Maersk Maritime Technology, 2013).

The largest ship up to November 2012 was the 16,000 TEU *'Marco Polo'*. She was the first in a series of three, the other two, namely the *Jacques Cartier* and the *Alexander von Humboldt*, were launched in 2013. The new Maersk '*Triple E'* vessel, with a carrying capacity of 18,270, is the largest ship in the world as of June 2014. It has set new standards in the shipping industry, not just for its size but also for its energy efficiency. Her unique design features much slower speeds and maximum efficiency allows her to emit 50% less CO_2 per container moved than the current average on the Asia-Europe route. A total of twenty of these vessels has been ordered by Maersk Line and will be phased in gradually over the next couple of years. They are derived from their three designs of principles: *Economy of Scale, Energy Efficiency and Environmentally Improved* (ibid).

The Maersk Mc-Kinney Møller is the lead ship in the Triple E class. It has the largest cargo capacity in TEU of any ship yet constructed, and is the longest ship in service worldwide as of 2014. She is not only the world's largest ship, but also the most efficient containership per TEU of cargo. These large ships have to be planned and coordinated in order to give a quick turn-around time which is crucial in vessel and port efficiency (ibid).

These large vessels operate over long distances between the larger ports in the world such as Asia, the America's and beyond. There are smaller shortsea vessels called feeder vessels that connect the large ports to the smaller ports such as Dublin. The feeder vessels calling at Dublin link Ireland to the larger ports in northern Europe such as Rotterdam, Antwerp and Le Havre, as well as ports in the UK and the Mediterranean. These feeder vessels have a carrying capacity of approximately 1,400 TEU.

2.7 Congestion in the Terminal

Congestion issues in the terminal are a major problem. Operations are slowed down because of overloaded areas and this congestion can easily spread to the whole system.

Terminal operations have to be planned to ensure a quick turn-around time for vessels. Lau & Zhao, (2008) discuss the importance of having a formal scheduling method for generating exact work orders to instruct cargo handling equipment to perform specific tasks in an automated terminal, which is essential for satisfactory overall performance. The problem of storage space allocation is discussed by Zhang et al, (2003) where two forms of approach are used to solve the problem of quay and terminal cranes, storage space, and internal trucks. Retrieval times of containers are not known before the vessel arrives, so the order in which the handling equipment will be used needs to be specified in advance. Productivity in container handling has become important because of the increase in vessel size. Kim & Park (2003) discuss how to allocate storage space for containers. According to them the main objective is to allocate space efficiently to make loading operations more efficient. However, their discussions focus on straddle carriers and yard cranes rather than automated vehicles.

2.8 Measuring Port Performance

Measuring performance in business is a fundamental concept; one is measuring achievements against goals and objectives, or against other competitors. Ports are no different and it is by measuring these achievements that performance can be assessed. However, port container terminals have a complex dynamic system which consists of a number of interacting components influenced by many factors (Sy and Mana, 2006). Therefore, the two major goals are the full utilization of available resources and the efficient management of terminal operations. Kuo, (1992) for example, notes that by achieving these two goals many objectives can be achieved such as increasing port throughput, the utilization of resources such as cargo handling equipment, reducing idle time and port congestion and minimizing demurrage (i.e. compensation for detention) and operational costs.

Experiences in Dublin Port have shown that port efficiency is essential if one is to survive in the shipping world of today. The different types of cargo handling equipment are expensive to purchase and operate. However, inadequate facilities result in delays which in turn can lead to customer and capital loss as stated by (Taher and Hussain, 2000) whose investigation is to improve the logistics processes of a container port. Ports are a vital connection in the transport logistics chain. Therefore port efficiency is an important contribution to a country's international competitiveness (Tongzon, 1989).

2.9 Customer Satisfaction

Generally, customer satisfaction is known as an outcome of service quality, which means that it is related to the quality of the products or services provided to the customer in a positive manner. The level of customer satisfaction is also believed to be enhanced, along with an increased level of perceived quality of the product or service. In particular, customer satisfaction is considered to be an intrinsic variable that explains returning customers and their post-behaviours of purchasing products and services (Oliver, 1980; Szymanski and Henard, 2001). Satisfaction is one of the most important elements for explaining any type of relationship amongst participants (Sanzo, et al., 2003). Customer satisfaction has become a vital issue for shipping operators in terms of product improvement and to guarantee customers' loyalty in markets exposed to intense competition. Customer satisfaction models are based on perceived performance of services, perceived value, brand image and customers' expectations of service quality levels (Cronin et al., 2000).

Today it is believed that socially responsible firms, which contribute both economically and ethically to the society and local communities they serve, are better positioned to grow in terms of reputation and revenues (Drobetz et al. 2014). In port container terminals the quality results from infrastructures and port and terminal services, commonly known as port and terminal characteristics. The main customers are the ship owners, who choose which ports to call, the shipping agents, and the shippers, who are usually represented at ports by the logistic chain operators (Magala and Sammons, 2008); as the final customers often ignore which port container terminal or logistic route is used.

According to Robinson (2002), from time to time new values emerge changing an old-fashioned business to one that better satisfies customers' needs, as those customers priorities change. In a changing environment, it is essential to understand how the modern port container terminal can actually satisfy customers. Nowadays, logistic functions are becoming increasingly integrated within inland networks and megacarrier maritime ones. Value has changed from individual logistic functions to the integration of supply chains in the hands of global logistic operators. The fulfilment of customers' needs and their satisfaction goes beyond the efficiency that was traditionally considered in the perspective of infrastructures (ibid). This means that the creation of value has changed from the simple container terminal operation to an integrated service, delivered to the final customer's door, including inland transportation and intermediate logistic areas.

In the very competitive container terminal operations market, quality is important in attracting and retaining customers. Freight operators have choices between different container ports that can meet their demand. This results in the increasing importance of quality and the ability to know the needs of customers. A favourable network position and well-organised processes are no longer sufficient. Meeting the customer needs and delivering quality services are also critical factors. In their supply chain, freight operators are interested in speed and reliability (see Figure 20). The time a ship stays in a port must be minimised, and, therefore, the handling of containers must be executed in a fast and reliable way. Minimising the number of containers that are damaged or lost forms another part of the quality picture. The operations at the terminal, after the handling of the containers on and off the ship, must be reliable as well.

As referred by Magala and Sammons (2008), the selection of a port has become more a function of the overall logistic chain performance that provides a full integrated service. The selection process is based on port elements, shipping lines and inland transport. According to Wiegmans et al, (2001) it is important for the terminal operator to provide services that deliver excellent quality and fit into the value chain of its customers. In port container terminals some of the quality elements that are important to freight operators are:

i. Accessibility - Ease to use the handling equipment e.g. different container types;

ii. Reliability – Refers to the level of time certainty with which the service is performed;

iii. Flexibility – To respond to malfunctions in operations and provide alternative service requirements;

iv. Speed – Time needed for a terminal transhipment;

v. Security – Risk of damage or loss of containers in transit;

vi. Efficiency – This is reflected in turnaround time of ships and cargo dwell time and;

vii. Costs – Cost per TEU for handling.

Source: (Wiegmans et al, 2001)

When selecting a shipping line, factors such as frequency, transit time, freight rate, and the level of integration within the logistic chain are considered. However, the shipping line's selection is not necessarily interrelated with the port choice, as shipping companies also choose the ports of call based on several factors such as location, markets, efficiency, services and infrastructure, prices and quality. Therefore, from the port perspective, the services and infrastructures provided should simultaneously satisfy both the logistic chain and ship-owners within their selection process.

Port specialization, namely the containerization rate, is mentioned by Trujillo and Tovar, (2007), Medda and Carbonaro, (2007) and Laxe, (2005), and it reflects the port evolution degree, from its industrial phase to a modern and commercial port. Ports who specialise in containers usually obtain higher efficiency levels in the use of quay infrastructures.

Frequent container line services allow a wider choice, greater flexibility and less transit times, being associated to a higher specialization of a container port (Tongzon, 2002). Also, alliances and specialized logistic networks in which maritime services are integrated also determine customers' satisfaction (Tongzon and Heng, 2005).

Wu and Goh (2010) use the capacity of handling equipment, number of quays or berths, terminal area and storage capacity as variables of the container terminal infrastructure. The latter is an important variable to customer's satisfaction and it may be represented by terminal width and layout, which configure an overall vision of the inland terminal infrastructure. Container terminal services are vital to a customer's satisfaction. Maritime accessibility limits the terminal capacity and determines the maximum vessel size calling at the port, the type and number of handling equipment to be used per vessel as well as cargo handling services to be provided. Maritime accessibility affects the terminal efficiency by modifying vessel size, freight rates and the quay productivity, which are reflected in the customer's satisfaction.

Tongzon (2002) and Wiegmans (2003) examine the importance of maritime accessibilities as being decisive for terminal efficiency. Maritime accessibilities define the type of market to which the terminal can have access to and determine the maritime services offered to customers. The size of the vessels that call at port container terminals is decisive and is an essential factor for their performance.

2.10 Conclusion

The preceding literature review began by examining a future for container ports with the introduction of new ITS. It then discussed academic research in ports. Next it explained operating equipment most frequently used in container terminals, before discussing the impact of terminal expansion, congestion in container terminals as well as port performance. It also assessed factors influencing customer satisfaction.

Chapter Three: Dublin Port Container Operations

3.0 Introduction

This chapter portrays the services of Dublin Port, the biggest and busiest port in Ireland. It explains how the Port operates and outlines its plans for future growth and prosperity. DFT one of the three container terminals in Dublin Port is discussed. Furthermore, containerisation and cargo handling equipment are explained.

3.1 Location of Dublin Port

Dublin Port's main function is to facilitate the movement of goods and people, which is crucial to the Irish economy, in an efficient and cost effective manner. The port is located on both sides of the River Liffey, approximately 4.8 km (3 miles) from Dublin's city centre. The main part of the Port, on the north side of the river, is situated at the end of the East Wall and the North Wall from Alexander Quay and covers an area of 205 hectares (507 acres). The area on the south side is much smaller, covering 51 hectares (126 acres), and is situated at the beginning of the Pigeon House peninsula (Dublin Port, 2011).

The reason why Dublin Port and Dublin city are closely interlinked with regard to establishment, growth and expansion is because the original port was situated further up the river, close to Christchurch Cathedral. The port remained in this area until the new customs house opened for business on the 7th November 1791 (Dublin Port Company Issue Papers, 2011).

New quay walls were built between 1828 and 1909. The 1960's and early 1970's saw the move to unitization of cargo, so Dublin Port had to set about providing the facilities necessary to cater for this innovation. To cater for the new type container vessel, land was reclaimed, berths dredged and quays built. Today Dublin Port is located downstream because the change in shipping, cargo handling and port operations dictated the need to build purpose built terminals with specialized crane facilities and cargo handling equipment. These changes brought the Port from the centre of the city out towards the current location of Dublin Port, at the eastern fringe of the city and at the mouth of Dublin Bay (Gilligan, 1988).

3.2 Port Activity

Port activity is a complex issue, and the collection and use of statistics for planning, evaluating and analytical purposes is essential for its improvement. Accurate and up-to-date data is essential for effective management, and will provide an understanding of the functions of a port such as Dublin. Statistical data is not the same for every port, due to the way port systems have to be established and operated, but some sort of uniformity is needed in the method in which data and information is collected and presented. Statistics are not only used for a broad analysis but are also used to evaluate performance in terms of efficiency. Each port will have to choose a method adapted to its requirements and resources. It has been established that findings will depend on the particular situation and circumstances of the port concerned. There are a number of reasons why a port should collect data:

i. To forecast and report on investment expenditure – it affects both the short-run business cycles and the long term economic growth;
ii. To analyse goods loaded – type of goods, quantity, weight and status;
iii. To analyse goods discharged – type of goods, quantity, weight and status and;
iv. To analyse the number of vessels calling at the port – daily/weekly.

Key performance indicators (KPI's) are required for management purposes and the key performance indicators considered include:

i. Average time vessels spend on the berth discharging/loading;
ii. Average waiting times of vessels and;
iii. The ratio of future waiting time of vessels.

The ratio of future waiting time of vessels is obtained by dividing the time a berth has been occupied by the time a berth is available during a considered period of time; for example a week, month or year (Alderton, 2008).

Another reason for collecting port data is to provide an appropriate basis for planning port development. Port data can be broken down into the following categories:

i. Port facilities and port services;
ii. Ship traffic;
iii. Port operations;
iv. Cargo flows and passenger traffic and;

v. Cost and revenue.

Some analyses that support the study in order to highlight previous findings in the following fields are:

i. Academic Research in the Area of Port Operations and Technology;
ii. Container Terminal Operations, Procedures and Practices;
iii. Operating equipment frequently used in the port environment;
iv. The impact of terminal expansion;
v. Congestion in the terminal and;
vi. Simulation of terminal operations.

3.3 Dublin Port Services

The main activity of Dublin Port is cargo handling, with some 17,000 vessels handled annually. These vary in size from large cruise vessels to small coasters. (Dublin Port Company, 2011)

The range of vessels includes:

i. *Roll/on, Roll/off (Ro/Ro) passenger and freight vessels*. This type of vessel has built-in ramps that allows cars and trucks to be driven on and off the ship on their own wheels;

ii. *Lift/on, Lift/off (Lo/Lo) container vessels*. This type of vessel uses a crane to load and unload cargo in containers;

iii. *Molasses and gas tankers*. There are specially designed tanks for the shipment of the by-product of sugarcane and liquefied natural gases;

iv. *Bulk carriers*. This type of vessel is specially designed to transport cargo in bulk for example grain, coal ore and cement;

v. *Car carriers*. These are distinctive vessels with a box like superstructure that runs the length and breadth of the ship carrying thousands of vehicles and;

vi. *Cruise vessels*. Also known as cruise liners, these are passenger ships used for pleasure voyages.

Dublin Port would have approximately 85 cruise vessels calling annually, as well as a range of specialist vessels such as naval vessels, light-tenders, tugs, supply ships, historic craft and large sailing ships (ibid).

Other services provided by the port are:

i. *Vessel Traffic Management* – all vessel movements are controlled by vessel traffic services, and vessel management information systems;

ii. *Pilotage* – operated by direct boarding fast cutters with speeds of up to 20 knots and equipped with VHF radio, Hague channels 16, 12 and 6 and;

iii. *Towage* – manoeuvring large vessels in and out of Dublin Bay (ibid).

3.4 Port Planning Process

In general the port planning process considers a number of aspects which examine the various prospects of the project so as to produce the overall port plan. It will set out the immediate requirements and the long term development of the port region. In the beginning work will be timed to coincide with the speed of growth of the traffic passing through the port, while all requirements will be carried out in a planned and orderly fashion.

From discussions with DFT management and Dublin Port Company during this research it has been established that owners and operators of ports today are faced with many demanding challenges which include:

i. Traffic and trade forecasts;
ii. Updated shipping requirements;
iii. Limited availability of land for expansion;
iv. Constantly changing regulatory frameworks;
v. Constantly changing cargo handling technology;
vi. Privatisation of government related port activities;
vii. Rapidly changing commodities and markets;
viii. Complicated and increased cargo security demands;
ix. Complicated and increased physical security and safety demands;
x. A steady downward pressure on costs;
xi. Demand for a higher return;
xii. Environmental impacts and pollution control and;

xiii. Financial and economic appraisal.

3.5 Original Development Plan

The original plan that involved the reclamation of 21 hectares of Dublin Bay was rejected by An Bord Pleanála in June 2010. The new draft ***Masterplan*** and ***Issue Papers*** were launched on 11th May 2011 and involved reclaiming between thirty and forty hectares of the sea to expand its existing two hundred and sixty hectare footprint. Reclaiming land is always a contentious issue with environmental and conservation groups and plans to relocate the bird colony in Dublin Bay would not make the development an easy one for Dublin Port Company. Local residents living on Pigeon House Road area (which is in close proximity to the south side of the Port) were also questioning the impact the expansion would have on their daily lives.

The second draft which would involve the permanent loss of wetland habitat was also rejected by An Bord Pleanála in 2011 stating the area is due to be designated as a Special Area of Conservation under the EU Birds Directive (2009/147/EC) and the Habitat Directive (93/43/EEC).

3.6 Dublin Port – Masterplan 2012-2040

The '*Dublin Port Masterplan'* which was published in early 2012 presents a vision for future operations at the port by reference to developments in merchandise trade and key sectors in the economy. According to Moglia and Sanguineri (2003), a port master plan sets out a 10-year port development option, taking into account different interests. The plan also examines the existing land utilisation and suggests some options for future development of Dublin Port to facilitate the handling of a doubling of trade volumes to 60 million tonnes by 2040, which is based on a expected growth rate of 2.5% per annum. Volumes in Dublin Port have grown for a third year in a row, ensuring that a record throughput of 32.8m tonnes was handled in 2015, representing a 6.4% increase on the previous year. The growth achieved was shared across both imports and exports. Imports grew by 6.5% from 18.3m tonnes to 19.5m tonnes while exports increased by 6.4% from 12.5m tonnes to 13.3m tonnes. In particular the Port continued to see strong growth in the unitised sector where volumes increased by 7.3% to 27.2m tonnes, while volumes in the non-unitised sector grew by 2.5% to 5.7m tonnes. The growth in throughput volumes has contributed to another strong financial performance in 2015 whereby:

i. Turnover increased by 7.8% from €72.1m to €77.7m;

ii. Operating Profit increased by 18.8% from €36.1m to €42.9m;

iii. Profit for the Financial Year increased by 19.0% from €30.6m to €36.4m;

iv. Earnings before interest, tax, depreciation, and amortisation (EBITDA) increased by 14.0% from €43.2m to €49.3m and;

v. The net cash position increased from €16.9m to €35.1m (Dublin Port Company, 2015).

The ***Masterplan*** will help Dublin Port Company to outline some of the options that are available to increase efficiencies and provide throughput capacity in the Port to cater for the projected growth in Port tonnage over the next 30 years (Dublin Port Company, 2012).

Table 1 Historical and Forecasted Throughput for Dublin Port

Year	***Throughput†***	***AAGR****
1980	7.3m tonnes	3.2%
2010	28.9m tonnes	4.7%
2040	60.0 tonnes	2.5%

† Five Year Averages
*Average Annual Growth Rate.

Source: Dublin Port Company, 2012

Table 1 looks at the proposed development of the port over the next thirty years. Based on past trends, a modest growth of just 2.5% would cause the volumes to double to 60 million tonnes Source: Dublin Port Company, 2012.

Table 2 Estimated Projected Throughput to 2040 for Dublin Port

	2013 † ***'000 tonnes***	***2040 '000 tonnes***	***AAGR*** * ***'000 tonnes***
Ro/Ro	18,122	41,920	3.18%
Lo/Lo	5,171	10,480	1.70%
Bulk Liquid	3,531	4,000	-0.01%
Bulk Solid	1,985	3.500	1.79%
Break Bulk	38	100	0.12%
Total Tonnes	28.847	60,000	2.47%

† Five Year Averages
* Average Annual Growth Rate

Source: Dublin Port Company, 2012

Table 2 indicates that there will be little growth in the bulk modes. On the other hand the unitised modes show a substantial growth with Roll/on-Roll/off traffic (i.e. passengers and freight) doing substantially better than Lo/Lo off traffic (i.e. container traffic).

Table 3 Forecasted Traffic for Ro/Ro and Lo/Lo in Dublin Port

	2013	2040
Roll on/Roll off ('000 units)	565	1,791
Lift on/Lift off ('000 units)	383	625
Total units	948	2,416

Source: (Dublin Port Company, 2012)

Table 3 translates the growth into a truck load where one truck load generates one truck movement in and out of the port.

In line with the ambitions and growth forecasts predicted by the Port Company, there is a need to optimise the use of ITS within international ports such as Dublin. Currently in Dublin Port, the movement of cargo is operated by shunter vehicles differing from AGV's as are used in other international ports.

At the launch of the Masterplan on 29th February 2012, the Port's Chief Executive Mr. Eamon O'Reilly stated:

''This is an exciting time in the development of Dublin Port. For the past year we have consulted extensively to get to the position today where we can unveil our Masterplan for the development of Dublin Port over the next 30 years. The projects identified under this plan will be advanced in stages based on capacity, economic demand and our ability to finance them. The fact that we are committing to a €110 million investment programme over the next 5 years shows our intent to implement the Masterplan. Dublin Port Company has committed to continuing to develop Dublin Port within its current footprint to the maximum extent possible before considering projects involving major land reclamation. Any projects from the Masterplan will be subject to the existing planning processes'' (Dublin Port Company Masterplan, 2012-2040).

The Masterplan clearly states that the port will need to increase its capacity over the next 30 years, but due to the economic downturn the port will have some breathing space to carry on with projected growth for a decade or more within its existing footprint and will focus on maximizing the use of the port's existing capacity. Projects involving reclamation will only be processed if and when they become necessary and if they can meet environmental and planning standards such as the Strategic Environmental Plan in compliance with Directive 2001/42/EC as transposed into Irish legislation through the European Communities (Environmental Assessment of Certain Plans and Programmes) Regulations 2004 (Statutory Instrument Number. 435 of 2004). The other environmental standards that must be met are The Birds Directive (2009/147/EC) as well as The Habitats Directive (93/43/EEC) (Dublin Port Company, Masterplan Issue Papers, 2011).

Mr Leo Varadkar, the then Irish Minister for Transport, Tourism and Sport launched the *Masterplan 2012 -2040* setting out the framework for the long term development of the port. Implementing the plan will cost in excess of €600 million over the next 30 years which will be financed by the company's own resources. He stated:

*''This is a comprehensive plan for the long term development of Dublin Port on its current site. As Ireland's most important port, Dublin Port is a vital part of our national infrastructure. It has a significant role to play in our growing exports, growing jobs and also with growing tourism, with 87 cruise ships calling last year (2012). This Masterplan follows a detailed consultation process and will ensure that Dublin Port continues to make a real contribution to the local economy and to our export led recovery'' (*Dublin Port Company Masterplan*, 2012-2040).*

The Masterplan is founded on three principles:

i. Maximizing the use of existing lands;

ii. Reintegrating the port with the city and;

iii. Developing the port to the highest environmental standards (ibid).

The first project that Dublin Port Company has identified to achieve is to build a dedicated car storage area which will free up valuable quay space for other port activity. Another major project is the construction of a new cruise terminal closer to the city to accommodate over 135,000 passengers and almost ninety cruise liners calling to the port each year, bringing high spending passengers and crew within easy reach of the city centre shops and other attractions. To help with this project the Dublin Port Company has formed Cruise Dublin, a joint venture with Dublin City Council and Dublin Chamber of Commerce to further develop the cruise tourism trade in Dublin. Work is already underway to assess the feasibility of constructing a dedicated €30 million cruise terminal in Dublin Port by 2017 (Dublin Port Masterplan, 2012).

In the context of integrating Dublin Port with Dublin city, improved walkways and cycle paths, public viewing platforms, the installation of maritime art displays and softer port boundaries are among the initiatives intended to bring real community gain. This will also include a visitor centre displaying archive material, old port equipment and video displays of port operations. It also envisages a simulator featuring crane operations and the piloting of a vessel safely into port.

Iarnród Eireann runs the national railway system in Ireland. The company operates its own freight service but this has been declining at a rapid rate over the years. As of 2016 there were only four freight services running throughout Ireland and one of these is the new rail extension which was recently opened in Dublin Port and will significantly improve the freight competitiveness of container traffic to and from the port (Iarnród Eireann Freight, 2016).

There are many economic and environmental benefits to be gained from using rail rather than road services. Rail uses 76% less CO_2 and uses less than half the fuel compared with road per tonne carried. Therefore rail transport can play a major role in the Irish Government's commitment under the Kyoto Protocol to limit the growth in its greenhouse gas emissions to 13% above 1990 levels by the first commitment period of 2008-2012 (SEAI, 2016).

Rail freight is expected to grow over the next 30 years and Dublin Port Company plan to extend their direct rail connections to all major train stations in Ireland. Four thousand trucks are removed from Irish roads every year through the existing rail network and the plan is to increase the service significantly (Dublin Port Company Masterplan, 2013).

The *Masterplan* provides long term planning for the future development of the port. Dublin Port Company has committed to create and apply rolling five year strategic plans from which individual projects will be brought forward, planned and developed (SKEMA Workshop, 2011).

3.7 Dublin Ferryport Terminals (DFT)

The container terminal considered in this research was DFT one of three container terminals located in Dublin Port. The other two are Marine Terminals Limited (MTL) and Portroe Stevedores. DFT was originally developed for British and Irish Steam package Company (B&I line) in 1972. It is now owned by Irish Continental Group (ICG) plc, a shipping and transport group principally engaged in the transportation of passengers and freight on routes between Ireland, the United Kingdom and Continental Europe. It provides services to Eucon (a Lo-Lo container shipping line also owned by ICG) and other Lo-Lo container shipping lines. DFT operates on the basis of lease agreements dating back to the 1970's and license agreements in respect of extensions to the terminal in recent years (Dublin Port, Internal Report, 2011).

DFT is conveniently located 3km from Dublin city centre and 2km from the entrance to the Dublin Port tunnel. The terminal recently completed an investment programme which has seen its plant and machinery updated the size of the terminal increased by 50% and the quay wall extended by 50 metres. The terminal has two berths with three quay cranes. The tinted green area indicates where full import and export containers are stored. The yellow area is the laneways between the stacks where the secondary handling equipment operates. The orange area shows where the locations of empty containers awaiting shipment are stored (see Appendix VIII). This information was supplied by the management of DFT.

Table 4 DFT Terminal Profile

Capacity	450,000 TEU
Berths	1 x 360 metres @ 9.5 metres depth 1 x 180 metres @ 11 metres depth
Ship – Shore Cranes	3 x 40t STS (2 with full curve going facility)
Secondary Handling Equipment	8 x 40t rubber gantry cranes 1 x 47t reach stacker 4 x empty container handlers 2 x 18t fork lifts
Reefers	275 points

Source: (DFT, 2011)

Capacity: Is the amount of land DFT has to stow containers

Berths: The place ships unload/load containers

Ship-Shore cranes: Cranes that unload/load containers from ships.

Secondary Handling Equipment**:** Cargo handling equipment that transports containers

Reefers: Plug- in points for refrigerated containers

Table 4 shows that DFT has the capacity for 450,000 TEU. It has two berths where it can facilitate up to three vessels at any one time. There are three ship–to-shore gantry cranes, with two having the ability to manoeuvre around corners allowing one, two or three cranes on one vessel at any one time. Secondary handling equipment is the cargo handling equipment for transporting containers for example shunter, straddle carrier, AGV's and reach stackers (see Chapter 3). Reefer points are located at the end of each stack where refrigerated containers can be plugged in. DFT provides container handling services to a range of third party customers, as well as to its sister company Eucon. It also operates a high frequency container freight service from its base in Dublin Port to Rotterdam, Antwerp, and Radicatel in Le Havre with connections to Cork and Belfast.

The following is a brief summary of the flow of operation and process that occurs when a container vessel arrives at DFT.

i. After arrival, a container ship is assigned to one of the two berths equipped with three ship-to-shore gantry cranes (single- trolley which are man driven are featured at DFT) to unload and load containers;
ii. The trolley travels along the arm of the crane and is equipped with a spreader, which is the device that picks up the containers;
iii. Although most ship-to-shore gantry cranes are man driven, the tendency is for automatic gantry cranes which are in use at some of the bigger European terminals such as Rotterdam, Hamburg and Thames-port, on the Thames Estuary;
iv. The technical performance of gantry cranes is approximately twenty moves per hour although DFT guarantee their customers twenty five moves per hour and can accomplish up to thirty moves per hour;
v. The shunter will transport the container to the storage area where it will be dismounted from the shunter by the RTG crane and placed in the stacking area;
vi. The stacking area is separated into different stacks (or blocks) which are differentiated into rows, bays and tiers (see Figure 1) and;
vii. The position of the container inside a block is identified by bay, row or tier.

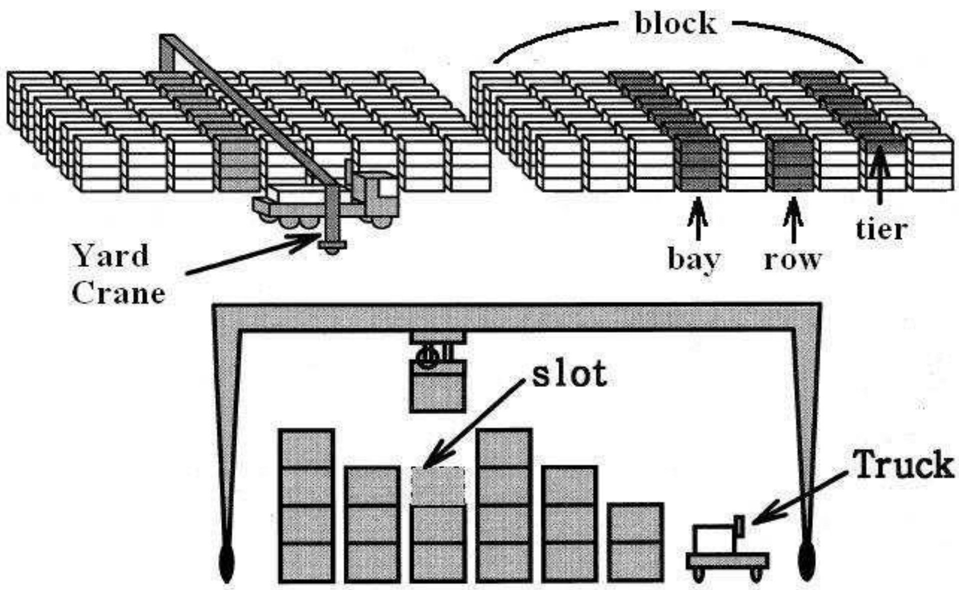

Figure 1 Stacking Area in Container Terminal (Vacca et al, 2007)

Stacks are separated into areas for imports, exports and empty containers. The area at the back of the stacks is reserved for special containers such as reefers which need electrical connection, dangerous goods, or out-of-gauge (i.e. over-height/over-width) containers that do not allow for normal stacking. Because of increased demand and limited storage space in most modern seaports, nowadays stacking on the ground is the most commonly used storage approach (Steenken et al. 2004).

Containers handled by the terminal are typically of two sizes, twenty-foot (TEU) or forty-foot (FEU) which is two TEU. There are also tanks ranging in size from 23ft to 29ft, flat bed trailers, reefers and 45ft containers. The shunter can carry one TEU, two TEU, or one FEU. A container is discharged from the vessel by a ship-to-shore gantry crane and mounted directly onto the shunter without first landing it on the ground. Landing the container on the ground will only add an additional lift cost when it is later lifted from the ground and put on the shunter, thus reducing the efficient throughput of the entire operation. In order not to delay operations a shunter has to be ready alongside the vessel when the container is being discharged from or loaded onto the vessel.

3.7.1 Traffic flows in DFT

A container terminal deals with a large quantity of containers on a daily basis. The workload will depend on the amount of containers arriving at and departing from the terminal by ship, train, barge, road and rail. DFT is mainly concerned with sea and road as it does not have a barge or rail service. The following is a list of the ships that arrive in DFT on a weekly basis and their schedules.

Table 5 DFT Operation Schedule (Week1) (DFT records – week commencing 9/5/2011)

Days	Date	Vessel Name	Discharge Day	Discharge Night	Load Day	Load Night	ETA	ETD	Comment	No. of Lifts
Monday	9/5/2011	Elbtrader Samskip Emstal	258 3	93	5	119 103	22.45	03.00	0	581
Tuesday	10/5/2011	Elbtrader Samskip Emstal	22	0	170 156	38	0	16.00 21.00	0	386
Wednesday	11/5/2011	Emstal	0	0	153	0	0	13.10	0	153
Thursday	12/5/2011	Petkum D Gothia Endurance	262	4 155 136	62	65 33	11.00 19.00 00.49	0	0	717
Friday	13/5/2011	Petkum D Gothia Endurance	144	0	148 58	6 263	0	15.00 23.00	Waiting on cargo	619
Saturday	14/5/2011	D Gothia Elbtrader	124	0	135 150	16	0	13.50 20.30	0	425
Sunday	15/5/2011	Samskip Elbtrader	0	0	0	276 149	19.00 23.00	0	0	425
		Moves	813	388	1037	1068	0	0	0	3306

Table 6 DFT Operation Schedule (Week 2) (DFT records - week commencing 16/5/2011

Days	Date	Vessel Name	Discharge Day	Discharge Night	Load Day	Load Night	ETA	ETD	Comment	No. of Lifts
Monday	16/5/2011	Elbtrader Samskip Emstal	193	111	65 65	72 55	0	0	0	561
Tuesday	17/5/2011	Elbtrader Samskip	0	0	128 155	0	0	16.00 18.00	0	283
Wednesday	18/5/2011	Emstal	0	0	149	0	0	12.50	0	149
Thursday	19/5/2011	Petkum D Gothia Endurance	128	20 250	0	36	22.00 15.30 23.30	21.05	Layover till 20/5/2011	434
Friday	20/5/2011	Petkum Endurance	241 22	59	106 218	150 90	07.00 23.59	0	Waiting on cargo	886
Saturday	21/5/2011	Petkum D Gothia Elbtrader	113	0	39 99 112	71	13.00	08.30 13.00 22.00	0	434
Sunday	22/5/2011	Samskip Elbtrader	0	261	0	0	21.00	03.00	07:00 eta Mon. high winds	261
	Total no. of lifts	3308	697	701	1136	474	0	0	0	3008

Table 5 and Table 6 describes two separate weeks, namely week 19 commencing on 9th May 2011 and week 20 commencing on 16th May 2011 the vessels working at DFT. It names the vessels, discharge/load details i.e. whether the vessel worked the day shift or the night shift night plus the number of lifts on each shift. It also shows estimated time of arrival (ETA), estimated time of departure (ETD) as well as the total number of lifts plus any comments such as waiting on cargo to arrive at the terminal.

3.7.2 Traffic Navigation Methods

Traffic navigation methods are in operation to allow for a more efficient movement of containers within the terminal. Data was provided by DFT regarding truck turn-around time in the terminal. The information includes the movement of containers from arrival at the in-gate to the departure at the out-gate i.e. containers that were dropped off and picked up at the terminal (see Table 8). This data provides a good understanding of the level of gate moves and the number of containers remaining on the terminal.

Table 7 Capacity, Dwell & Gate Report of DFT 2011

Date	Day	Import	Total	%	Exports	Total	%	Imp. Gate moves Total per day/week		Avg. truck turn time (mins)	Weekly Avg.	Total full on quay
4/4	Mon	242	1028	24	186	655	28	441	0	23	0	1683
5/4	Tues	230	1016	23	181	615	29	372	0	17	0	1631
6/4	Wed	179	729	25	217	642	34	278	0	16	0	1371
7/4	Thur.	172	489	35	196	587	33	210	0	15	0	1076
8/4 9/4	Fri/Sat	162	714	23	226	807	28	373	1674	24	19	1519
11/4	Mon	247	1029	24	153	723	21	414	0	24	0	1752
12/4	Tues	213	1144	19	161	598	27	370	0	16	0	1742
13/4	Wed	170	824	21	208	768	27	305	0	16	0	1592
14/4	Thur.	178	780	23	168	702	24	256	0	14	0	1482
15/4 16/4	Fri/Sat	189	781	24	140	677	21	395	1740	19	18	1458
18/4	Mon	276	1167	24	90	578	16	472	0	22	0	1745
19/4	Tues	253	1068	24	98	516	19	393	0	17	0	1584
20/4	Wed	212	727	29	136	705	19	294	0	20	0	1432
21/4	Thur	246	492	50	108	500	22	235	0	17	0	992

22/4 23/4	Fri/Sat	205	688	30	144	734	20	283	1677	17	19	1422
	Easter											
25/4	Mon	**Bhol***	0	0	0	0	0	34	0	25	0	0
26/4	Tues	289	1430	20	116	391	30	456	0	21	0	1821
27/4	Wed	239	1044	23	168	541	31	413	0	19	0	1585
28/4	Thur.	283	699	41	114	460	25	295	0	20	0	1159
29/4 30/4	Fri/Sat	231	682	34	148	670	22	346	1544	16	20	1352

Source: DFT records-accessed 1 April 2011

Bank Holiday

Table 7 shows the gate moves per day plus the total and the percentage over a four week period in DFT. The average truck turn-around time (i.e. the time it takes a truck to enter and leave the terminal) plus the weekly average truck turn - around time is presented. The table also shows the number of units on the quay for a particular day. The table includes the Easter Bank Holiday: as it was a holiday, only a skeleton staff was working to facilitate the major customers. Again no ships were worked on the Monday as it was a holiday.

3.7.3 Automatic Control Method

An automatic control method is used to monitor the arrival and departure of each truck. This allows the terminal operator to estimate the turn-around time of a particular container from arrival to departure. A lower priority is usually given to the gate side operation than to the vessel side of operation. This is due to the control problem of discharging and loading containers from a vessel which is more important, as vessels need a quick turn- around time.

Table 8 Actual Turn-Around Time of Trucks at DFT Gate

Container No.	Size	Customer	Date in	Time in	Date out	Time out	Time mins
LYSU 045479/1	45HR	DFD	29/08/11	06.20	29/8/11	06.39	19
NFLU203361/3	45CS	DFD	29/08/11	06.18	29/8/11	06.40	22
HKCU459685/0	45PH	EUC	29/08/11	06.20	29/8/11	06.40	20
CRXU065324/0	45HC	DFD	29/08/11	06.21	29/8/22	06.44	23
COCU100055/5	45RH	BGF	29/08/11	06.31	29/8/11	06.45	14
EUCU451525/9	45PH	EUC	29/08/11	06.36	29/8/11	06.45	9
CLXU450242/6	45PH	SAM	29/08/11	06.28	29/8/11	06.45	17
EUCU459652/2	45PH	EUC	29/08/11	06.35	29/8/11	06.46	11
ARMU071713/9	45PH	BGF	29/08/11	06.21	29/8/11	06.50	29
BGFU796132/1	40ST	BGF	29/08/11	06.22	29/8/11	06.56	34
HKCU459781/4	45PH	EUC	29/08/11	06.28	29/8/11	06.56	28
MSCU270147/5	20ST	MSC	29/08/11	06.24	29/8/11	06.58	12
LYSU545093/1	45PH	DFD	29/08/11	06.49	29/8/11	06.59	10
YMLU847209/6	40HC	EUC	29/08/11	06.24	29/8/11	06.59	35
BGFU971634/4	45PH	BGF	29/08/11	06.23	29/8/11	07.01	38
LYSU545256/0	45PH	DFD	29/08/11	06.51	29/8/11	07.04	13
BGFU971572/7	45PH	BGF	29/08/11	06.26	29/8/11	07.05	39
CRTU092196/2	40ST	BGF	29/08/11	06.54	29/8/11	07.05	11
EXFU877362/4	23TK	BGF	29/08/11	06.40	29/8/11	07.05	25
GNSU596443/0	45PH	SAM	29/08/11	06.26	29/8/11	07.06	40

Source: DFT records, data captured on 29/8/2011

Table 8 shows the actual turn- around time of a particular truck. It states the container/unit number, the size of the container, the customer who owns the container, date in/date out and the actual time the truck was on the terminal. The table provides the average turn-around time of a truck as 22.5 minutes, i.e. from the time the truck driver checked in at the in-gate until he checked out at the out-gate. ITS potentially will make it possible to reduce human intervention in maritime activities, allowing for a higher control of the equipment and processes involved. This will result in the standardisation of performance and service levels, the elimination of uncertainty in response times and the reduction in operational costs and human errors. These advantages, coupled with technological developments and given that the current volume of worldwide trade means that an economy based only on manual labour is today unconceivable, convert automation into a global flow which is present, to a greater or lesser extent, in nearly all industrial fields (Soberon et al, 2014). ITS, has the potential to significantly shape the future of multimodal logistics and in particular port container terminals.

3.8 Containerisation and Cargo Handling Equipment

Containerisation began back in 1955 when Malcolm McLean, a former truck company owner worked with Keith Tantlinger, an engineer, to develop the current intermodal container. They designed a box with a twist lock mechanism in each of the four corners on top of the container allowing it to be lifted by means of a crane. Containers are closed on three sides with swing doors fitted at one end. They are made from aluminium or steel and are lined with plywood and are designed to carry different types of cargo and can be stacked up to seven high (Intermodal Container, 2012) (see Appendix X).

Containerisation was developed to meet the requirements of the global trade and is the system of transporting cargo in a range of standardised reusable, corrugated-weathering steel enforced boxes called containers. It is also referred to as intermodal transport meaning that containers can be loaded on different types of transport easily and efficiently: for example, ships, trains, trucks etc. One of its more positive advantages is its suitability for a door- to-door service, i.e. a shipment can be made from the consignor's (seller's) premises in one country to a consignee's (buyer's) premises in another country under a single contact. This makes the overall process easier, cheaper and less time consuming (ibid).

Since the introduction of the first internationally-standardised container, trade has grown rapidly to reach an estimated 143 million in TEU and 1.24 billion in tonnage (UNTCAD, 2008), comprising over 70% of the value of world international seaborne trade (Liu, 2010; Drewry Shipping Consultants, 2006).

All containers comply with ISO (International Standards Organisation) qualifications, giving them a visual identification system which includes a unique serial number. Each number consists of four capital letters which identifies the owner and seven digits. The last digit is a check digit, making the container easy to track.

Consequently, the port container sector continues to invest in larger container ships. The latest addition is the 18,270 TEU Maersk Mc Kinney Moller, the first Triple–E and the largest vessel afloat to date which made her maiden call to Rotterdam on 16th August 2013. The vessel was built at South Korea's Daewoo Shipbuilding and Marine Engineering (DSME) at a cost of $185 million. It was formally launched on July 15th 2013 at the Port of Busan, South Korea. It is the first of twenty such vessels and the goal is to move as many containers as possible around the world while lessening the impact on the environment. The size of these ships is equivalent to a theoretical loaded train of 280km, the distance between Rotterdam and Dusseldorf (Europe's Seaports, 2015).

With the constant changing of the container industry, these new giants of the sea are expected to be regulars at container terminals around the world. Today's ports are gearing up to meet the challenge of handling mega vessels capable of carrying 18,000 and beyond. Baird, (2006) gives a short overview of increasing ship sizes and traffic growth.

3.8.1 Different Types of Containers and their Specification

i. *Standard Container* - also known as general purpose containers are 20ft and 40ft in size.

   They are used to transport individual boxes, cases, sacks, bales and drums (Transport Information Services, 2012).

Table 9 TEU Capacities for 20ft and 40ft Standard Container

Length	Width	Height	Volume	TEU
20ft (6.1m)	8ft (2.44m)	8ft 6ins (2.59m)	1,360cu ft ($38.5m^3$)	1
40ft (12.2 m)	8ft (2.44m)	8ft 6ins (2.59m)	2,720 cu ft ($77m^3$)	2

Source: Twenty Foot Equivalent Unit, 2012

ii. *High Cube Container* – is similar in construction to the standard container only higher. They are 40ft and 45ft in size (ibid).

Table 10 TEU Capacities for 40ft and 45ft High Cube Containers

Length	Width	Height	Volume	TEU
40ft (12.2 m)	8ft (2.44m)	9ft 6 in (2.90 m)	2,720 cu ft ($77m^3$)	2
45ft (13.7 m)	8ft (2.44 m)	9ft 6 in (2.90 m)	3,060 cu ft ($86.6\ m^3$)	2[3] or 2.25

Source: Twenty Foot Equivalent Unit, 2012.

iii. *Pallet Wide Container* – is the same as the standard and high cube containers but it is approximately two inches (5cm) wider to accommodate the Euro pallet common in Europe. It allows two pallets to sit side by side in the container (ibid).

iv. *Ventilated Container* – has openings/air vents in the side and/or end walls to permit air to circulate inside the container when the doors are closed (ibid).

v. *Flat Rack* – also known as flat –bed or platform containers are used for cargo that falls outside the convenient dimensions of a standard container for example industrial parts, machinery, small sailing vessels and wooden logs (ibid).

vi. *Curtain Sided Container* – also known as a taut liner is equipped with curtain sides made from tarpaulin to enable easy loading and off -loading from the sides. It is used for the transportation of long sized cargos such as timber and bales (ibid).

vii. *Open Top Container* – has no roof allowing the transportation of out-of-gauge cargo, i.e. cargo that will not fit in a standard container; for example tall cargo that can be loaded/unloaded by means of a crane (ibid).

viii. *Bulk Container* – a container with a top opening for loading and a side or bottom opening for unloading. It is used for the transportation of cement, grains and ores (ibid).

ix. *Insulated Container* – there has been a downturn in insulated containers in recent years as users now favour refrigerated containers (ibid).

x. *Refrigerated Container* - also known as a reefer is temperature controlled for the transportation of temperature sensitive cargo; for example, fruit, vegetables, ice cream and fish (ibid).

xi. *Tank Container* – a tank surrounded by a specifically constructed steel frame with corner castings, giving it easy loading and unloading capabilities. It is used for the transportation of liquids and powdered goods (ibid).

3.8.2 Quay Crane (QC)

When a vessel arrives at a port, the import containers have to be discharged from the vessel. This is done by a Quay Crane (QC) (see Appendix I), also known as a ship-to-shore gantry crane which takes the containers off the deck and out of the hold of the vessel. There are two types of crane: a single trolley crane, featured at DFT, and a dual trolley crane, used in the bigger ports such as Rotterdam and Hamburg. The trolley travels along the arm of the crane. It is equipped with a spreader which is lowered down on top of a container and locks into its four locking points (also called corner castings) using a twist lock mechanism. Then the QC loads the containers onto a shunter (terminal tractor) which travels between the vessel and the storage area and vice versa for the loading cycle. The QC can travel the length of the quay wall. It can also manoeuvre around corners as is the case in DFT giving more flexibility and productivity to the cargo handling operations in the terminal. The crane operation is the key factor that determines the efficiency and effectiveness of a container terminal (Kim and Park, 2003).

3.8.3 Shunter (Terminal Tractor)

The shunter (see Appendix II) is a specialized type of terminal vehicle in the form of a tractor used to operate equipment such as a twenty or forty foot trailer. The shunter is secured to the trailer, which can then be used to transfer containers from ship to stacking area and vice versa. It is manually operated with a diesel engine. During the import process, containers flow from the ship to the storage area. The export process is the reverse of the import process. One shunter is capable of carrying one TEU (twenty foot equivalent unit), two TEU, one FEU (forty foot equivalent unit) or a 45ft container.

3.8.4 Straddle Carrier

The first straddle carrier for transporting containers was introduced in container terminals in 1971 and has constantly further developed over the years (Hamburgen, Halen and Logistik, 2011). The straddle carrier (see Appendix III) has the ability to combine the properties of a crane and a vehicle. It is an eight wheeled vehicle that straddles a container, grabs it using an overhead crane, lifts it to the required height and drives away with it in its belly (Spasovic, 1999). It not only transports containers but is also used to stack containers in the terminal. These vehicles are manually operated and are able to stack three or four containers high; i.e. they can move one container over two or three other containers, respectively. Straddle carriers need space to manoeuvre and are not suitable where land is scarce. This type of equipment has been replaced in some ports by Rubber Tyre Gantry (RTG) cranes and Rail Mounted Gantry (RMG) cranes. One of the main advantages of the straddle carrier is that a container can be picked from the stacking area and placed under the gantry crane without any assistance from the gantry crane. Belfast Container Terminal (BCT) use straddle carriers as they have ample space to manoeuvre. They have the ability to carry one twenty foot, or one forty foot unit. Some straddle carries are capable of lifting two containers simultaneously but this will depend on the weight of the container being lifted as the lifting capacity of the straddle carrier is sixty tons (Port Technology, 2012).

3.8.5 Reachstacker

Reachstackers (see Appendix IV) are mostly used in smaller terminals because they not only stack containers but can also lift out–of–gauge units i.e. over-height/over-width cargos. They have a slower speed compared to the shunter and straddle carrier. DFT did purchase one in 2001 but are not inclined to use it as it is very severe on the infrastructure, damaging the road surface, another disadvantage being that it is not fuel efficient.

3.8.6 Automated Guided Vehicle (AGV)

AGVs were first used for transporting containers at the Delta/Sea-Land terminal located in Rotterdam in 1993 and are currently the most up to date equipment used to transport containers in larger ports (Henesey et al, 2009). The AGV (see Appendix V) is a robotic vehicle that drives on a road network that needs electric wires or transporters in the infrastructure to control the position and operation of the vehicle. They can load one TEU, two TEU, one FEU or a 45 ft unit (Vis and Koster, 2003).

Since the AGV system demands high investment capital costs, they are only operated where labour costs are high; and are now in operation at European Container Terminal (ECT), Rotterdam and at Hamburgen, Halen and Logistik AG (HHLA), Hamburg in combination with automatic gantry cranes (Böse, 2011).

Duinkerken and Ottjes, (2000) developed a model to determine the sensitivity of the AGV, as well as speed, crane and stack capacity. While they concluded that the AGV is one of the major obstacles for increasing throughput in a container terminal meaning more emphasis should be given to the dynamic routing of the AGV, the researcher believes the IAV will potentially overcome the issues as highlighted by Duinkerken and Ottjes.

3.8.7 Lift AGV

Lift AGVs are a further development of the AGV technology. Unlike conventional AGVs, the lift AGV has two active lifting platforms. These enable the vehicle to lift and place containers independently on transfer racks in the interchange zone in front of the stacking cranes by using a lift mechanism. Two twenty-foot containers can be handled independently of each other or one container of any size. Lift-AGVs need to make an additional stop in front of the container rack to lower or hoist the platform. This is an extra move in their routing process and costs additional time (15–25 seconds per stack visit). This decreases productivity (Port Technology, 2014).

The different systems considered above are the most common used for transporting containers from shipside to storage area and vice versa. There is no 'ideal' container terminal therefore the right selection of cargo handling equipment is suited to each individual terminal. The decision as to which technology will be used will be determined by the space available and the general layout of the terminal, as well as the cost of procuring the equipment.

3.9 Financial Analysis of Shunter versus IAV

This section presents the financial results of the two alternative vehicles, namely the shunter and the IAV. The following financial calculations provide a comparison between one alternative and the other. All data and figures regarding the shunter have been provided by DFT management. DFT operate ten shunters. Net Present Value (NPV) for the shunter was calculated using MS Excel.

3.10 Conclusion.

In the above chapter port operations was explained and plans for the future of Dublin Port were discussed. The chapter included container operations carried out in DFT. Comparisons between current technologies used in container terminals versus new technologies was also carried out. Containerisation and cargo handling equipment were discussed.

Table 11 Expected Net Present Value: in relation to existing Shunter

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	€	€	€	€	€	€	€	€	€	€	€	€	€	€	€
Shunter Capital	0	0	0	0	0	90,000	90,000	90,000	90,000	90,000	90,000	90,000	90,000	90,000	90,000
Trailer Capital	0	0	0	0	0	23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000
Diesel Fuel Costs (One Vehicle)	21,600	22,032	22,473	22,922	23,380	23,848	24,327	24,812	25,308	25,814	26,330	26,857	27,394	27,942	28,501
Diesel Fuel Costs (Nine Vehicles)	194,400	198,288	202,257	206,298	210,420	214,632	218,943	223,308	227,772	232,326	236,970	241,713	246,546	251,478	256,509
Driver wages (One Driver)	69,859	71,256	72,681	74,135	75,618	77,130	87,673	80,246	81,851	83,488	85,158	86,861	88,598	90,370	92,177
Driver Wages (Nine Drivers)	628,731	641,306	654,132	667,214	680,559	694,170	708,053	722,214	736,659	751,392	766,420	781,748	797,383	813,331	829,597
Annual Leave (One Driver)	6,080	6,202	6,326	6,452	6,581	6,713	6,847	6,984	7,124	7,266	7,411	7,560	7,711	7,865	8,022
Annual Leave (Nine Drivers)	54,720	55,814	56,931	58,069	59,230	60,415	61,623	62,856	64,113	65,395	66,703	68,037	69,398	70,786	829,597
Service Costs (One vehicle)	8,000	8,160	8,323	8,490	8,659	8,833	9,009	9,189	9,373	9,561	9,752	9,945	10,146	10,349	10,556
Service Costs (Nine Vehicles)	72,000	73,440	74,908	76,407	77,935	79,494	81,084	82,705	84,359	96,047	87,768	89,523	91,313	93,140	95.002
Total Annual Cost (One vehicle)	105,539	107,650	109,803	111,999	114,238	229,523	231,856	234,231	236,656	239,129	241,652	244,225	246,849	249,526	252,257

Total Annual Cost (Nine vehicles)	949,851	968,848	988,228	1,007,989	1,028,144	1,161,712	1,182,704	1,204,084	1,225,903	1,248,160	1,270,861	1,294,021	1,317,641	1,341,734	1,366,311
N PV of Total Cost (Ten Vehicles)	**949,851**	**910,571**	**872,919**	**836,816**	**802,209**	**851,901**	**815,129**	**779,747**	**746,317**	**714,160**	**683,410**	**654,009**	**625,889**	**598,998**	**573,280**

NPV for shunter = €11,415,206

Note: Inflation at 2% will apply to energy, service and wages costs

Source: Central Statistics Office, (2012) It has been advised by DFT that the average age of the existing shunters/trailers is four years and will have a remaining life of six years. Replacement of existing shunters is not necessary at this moment in time. Replacement dates will be 2018 and 2027. Table 11 shows NPV calculation on the basis of one shunter being replaced each year from 2018 until all ten units have been replaced.

Table 12 Fuel Costs

Hours per operation	Litres diesel consumed per hour	Litres per year	Price per litre	Fuel cost per year
3,000 hrs.	8 Litres.	24000 Litres.	€0.90	**€21,600**

Source*:* DFT Management, (20 June 2011)

Fuel costs are the costs of the diesel to run the shunter for one year. The shunter works 3,000 hours per year. It consumes 8 litres an hour which amounts to 24,000 litres per year. The price of one litre of diesel is €0.90 as of 21st June 2012. Therefore, the cost of running the shunter on diesel for one year is €21,600.

Table 13 Wages

Operations per year	Wages cost per hour	Wages cost per year	Provision for holiday pay	Employers PRSI @10.75%	Total Wages Cost
3,000 hours	€19	€57,000	€6,080	€6,779	**€69,859**

Source: DFT Management, (20 June 2011)

A wage is remuneration paid by DFT to the driver of the shunter for one year. The driver works 3,000 hours per year. He is paid €19.00 per hour, making the payment for one year €57,000. The cost of holiday pay is €6,064 and employers PRSI amounts to €6,779, bringing the total wages cost for one driver to €69,843.

Table 14 Service Costs

Hours operation per year	Hours – service interval	Services required per year	Cost per service	Service cost per year
3,000 hours	300 hours	10	€800	**€8,000**

Source: DFT Management, (20 June 2011)

Service costs are the costs for servicing the shunter for one year. The shunter works 3,000 hours per year. It is serviced after every 300 hours, making 10 services per year. The cost per service is €800 making the total service cost for the year €8,000.

Table 15 Annual Leave

Operation per year	Hours per employee per week	Operations per week.	Weeks worked per employee	Employees required per shunter	Weeks leave per employee	Annual leave hours per year	Cost of annual leave pay @ €19 per hour
3,000 hours	40 hours	75	47 weeks	1.60	5 weeks	320 hours	**€6.080**

Source: DFT Management, (20 June 2011)

All employees are entitled to annual leave each year in accordance with EU Employment Directives. The driver works a 40 hour week, i.e. 75 operations per week making 3,000 hours worked in one year. There are 75 operations per week and each driver works 47 weeks. 1.6 drivers get 5 weeks holidays which is 320 hours per year at €19 per hours making the cost of holiday pay €6,080.

Table 16 Expected Net Present Value: in relation to IAV.

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	€	€	€	€	€	€	€	€	€	€	€	€	€	€	€
IAV Capital	1,000,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cost of Installing Charger	20,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Energy Costs (One vehicle)	2,918	2,976	3,036	3,097	3,159	3,222	3,286	3,351	3,418	3,486	3,556	3,627	3,700	3,774	3850
Energy Costs (Nine Vehicles)	26,262	26,787	27,323	27,869	28,427	28,995	29575	30,167	30,770	31,385	32,013	32,654	33,307	33,973	34,652
Computer Operator (One)	69.859	71,256	72,681	74,135	75,618	77,130	78,672	80,246	81,851	83,488	85,157	86,861	88,598	90,370	92,177
Computer Operator (Two)	69.859	71,256	72,681	74,135	75,618	77,130	78,672	80,246	81,851	83,488	85,157	86,861	88,598	90,370	92,177
Annual Leave Computer Operator (One)	6,080	6,202	6.326	6,452	6,581	7,613	6,847	6,984	7,124	7,266	7,411	7,560	7,712	7,865	8,022
Annual Leave Computer Operator (Two)	6,080	6,202	6,326	6.452	6,581	6,713	6,847	6,984	7,124	7,266	7.411	7,560	7,712	7,865	8,022
Service Costs (One Vehicle)	4,000	4,080	4,162	4,245	4,330	4,416	4,505	4,595	4,686	4,780	4,876	4,974	5,073	5,174	5,278
Service Costs (Nine Vehicles)	36,000	37,720	37,454	38,204	38,968	39,747	40,542	41,353	41,180	43,023	43,884	44,761	45,657	46,570	47,501
Total Annual Cost (Ten Vehicles)	1,221.058	225,479	229.989	234,588	239.280	244,066	248,947	253,926	259,005	264,185	269,649	274,858	280,355	285,962	291,681
NPV Total Cost (Ten Vehicles)	**1,221,058**	**211,916**	**203,153**	**194,752**	**186,698**	**178,978**	**171,576**	**164,481**	**157,679**	**151,159**	**144,908**	**138,915**	**133,170**	**127,664**	**122,384**

NPV for IAV = €3,508,491

Note: Inflation at 2% will apply to energy, service and wages costs

Source: Central Statics Office, (2012).

The initial cost of the prototype IAV is €500,000. This cost includes all materials and research. It has been advised that additional vehicles will cost €100,000. This information regarding the IAV has been provided by Professor Rochdi Merzouki, InTraDE Project Manager, Polytechnic, Lille, France.

Net Present Value for the IAV was calculated in Microsoft software package Excel. The risk adjusted discount rate used was 6.4% (Dublin Airport Authority Cost of Capital, 2005).

Table 16 shows the NPV for subsequent vehicles assuming a cost of €100,000 purchasing all ten vehicles in 2013. The useful life of the IAV is expected to be more than 15 years. Replacement date will be sometime after 2027. The IAV is electric. It has thirty units and each unit has six cells enclosed. It also has a battery voltage of 12 volts with a capacity of 108 amp-hours. It has been advised by Electric Ireland that electricity is billed in cents per kilowatt hour. The rate charged will depend on the following:

i. Which supplier is chosen and;
ii. What tariff is applicable i.e. large companies can negotiate low tariffs because of their barging power, or some customers may have day/night metering.

The batteries fully charged will operate a four hour cycle. It has been suggested the best rate for the IAV would be approximately 10 cents per kilowatt hour.

Table 17 Cost per Charge

Volts	Amp hours	Watt hours	Kilow att hours	Units	Kilowatt per hour	Cents per kilowatt hour	Full Charge
12	108	1296	1.296	30	38.88	10c	€3.89

Table 18 Cost per Year

Hours operation per year	Hours per charge	Charges per year	Cost per charge	Cost per year
3,000	4	750	€3.89	€2,918

No information on wages costs has been received for the operation of the IAV. It has been assumed that engineering operating vehicles will be paid on a similar basis.

No exact information has been received on the annual service costs of the IAV. As the IAV is electric, half the cost of maintaining the shunter is been assumed.

3.10 Conclusion.

In the above chapter port operations was explained and plans for the future of Dublin Port were discussed. The chapter included container operations carried out in DFT. Comparisons between current technologies used in container terminals versus new technologies was also carried out. Containerisation and cargo handling equipment were discussed.

Chapter Four: InTraDE (IAV) Project

4.0 Introduction

This chapter introduces the InTraDE (IAV) project and explains it aims and objections. The project partners and their work packages are presented. Automation and the intelligent autonomous vehicle (IAV) are also discussed.

4.1 InTraDE Project

The InTraDE (IAV) project, in which Dublin Institute of Technology (DIT), (School of Spatial Planning and Transport Engineering) was a partner with Dublin Port Company as a sub-partner, received European Regional Development Funding through InterReg IV B. Within North West Europe (NWE), a few ports such as Zeebrugge, Gwent and Antwerp (Portstrategy, 2014) are able to keep pace with the activity similar to that experienced in Dublin Port. The main problem in handling increasing levels of cargo is managing the internal traffic and optimizing space in the small/medium sized ports. Participation in the InTraDE (IAV) project has contributed to improving the traffic management and space optimization inside smaller and medium sized ports by developing a clean and safe ITS, such as the IAV.

InTraDE was a €7 million project, with 50% co-financed by European Regional Development Funds under the InterReg IVB trans-national cooperation North West Europe Programme. The project started in September 2009 and ended in March 2014. It was led by

Polytech'Lille in France and brought together seven partners from France, Ireland, Belgium and the UK:

i. Pollytech'Lille, France (lead partner);
ii. Laboratoire Lorrain de Recherche en Informatique et ses Applications (LORIA), Nancy, France;
iii. Centre Regional d'Innovation et de Transfert de Technologie-Transport et Logistique (CRITT-TL), Le Havre, France;
iv. AG Port of Oostende (AGHO), Belgium;
v. Liverpool John Moores University (LOOM) UK and;
vi. South East England Development Agency (SEEDA) UK.

Source: InTraDE, 2010.

Just two years into the project, due to a lack of funding from the British Government, SEEDA had to pull out of the project.

Figure 2 below describes all partners and the packages they were assigned in the project.

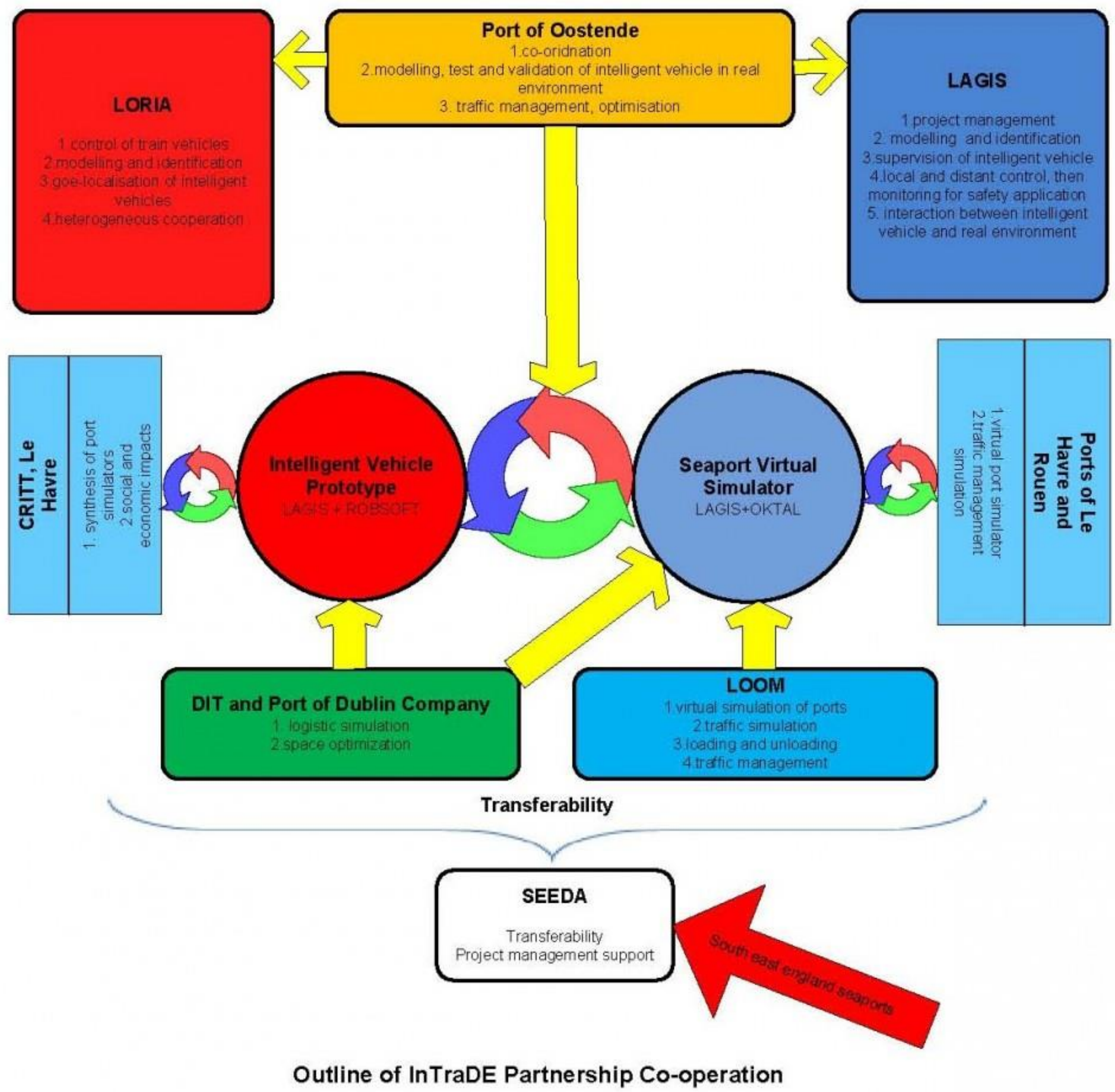

Figure 2 InTraDE Partnerships (InTraDE, 2010)

4.2 InTraDE Objectives

i. To study traffic flows;

ii. To investigate existing traffic control methods and develop new methods where necessary to improve efficiency whilst ensuring safety;

iii. To identify automatic navigation methods;

iv. To develop new algorithms, and investigate practical issues in implementing an automatic navigation system in container terminals;

v. To develop an automatic traffic time-domain simulator for autonomous vehicles within terminals and to carry out a design case study of terminal layout using the simulator and;

vi. To design, test and validate Intelligent Transport Vehicle prototype.

Source: InTraDE, 2010

4.3 InTraDE Aims

i. To improve productivity of small and medium sized ports so they can be more competitive;

ii. To contribute to the effort of national & EU governments to divert some road traffic elements on to the sea by improving efficiency of short sea shipping;

iii. To improve the operational safety and environmental impact in container ports and;

iv. To reduce the gap between economically developed and less developed ports.

(ibid)

4.4 Intelligent Autonomous Vehicle (IAV)

The InTraDE project contributed to improving traffic management and space optimization inside confined spaces by developing a clean and safe ITS (Intelligent Transport System) such as the IAV (Intelligent Autonomous Vehicle). The technology will operate in parallel with virtual simulation software of the automated site, allowing a robust and real-time supervision of the goods handling operation using virtual simulation software (InTraDE, 2010).

The IAV is the logical transition from mobile robotics to that of urban vehicles. The technology will have a specific design, with multi-actuated traction and steering systems. This configuration will allow the system to be redundant in control, so that different scenarios can be defined to run the vehicle on a segment of the road or particular pre-defined trajectory. Multi-decentralized inputs help find reconfigurable solutions when an input fault is detected and isolated. In this case, the vehicle will avoid the stop situation, without obstructing the traffic operation.

IAVs will improve the traffic in international ports in terms of congestion, when the volume of vehicles is dense according to space motion. These vehicles will alter their speeds and trajectories according to the traffic status and environmental changes such as pollution and noise. The auto-control will help significantly in decreasing the emission rate of pollution gases during the vehicles' mission. In order to meet requirements of a changing industry and to service the needs of a rapidly developing economy in the long term, the IAV will reduce the time lost in moving cargo from ship to stacking areas and vice versa by 10%. In turn, this will impact on the turnaround time of vessels, a crucial factor in port and vessel efficiency, particularly in Dublin Port. In addition, the environmental benefits will include a 20% reduction in air pollution.

The IAV uses a GPS guidance system to move unmanned around port terminals, delivering containers to and from marshalling areas. Although the IAV is not exactly new, what makes it different is that it does not require a guidance system such as rails or transponders set into the ground. Traffic management is a problem with the future development of port terminals such as in Dublin Port. The problem can be solved by having a remote ‘traffic control centre’ directing vehicles to marshalling areas where the containers are handled by IAV’s (ibid).

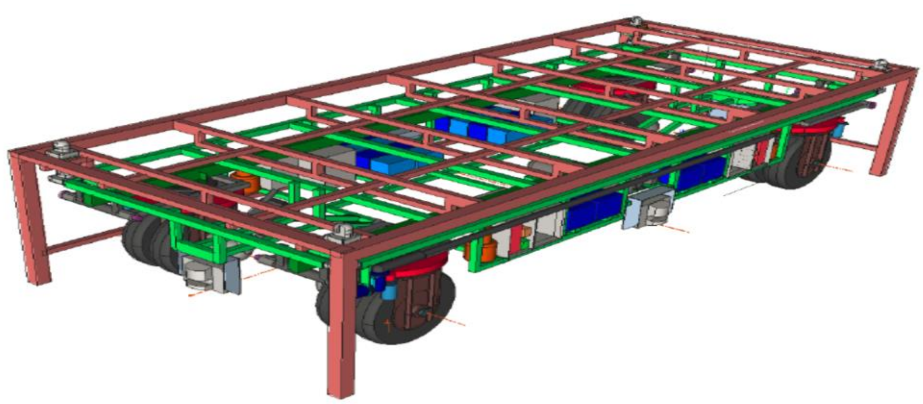

Figure 3 Intelligent Autonomous Vehicle (IAV) with cassette (InTraDE Project, 2011)

4.4.1 IAV Using Cassette System

The IAV can work as a single unit or with a cassette. The cassette system meets the challenges of modern cargo handling technology by improving capacity, productivity, reliability and safety. The cassette works as a transportable steel table with legs that sit on top of the IAV. The key innovation of this system is the implementation of the container cassette as a 'floating buffer' between the quay crane and the stacking area. Using the cassette, the containers are disconnected from the IAV, leaving the cranes to work without stopping. The IAV can pick up, transport and drop off cassettes without waiting for a container to be loaded or unloaded.

Using the cassette system increases the quay crane productivity because the transfer of containers between vessel and stacking area uses the cassette as a buffer, minimizing the waiting time for containers to become available. Containers on cassettes are disconnected from the IAV, delivering higher efficiency and productivity since idle time is reduced.

4.4.2 Control Centre

Port container terminals are run by a team of different specialists such as managers, logistics and maintenance staff, who plan and manage the terminals together. The control centre will allow the work force to come together in one location where everyone can easily interact and share the same views. It will also provide an overview of the entire terminal which will enable the workforce to identify bottlenecks and optimize processes which help to increase productivity and efficiency, and improve safety.

4.5 Simulation of Terminal Operations

Simulation is "*the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behaviour of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system"* (Ingalls, 2008). In other words, simulation is the process of creating a computer model in order to understand the impact of modifications and the effect of introducing different scenarios to determine results. Simulation is also the perfect tool for evaluating system parameter values as it reduces the cost and time of a project by allowing the user to quickly evaluate the performance of different layouts, a process that is time consuming and extraordinarily expensive. The simulator used has adopted techniques to study traffic flows within a port environment. Data and information regarding DFT was inputted into the simulator to generate a generic 3D dynamic layout of the terminal. The tools employed an interactive approach between vehicles, traffic lights and roads that enable users to visualize a real terminal network and the vehicles that drive in it.

The simulation model used to predict the behaviour of the IAV was SCANeR Studio, designed and developed by OKTAL, France as part of the InTraDE project (SCANeR Studio, 2011). The SCANeR studio simulator was developed based on the existing conditions at the port which consisted of the physical layout and characteristics of DFT operations, including traffic management and space optimisation. It also simulated the external environment and accidental situations. Potential terminal improvements were also included in the model. The objective is to minimize ship turn-around time and to better utilize the available cargo handling equipment.

Simulation ensures that the design solution works making capital justification much easier. The simulation of the current technology versus the new technology demonstrates a whole process of 'what if ′ scenarios; e.g. breakdowns, seasonal changes, time travelled from ship to storage areas and vice versa, absenteeism etc. It allows robust and real-time supervision of the goods handling operation.

In order to optimize a system two costs have been analysed – the current system (shunter with driver) and the new system (IAV with no driver). The goal is to keep both costs at a minimum so that the total system cost is minimized. The model has been validated using terminal observed data and statistical testing. Extensive data collection included field observations, online camera observation and terminal day-to-day operation records. Comprehensive data analysis provides a solid foundation to support the development of the optimisation model.

The simulator was used as a demonstration tool to illustrate the prototype of the IAV and has been an invaluable tool when considering strategic change. Use of the SCANeR Studio simulator optimized the process at the design stage eliminating months of trial and error with the live model. It has allowed design, validation and implementation without disturbing the production process. Experiments with different solutions allowed for decisions on the best scenarios for the operation. It brought the analysis to life by giving a greater level of accuracy and understanding of the process, achieving the best solutions faster.

4.6 Benefits of Simulation in DFT.

As a result of experience in port container terminals and seeing the simulator used as a demonstration tool in DFT the benefits expected include:

i. Reduced operational costs;
ii. Improved throughput;
iii. Capital investment optimisation;
iv. Bottleneck investigation and resolution;
v. Realization of best practice;
vi. Better utilization of resources (labour and equipment) and;
vii. Validation of new process prior to launch.

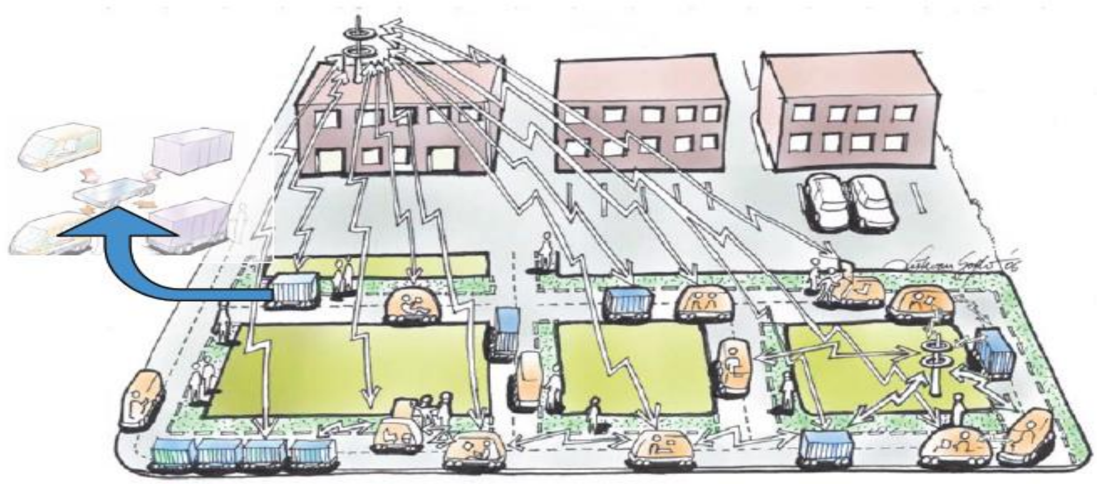

Figure 4 Graphic Illustration of IAV's working (InTraDE Project)

Figure 4 is an illustration of how a future container terminal will look operating IAV's.

4.7 Application of Port Simulator

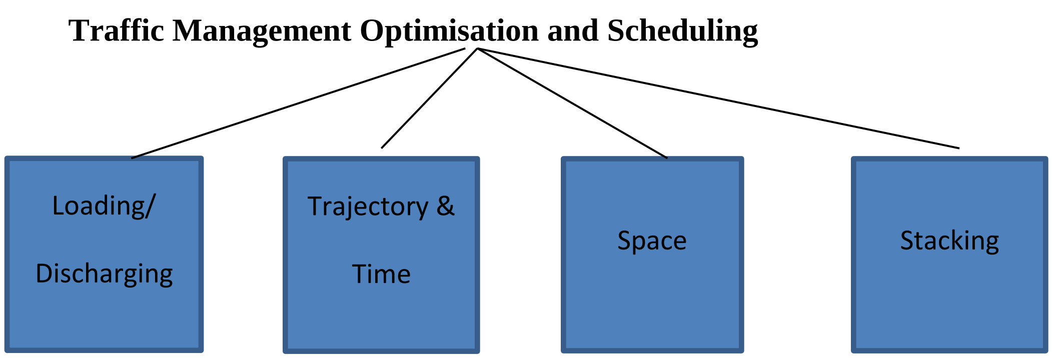

Figure 5 Simulation Tasks in Terminal Operation

Figure 5 concerns the operation of loading and unloading of a container vessel; namely routing, dispatching and scheduling. The main objectives are:

i. To minimise the time taken by the quay crane operation i.e. loading and unloading;
ii. To minimise the total distance travelled by the IAV and;
iii. To minimise the difference of working time between all vehicles.

4.8 Container Terminal System

A container terminal is a complex system. It will only function efficiently when its layout is designed in such a way that the loading and discharging process of the vessels calling at its berths run smoothly. DFT consists of the following operational areas:

i. *Ship-to-Shore*: Movement of containers from vessel to berth and vice versa. Quay cranes are assigned to a vessel for the task of unloading and loading containers;
ii. *Transfer*: The movement of containers from a vessel to a stacking area;
iii. *Storage*: A stacking area where containers are transported to, and then placed before being loaded on a vessel for export or placed on a vehicle for delivery and;
iv. *Delivery / Receipt*: Movement of containers between the ‘gate’ and the storage/stacking area and vice-versa depending on whether the container is an import or an export. The gate acts as an interface for the container terminal with the trucks coming in from and going out onto the road.

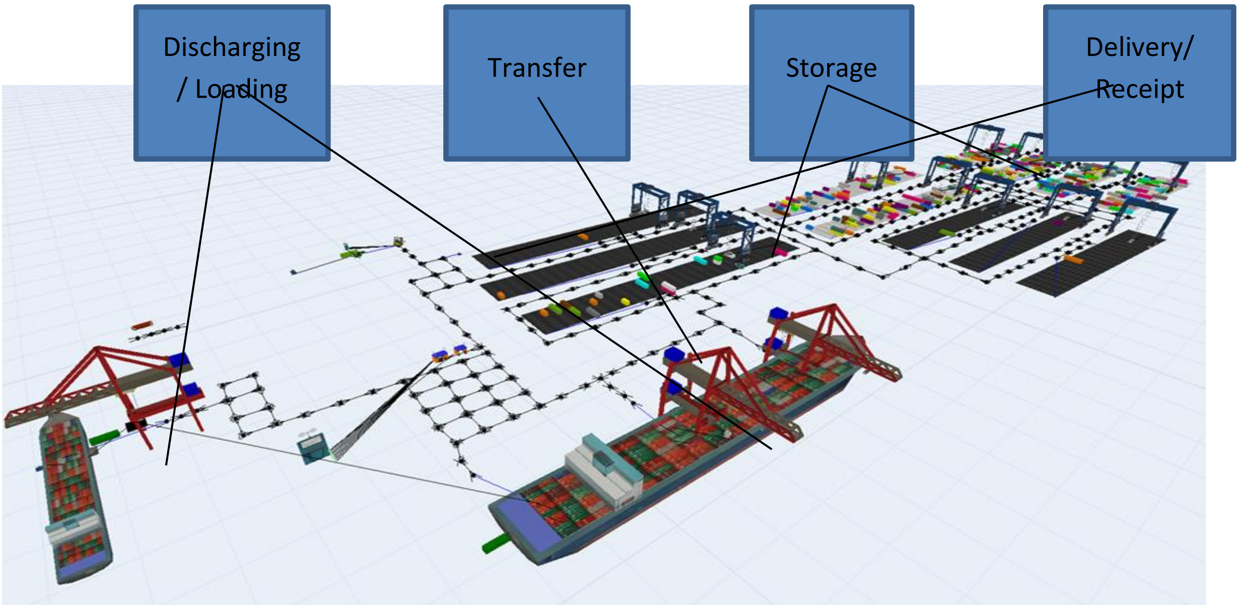

Figure 6 3D Image of DFT (InTraDE, 2010)

4.9 Application Programming Interface (API) for Port and IAV Simulation

Application Programming Interface (API) is used for on- line and off-line simulation of intelligent transport systems. (InTraDE Project, 2010). The off-line is used to provide a simulation tool for the control of the IAV, in an online virtual environment, and on-line, is used to supervise a real IAV. The API facilitates the control of the vehicle with a single set of commands. These commands allow the user to define a vehicle's trajectory by specifying its identity, since there may be many IAV's involved in an operation, it will set the speed of the IAV and aim it at a target point

Object management is another function fulfilled by the API. The function allows the user to move the IAV by specifying the identity, load a container by a quay crane onto the IAV and unload a container from the IAV in the stacking area. It also offers the possibility to search for an object near a given position.

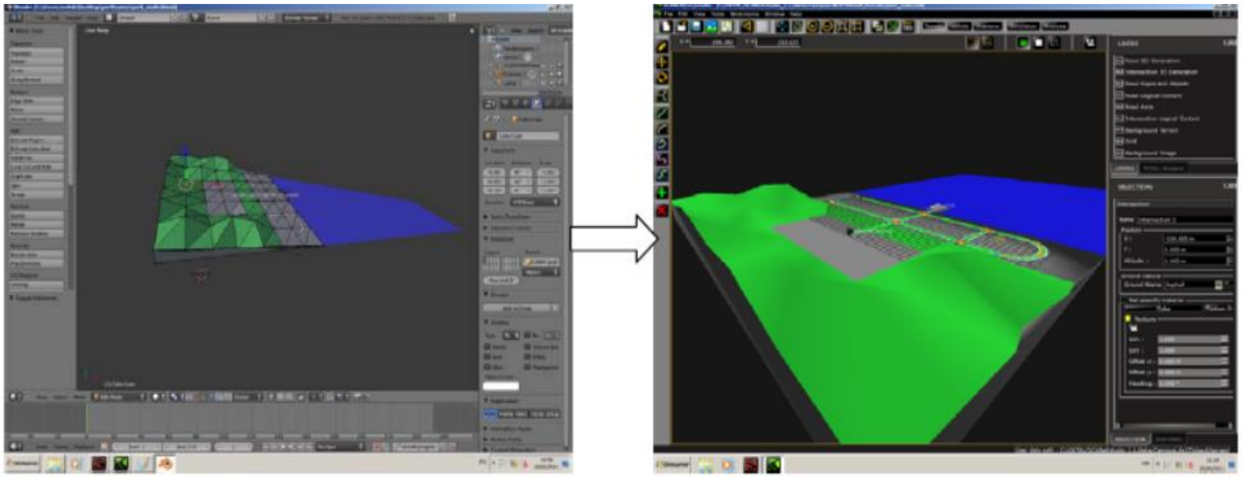

Figure 7 Export of a 3D Port Environment to ScanerStudio (InTraDE, 2011)

4.10 SCANeR Studio

Since 1989, Oktal has been a major player in providing innovative and durable simulation software systems. The SCANeR Studio simulation engine developed by Oktal is the software engine used by the InTraDE project for testing and driving in different and difficult environments. The port environment has been designed and different simulations have been performed in order to be able to display the real movement of the IAV within SCANeR Studio by acquiring different data from sensors, for example GPS, which will supervise and control the IAV and will ensure safety and reliability. SCANeR Studio is limited in what it can do. It is restricted to only a few vehicles, is used solely to supervise these vessels, and is not involved with the simulation of the overall environment.

4.11 Flexsim

Because SCANeR Studio is so restricted, Flexsim simulation software was introduced to overcome these restrictions. It deals with modelling, analysing, visualizing and optimizing traffic management, as it adapts better to changes and disturbances in the environment.

Flexsim can take each vehicle, each crane, and each container as an element i.e. a large number of vehicles, unlike SCANeR Studio which can only deal with a finite number of vehicles. It shows different container layouts, cranes etc. to minimize waiting time and improve the strategies of containers discharging, loading, unloading and their transport time from ship to stacking area and vice versa. Furthermore, Flexsim allows the integration of 3D visualization and animation. It can also be integrated with Excel and linked to any data base. The purpose of this tool is its ability to solve problems with regard to the layout of terminals, and to estimate the time of execution of different tasks.

Simulation modelling was used in this research in order to predict the turnaround time of vessels while minimising cargo handling equipment costs. Container terminals require new cargo handling technologies for finding solutions to improving productivity, while maintaining costs at a minimum level of acceptability. The researcher was not skilled in dealing with simulation; so a skilled computer simulation person with the correct knowledge was sought and contracted to perform the simulation of DFT. This person was managed by the researcher to ensure the logistic simulation task (see Figure 2) was carried out to the satisfaction of the project leader.

The essence of simulation modelling is to help the ultimate decision-maker solve a given problem. Therefore, efficient problem-solving techniques are combined with good software engineering practice (Akbay, 1996; Solomenikovs, 2006). Simulation studies normally propose the following steps for creating a model:

i. *Problem Definition*: Clearly defining the goals of the study so that it is known why the problem is being studied and what questions to answer;
ii. *System Definition*: Determining the boundaries and restrictions to be used in the system or process and investigating how the system works;
iii. *Input Data Preparation*: Identifying and collecting the input data needed by the model;
iv. *Conceptual Model Formulation*: Developing a preliminary model either graphically (e.g. block diagrams) or in pseudo-code to define the components, descriptive variables and interactions that constitute the system;
v. *Experimental Design*: Selecting the measures of effectiveness to be used, the factors to be varied and the levels of those factors to be investigated i.e., what data needs to be gathered from the model, in what form and to what extent;
vi. *Model Translation*: Formulating the model in an appropriate simulation language;
vii. *Verification and Validation*: Confirming that the model operates the way the analyst intended (debugging) and that the output of the model is believable and representative of the output of the real system;
viii. *Experimentation*: Executing the simulation to generate the desired data and to perform a sensitivity analysis;

ix. *Analysis and Interpretation*: Drawing conclusions from the data generated by the simulation and;

x. *Implementation and Documentation*: Putting the results to use, recording the findings. (ibid).

Because of the increasing goods flow and growing importance of container terminals, there have been several international projects funded by the EU covering issues of container terminal simulation modelling such as;

i. AMCAI-EU project (1995-1997)
ii. DAMAC-HP-EU project (1998-2000)
iii. SPHERE- EU Project (1996-1999) and;
iv. BALRPORTS-IT

The main objective of BALTPORTS-IT was the dissemination of research knowledge gained during the execution of the other three projects in the area of IT solutions and simulation for harbour managing and control. These covered general issues relating to container terminals such as:

i. Simulation based layout planning;
ii. Re-engineering of logistics processes;
iii. Design and visualization of information flow processes and;
iv. Process control by interconnection of simulation and terminal interaction system. (BALTPORTS-IT, 2001)

Grunow et al (2006) examine the efficiency of different dispatching strategies by using a simulator to study AGV's in container terminals. Only one AGV is allowed to occupy a particular zone at any time meaning other AGV's wanting to occupy the same zone have to wait until the original AGV has cleared the area. It is envisaged that a sequence of pick-up and drop-off operations are available during a given look-ahead horizon.

4.12 Conclusion

This chapter has presented how the InTraDE project was established. It has explained the object of the project, which was to test and validate the reliability of the IAV in a dynamic environment, with control, optimisation, traffic management and monitoring methods. Simulation of terminal operations has also been discussed. For the researcher's publications related to the InTraDE project see Appendix IX.

Chapter Five: Research Methodology

5.0 Introduction

This chapter presents the research methodology used in order to complete this research. It explores the major research philosophies, the research process, quantitative and qualitative research strategies, secondary research, primary research and the validity and reliability of this research. The aim of this chapter is to present a justification for the research tools that are utilised to carry out the research involved.

5.1 Research Philosophy

The research philosophy that is followed by a researcher can have the ability to greatly influence the choice of research strategy and the manner through which a researcher sets about achieving the aims of their research (Saunders et al, 2009). Additionally, it is suggested by Gratton & Jones (2010) that the research philosophy that is followed can influence the type of research questions that are developed, the methodology adopted by the researcher, the nature of the data that is collected as part of the research and the analysis and interpretation of such data. Therefore, it is imperative that great attention must be paid to the area of research philosophies both prior and during the completion of research. With this in mind, the two major research philosophies are positivism and interpretivism. Table 19 below explores positivism and interpretivism in greater detail.

Table 19 Positivism and Interpretivism Compared

	Positivism	Interpretivism
Basic Principles		
View of the world	The world is external and objective	The world is socially constructed and objective
Involvement of researcher	Researcher is independent	Researcher is part of what is observed and sometimes even actively collaborates
Researcher's influence	Research is value-free	Research is driven by human interest
Assumptions		
What is observed?	Objective, often quantitative, facts	Subjective interpretations of meanings
How is knowledge developed?	Reducing phenomena to simple elements representing general laws	Taking a broad and total view of phenomena to detect explanations beyond the current knowledge

(Source: Blumberg, Cooper & Schindler, 2011, p. 19)

Positivism suggests that the social world exists externally and can be viewed objectively (Blumberg et al., 2011). Hence, a real truth exists and it can be understood by reading into its simplest possible elements (ibid). This implies that positivistic research is value-free, without the influence from the surroundings and any social or individual norms (Lincoln & Guba, 1985). On the other hand, interpretivism supposes that the social world is constructed and people give subject meaning to it (Blumberg et al., 2011). Hence, the social world is an individual construction and, to understand it, the researcher needs to look at a total picture (ibid). This implies that interpretivism enables the researcher to take socially constructed and subjective perspectives into consideration (Saunders et al, 2012) and essentially interpret the meaning of the data.

As Intelligent Autonomous Vehicles in port container terminals are quite a modern phenomenon it would be beneficial to utilise the positivism approach as it allows the researcher to gain unknown, but actual facts surrounding the topic area (Silverman, 2006). However, with that being said, port container terminal operations can be different for every individual, thus it involves the actions of humans, which can be best interpreted through interpretivism (Bryman, 2012). As a result this research uses the pragmatism philosophy, which is described as '*a position that argues that the most important determinant of the research philosophy adopted is the research question, arguing that it is possible to work within both positivist and interpretivist positions'* (Saunders et al., 2012, p. 678). As such, it is able to apply a practical approach, integrating different perspectives to help collect and interpret data.

Many social scientists regard the two philosophies as incompatible with each other and argue that it is impossible to combine them as part of one piece of research (Sale et al, 2002). However, in recent years researchers have begun to state that the divide between positivism and interpretivism is overstated and overdrawn, and that a common ground can be found (Blaikie, 2010). This illustrates Dawson's (2009) point that different methodologies become popular at different social, political, historical and cultural times and that each of these methodologies has their own strengths and weaknesses. Thus, a mixed method approach involves the use of both approaches in tandem so the overall strength of a study is greater than just a quantitative or qualitative piece of research on its own (Creswell, 2014). Moreover, it is suggested by Bryman (2012, p. 631) that today, mixed- methods research has become '*feasible and desirable'*.

For the purpose of the research a mixed-method approach is being undertaken in order to improve the quality of the research. This can be achieved through triangulation, offset and completeness; where triangulation refers to the combination of quantitative and qualitative research methods in order to corroborate the findings; where offset refers to the process of combining quantitative and qualitative research methods in order to offset the weaknesses of each; and where completeness refers to the process of combining quantitative and qualitative research methods in order to give a more comprehensive account of the area of enquiry (Bryman, 2012). Hence, rather than being constrained by one research philosophy (Collis & Hussey, 2014), this research is opting to employ a pragmatist philosophy; and thus working within the most appropriate research philosophy given the nature of the research topic under investigation (Onwuegbuzie & Leech, 2005).

5.2 The Research Process

The research process involves the formation of a research question and the designing of a method through which that question can be accurately answered (Malhotra & Birks, 2007). Gratton & Jones (2010) suggest that there are many different approaches that a researcher can take but it is important to maintain a sense of coherence, which may be referred to as the vertical thread. The thread should start with a research question and everything within the research process should relate to answering that question (ibid). Domegan & Flemming (2007) suggest a six-stage research process. This can be seen in Table 20 below and has been adapted for this research.

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Table 20 The Research Process

	Stage of Research	This Research
Stage 1:	Research Question:	Could Dublin Port container terminal operators improve their productivity and efficiency by implementing new ITS for example the IAV?
		Literature used: • Intelligent Autonomous Vehicles (Cheng, 2011; Bahnes et al., 2016; Crainic et al., 2009: Taniguchi & Thompson, 2011; Giannopoulos, 2009; Kia et al., 2000; Bae et al, 2011). • Container operations in ports (Robinson, 2002; Notteboom and Winkelmans, 2001b; Heaver et al., 2000; Martin and Thomas 2001; Slack et al., 2002). • Operation planning in ports (Crainic and Kim, 2007; Kim, 2007, Bose, 2011). • Evaluation of container terminal efficiency (Henesey, 2006; Haralambides, 2002; Lun & Cariou, 2009). • Customer Satisfaction (Sanzo et at., 2003; Cronin et al., 2000; Magala and Sammons, 2008; Robinson, 2000; Trujillo and Tovar, 2007; Medda and Carbonaro, 2007; Laxe, 2005; Tongzon and Heng, 2005; Wu et al., 2010; Wiegmans et al.,2001;Tongzon, 2002; Wiegmans, 2003.

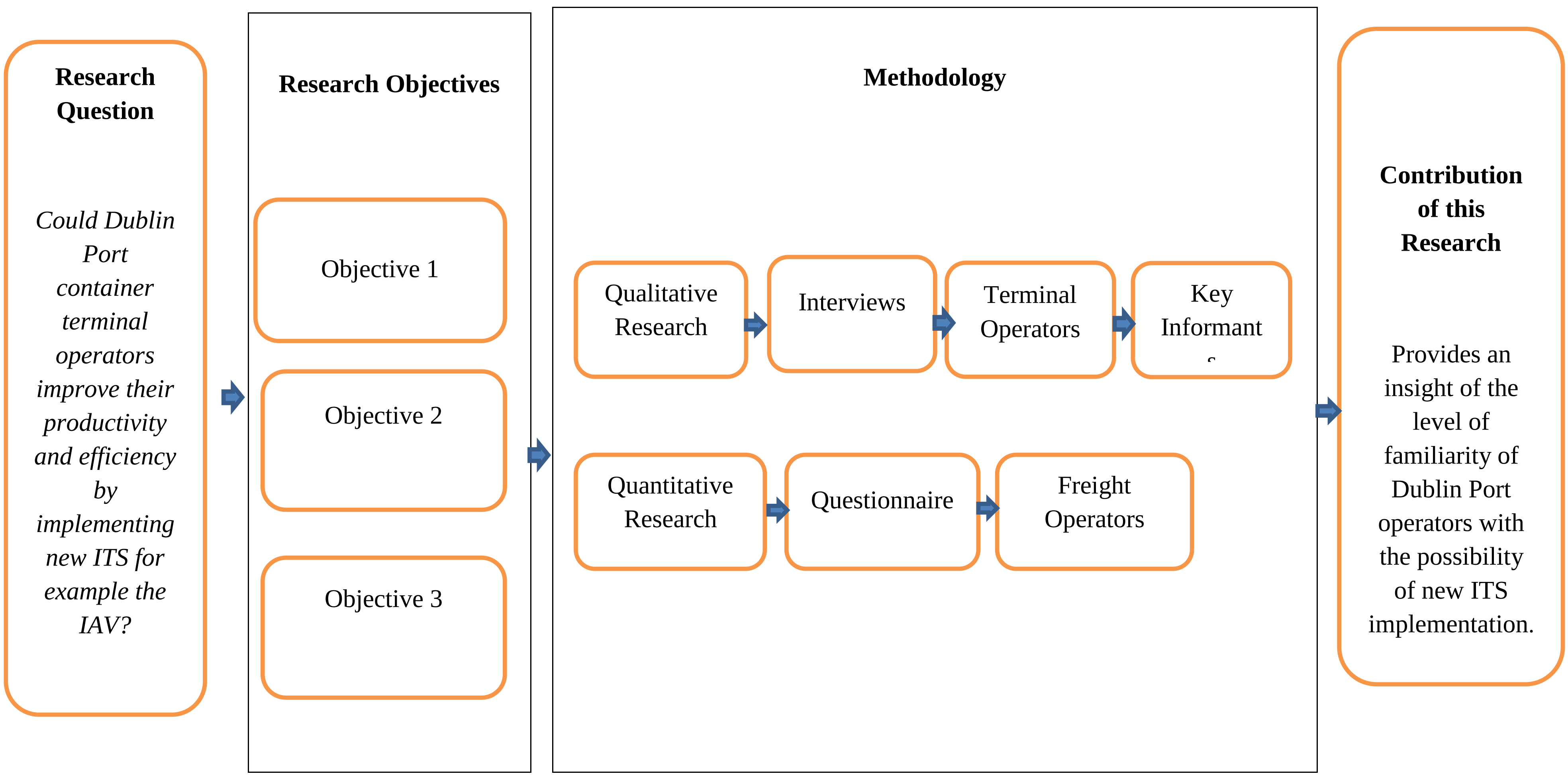
Stage 3:	Sampling:	Questionnaires Semi-structured interviews Shipping Operators Freight Operators
Stage 4:	Primary Research: **Qualitative Research** Semi-structured interviews **Quantitative Research** Questionnaires	**Qualitative Research:** • Shipping Operators **Quantitative Research:** • Freight Operators
Stage 5:	Analysis:	Usage of Survey Monkey to interpret the questionnaire, and the semi-structured interviews.
Stage 6:	Presentation of Results:	The presentation of the results will be categorised according to the primary research method used to gather the data; where it is applicable diagrams will be used to present the findings.

(Domegan & Fleming, 2007, p. 21)

5.2.1 Research Methodology Outline

Figure 8 below illustrates steps taken in the key stages of the study that will facilitate the achievement of the research objectives.

Figure 8 Outline of Research Methodology



5.3 Research Rationale

A question that should be asked by a researcher when undertaking any form of research is whether the piece of research they are working on is actually relevant and ultimately, needed (Cohen et al, 2013). With this in mind, this section explores the rationale for undertaking the research. As the IAV is a relatively new phenomenon, it is still evolving and needs reshaping. As a result, literature on intelligent transport systems in port container terminals is constantly changing. Therefore, this research aims to highlight the current intelligent transport system environment in Dublin Port. In doing so, this research should be able to paint the current picture of intelligent transport systems in Dublin, identify areas that are matching or exceeding what is stated within the literature and identify areas that are not up to the standard of what is stated in the literature. Additionally, this research also looks at intelligent transport systems from the view of the shipping operators and their customers i.e. freight operators. This is because intelligent transport systems have largely come about because of customer demand and thus it is driven by customer demand (see Section 2.9). As a result, this research should be able to be used by industry professionals to determine what today's customer demands are and to establish whether their organisation is able to meet those demands.

5.4 Research Objectives

Research objectives are essential in guiding a researcher's approach and they need to be achieved in order to be able to answer the research question (Gratton & Jones, 2010). As a result, in order to explore the area of research in enough detail, the research objectives need to be achieved. The research objectives are as follows:

i. *Identify the current intelligent transport systems offered by container terminal operators in Dublin Port and investigate the possibility of introducing new ITS.*
ii. *Explore the factors that influence the customer satisfaction of freight operators provided by container terminal operators in Dublin Port and analyse their views.*
iii. *Determine if container terminal operators are currently meeting the intelligent transport systems demands of consumers and explore their plans for the introduction of ITS in the future.*

5.5 Research Question

The research question is a '*broad question that asks for an exploration of the central phenomenon in a study and deals with the relationship of the variables that the investigator tries to find out'* (Creswell, 2009, p. 129). Taking this into consideration, the research question for this research can be summed up in the following;

Could Dublin Port container terminal operators improve their productivity and efficiency by implementing new ITS for example the IAV?

5.6 Secondary Research

Secondary research refers to the collation of historic data generated by another researcher (Malhotra & Birks, 2007). Secondary sources can come in the shape of books, academic journals (Easterby-Smith et al., 2008), encyclopaedias, oral histories of individuals or groups, newspaper reports and governmental or industry reports (McNeill & Chapman, 2004). Data that is present in secondary sources has previously been verified and are therefore likely to be true (Easterby-Smith et al., 2008). However, Saunders et al. (2009) propose that a researcher should never accept that secondary research is totally dependable, as the data can often be one-sided or not comprehensively researched.

There are many advantages and disadvantages of undertaking secondary research. Blumberg et al. (2011) suggest that using secondary data can save time and it is usually more cost effective than undertaking primary research. However, the main disadvantage with undertaking secondary research is that the data may not have been collected with one's specific research question in mind; thus, the secondary data may not be detailed enough or it may not cover all of the information that one's research topic requires (ibid). Collis & Hussey (2009) suggest that the information obtained should be specifically selected and a broad range of sources should be used. Moreover, Saunders et al. (2009) propose that researchers should use both primary and secondary research data when undertaking research. With this in mind, a wide range of sources, such as peer reviewed journal articles, textbooks, industry journals and industry reports were thoroughly analysed for the purpose of this research. The secondary research undertaken as part of this research has contributed to a greater understanding of the topic area of IAV's in port container terminals;

additionally, it has helped to develop the exploratory parameters on which the primary research is based.

5.7 Primary Research

The two main types of data are primary and secondary data. Primary data is described by Walliman, (2001, p.198) as *"data gained by direct, detached observation or measurement of phenomena in the real world, undisturbed by any intermediary interpreter"* and secondary data as *"data that have been subjected to interpretation they are referred to"* The method used for primary data collection for this research is a survey. According to Fink (2003) a survey is "a system for collecting information from or about people to describe, compare or explain their knowledge, attitude or behaviour". Primary data are original in character and are collected by research institutions or individuals for the purposes of a specific study or enquiry (Appannaiah et al., 2010).

Primary research refers to the collection of data for the research project being undertaken (Saunders et al., 2009). According to Dawson (2009), primary research involves the study of a subject through first hand observation and investigation. Primary research instruments can be broadly separated into two different types of research; qualitative and quantitative research (Creswell, 2009). Primary research instruments can include focus groups, in-depth interviews, case studies, questionnaires and observational surveys (Veal & Darcy, 2014).

5.7.1 Qualitative Research

Qualitative research, broadly defined, means any kind of research that produces findings that are not arrived at by means of statistical measures or other means of quantification (Corbin & Strauss, 1990). Quinlan (2011) highlights the fact that qualitative research usually focuses on words rather than numbers in the collection of data. Hence, qualitative research is useful for addressing ‘why’ and ‘how’ questions, to research new topics, understand complex issues, explain behaviour and identify social or cultural norms (Hennink et al., 2010). The goal of qualitative research is to develop concepts that enhance the understanding of phenomena in natural settings, with the emphasis on the meanings, experiences and views of all experiences (Neergaard & Ulhøi, 2007). With this in mind, the qualitative research method of interviews is utilised in the research in order to get a better understanding of people’s actions with regard to intelligent transport systems in port container terminals and hence give greater meaning to the quantitative primary data.

5.7.2 Interviews

Interviews and particularly in-depth interviews are one of the most common qualitative research method used for gathering primary data related to a research topic area (Dawson, 2009; Patton & Applebaum, 2003). An interview can be described as a conversation with a purpose (Berg, 2009) or a purposeful discussion between two or more people (Saunders et al., 2012). It is highlighted by (ibid) that interviews are an appropriate method to use when looking to understand the decisions that participants take, or the opinions and attitudes that they possess. Additionally, interviews can be extremely beneficial in cases where understanding people’s decisions are crucial to answering the research question. At this point it should be highlighted that interviews are not without their drawbacks. Malhotra et al., (2012) stress that the lack of structure in interviews, the lack of the interviewer’s interviewing skills and the potential for bias can all have negative effects on the data collected from interviews. Additionally, this is supported by Saunders et al. (2012) who also cite disadvantages of the interview as its reliability, potential bias and the impact of the interviewer. With this in mind, a semi-structured interview method is formulated where every interviewee is asked the same questions (i.e. an interview protocol is designed and implemented). Additionally, the interviewees are provided with information regarding the research to ensure that they are prepared for the interview. A successful series of interviews should enable this research to validate the findings from the questionnaires (ibid) and in turn, further validate this research. As part of this research, five semi-structured interviews with shipping operators were carried out in order to add to the findings of the questionnaire (see Section 6.9).

5.7.3 Interview Design

As the research is using a mixed research method, the main purpose of the interviews is to aid the research to achieve triangulation, offset and completeness as discussed previously. With this in mind, the interviews are a natural extension of the questionnaires; in as much as that the interviews are aiming to find out the ‘why’ behind the answers to the questionnaire. Essentially, the interviews pose similar questions to those of the questionnaire, however as the interviews are semi-structured there is scope for the interviewer to probe with additional questions (Saunders et al, 2012) to elicit the reasoning for the answers given by the interviewees. It is suggested by (ibid) and Sekaran & Bougie (2013) that recording interviews could bias the interviewees' responses, as they know that their voices are being recorded. As a result, notes were also taken during each of the interviews to ensure that the key points are documented so the interviewer does not have to work off memory at a later date, which according to Brinkmann & Kvale (2015) can limit the research as memory is imprecise and often likely to be incorrect. Furthermore, in order to keep alive the interest of the respondent in the interview, the interviewer aims to follow the tips highlighted by Sekaran & Bougie (2013) who suggest that listening attentively, evincing keen interest in what the interviewee has to say, repeating and/or clarifying questions and paraphrasing some of the answers to ensure the interviewees' thorough understanding; as these methods can have a great effect on interviewees' interest in the interview.

5.7.4 Quantitative Research

Quantitative research is described as research techniques that seek to quantify data and apply some form of statistical analysis (Collis & Hussey, 2014). Quantitative research can be applicable to a piece of research that requires numerical methods to answer questions (Muijs, 2011). Additionally, it is useful for research that is attempting to measure phenomena, as it is objective in nature (Collis & Hussey, 2014). With this in mind, the quantitative research method of questionnaires is used in order to gain an insight into the phenomenon of intelligent transport systems in port container terminals within Dublin Port.

5.7.5 Questionnaires

A questionnaire is a technique of data collection in which each individual is asked to respond to the same set of questions in a predetermined order (Saunders et al., 2012). It can be of great benefit as it enables the researcher to easily reach a large number of respondents in an effective and efficient manner (Malhotra & Birks, 2007). Although this may be the case, Gratton & Jones (2010) points out that as questionnaires rely on self-reporting and as such some participants may wish to alter information about themselves; leading to unreliable results. For to this reason, the research also uses the interviews highlighted previously.

5.7.6 Survey / Questionnaire Design

The research employed an exploratory approach using a descriptive survey design in order to assess factors influencing ITS in container terminals in Dublin Port. A descriptive survey design presents and reports the way things are (Mugenda and Mugenda, 2003). Descriptive survey design is also used when data is collected to describe persons, organizations, settings or phenomena (Creswell, 2003). Kothari (2004) mentions, that descriptive design has enough provision for protection against bias and to ensure reliability. The study adapted a quantitative survey as a major research method. The quantitative survey is designed to fit a questionnaire schedule. This is the most commonly used technique in research methodology (Veal, 2006).

Saunders et al. (2009) propose that the validity and reliability of the data that a piece of research collects and the response rate that a piece of research achieves depend largely on the design of the questions, the structure of the questionnaire and the rigor of pilot testing. Additionally, Dawson (2009) highlights that when designing a questionnaire one should aim to keep it as concise as possible, start with simple questions, then lead to more complex questions and make sure that the questionnaire is interesting and easy to follow. Moreover, it is proposed by Malhotra & Birks (2007) that a questionnaire has three major objectives: to translate the information needed for the research into questions that respondents can and will answer; to motivate respondents to complete the questionnaire; and to minimise as much as possible the possibility for response error. With these points in mind the researcher is utilising the seven-step questionnaire development process proposed by Domegan & Fleming (2007) as seen in Table 21.

5.7.7 Target Population

The target population is a group that a researcher is interested in studying**.** The results of the study are generalized to this population, because they all have significant traits in common. Sekaran (2010) refers to the population as the entire group of people or things of interest that the researcher aims to assess. Population as defined by Mugenda and Mugenda (2003) is an entire group of individuals or objects having common observable characteristics. The research therefore engages most of the freight operators in Dublin Port who make use of the facility in port operations. The target population in the research is comprised of freight operators who number thirty persons. It also targets key informants from Dublin Port Company and the three container terminals in Dublin Port.

5.7.8 Data Collection Methods

The type of data used was quantitative and qualitative in nature. The data collection process was done through a systematic sequence of events. The main data collection instrument was an on-line questionnaire. The process began by constructing a list of freight operators who operated containers in Dublin Port. A telephone phone call was made to each company to find the correct person with an in-depth knowledge of the logistics of Dublin Port and to secure their email address. An introductory email (see Appendix VI) was constructed which included a Survey Monkey web address: (https://www.survey monkey.com/r/R2Z78JR). The questionnaire (see Appendix VII) was then distributed through e-mail to the identified contact person. Since container transportation is mainly a business entity, random sampling was not an appropriate method because the most important container terminal choice decisions are usually made by a senior person within the freight operation companies i.e. port operators. Thus, it was important to find the person authorised in making such decisions. The research was further strengthened by conducting a semi-structured interview with key participants from Dublin Port Company as well as the three container terminals in Dublin Port (see Chapter 6**)**

Table 21 Questionnaire Design Process

Step 1: Preliminary Considerations
• What information is required? • Who are target respondents? • What method of communication will be used to contact respondents? • How will the data be analysed
Step 2: Question Content
• Is the question really necessary? • Does the respondent have the information requested?
Step 3: Response Format
• Open-ended questions • Multiple-choice questions • Dichotomous questions • Likert scale questions
Step 4: Question Wording
• Use simple & unambiguous words • Avoid leading/loaded questions • Avoid double-barreled questions • Avoid generalisations and estimations
Step 5: Sequence of Questions
• Questionnaire should be simple and interesting • Warm-up questions to encourage cooperation • Relate topic questions together
Step 6: Physical Characteristics
• Should appear as short as possible • Professional looking • Allow for plenty of open space
Step 7: Pilot-Test
• Should simulate actual research conditions • Respondents should be similar to target respondents

(Domegan & Fleming, 2007, p. 292)

5.8 Ethical Consideration

'*Ethics can be described as the moral principles governing the conduct of an individual, group or an organisation'* (Quinlan, 2011, p.70). Ethical issues can range from integrity, fair and just treatment of respondents, confidentiality and anonymity (Domegan & Fleming, 2007). Creswell (2009) states that it is imperative that researchers engage in ethical practices and anticipate and plan for any ethical issues that may arise. Atkinson (2012) suggests that there are three aspects to research ethics. The first is to safeguard participants from being harmed in the research process; the second is to ensure that the research is carried out in a manner that serves the interests of the individual or society as a whole; and the third is to examine any research instruments that are utilised for their ethical soundness. Taking these considerations into account, this researcher takes the responsibility to ensure that the respondents are not identified, their data is confidential and the data obtained is only used for the purpose intended as recommended by Dawson (2009).

During the course of the InTraDE project, field work was carried out in DFT. During this field work, tests were carried out on the IAV where the following ethical issues were raised and resolved:

i. Physical hazards – *container terminal and coastline;*
ii. Biological hazards – *none;*
iii. Chemical hazards – *none;*
iv. Man-made hazards- *tests to be carried out in a cordoned-off area;*
v. Personal safety – *working in accordance with and under the supervision of the terminal management;*

vi. Environmental impact – minimum and;

vii. Emergency procedures – *terminal have their own emergency procedures in place.*

After acknowledging the above ethical issues, tests were approved by the ***'Dublin Institute of Technology Research Ethics Committee.'***

5.9 Validity & Reliability

Validity '*relates to how logical, truthful, robust, sound, reasonable, meaningful and useful the research is'* (Quinlan, 2011, p 42). In other words, validity refers to whether or not the primary research has the ability to measure what it is intended to measure (Saunders et al., 2009). This implies that the questionnaire and in-depth interviews must be appropriate to and correspond with the research objectives which ensure that the research has validity. Reliability refers to '*the dependability of the research, to the degree to which the research can be repeated while obtaining consistent results'* (Quinlan, 2011, p 482). Validity for this research is ensured through designing a research process that is supported by relevant literature and ensuring that the research process can be easily replicated through providing a detailed description of the methodology of this research.

5.10 Pilot Testing

It is highly recommended by Domegan & Fleming (2007) to conduct a pilot study of a self-completion questionnaire or structured interview prior to said questionnaire or structured interview being utilised as part of the research. Moreover, Bryman & Bell (2011) note that the desirability of piloting questionnaires is not solely to do with ensuring that the survey questions operate well but piloting also has a role in ensuring that the research instrument as a whole functions well. Malhotra & Birks (2007) also propose that pilot testing is essential in order to identify and eliminate any difficulties or problems that may arise with a research tool. As suggested previously in Table 21 a pilot test for the questionnaire was undertaken. This pilot test was undertaken with respondents that are similar to the target respondents. Discrepancies occur and they are amended to ensure the research tools function well.

5.11 Limitations

According to Collis & Hussey (2014) a limitation is a weakness or deficiency in a piece of research. A limitation of the research is that it solely focuses on the views of shipping operators and freight operators who are their customers. It does not take into consideration any of the views of the freight operators' customers.

The research was limited to a specific transport segment i.e. freight operators using Dublin Port. The result of the research was limited to container terminals in Dublin Port; therefore the findings may differ in container terminals in other regions. The individual performance in these other terminals is not reflected in this research. This research presents freight operators and shipping operators' behaviour at this moment in time. Their behaviour will no doubt change as the market further develops.

5.12 Conclusion

The primary goal of this research was to determine if Dublin Port was meeting the current demands of customers with regard to intelligent transport systems. This chapter gave an overview of the methodology utilised in order to achieve this goal. It justifies the choices for taking a pragmatic philosophy approach and using in-depth interviews and questionnaires as primary research instruments. The research methodology is appropriate to achieve the objectives of the primary research.

Chapter Six: Analysis and Findings

6.0 Introduction

The primary data in the research was gathered through a survey conducted with freight operators operating in Dublin Port. The survey uses an online questionnaire constructed to detect which attributes of a port are crucial for its selection when choosing a container terminal. Semi structured interviews with key participants from Dublin Port Company and all three container terminals in Dublin Port were also carried out.

6.1 Pilot Testing

"It is important that all surveys are tested before the actual survey is conducted. This is done to ensure that the questionnaire is clear to respondents and can be completed in the way the researcher wishes" (Adams et al., 2007). Pilot testing is an activity that helps the study in determining whether there are errors, limitations, or other weaknesses within the design and allow for necessary adjustments and corrections before embarking on the survey. The first questionnaire was structured in Google forms. The respondents selected for the pilot survey were broadly representative of the type of respondent to be interviewed in the main survey. The respondents were unable to access the questionnaire unless they had a Google account. This questionnaire format was then discarded. The second questionnaire was structured using Survey Monkey where the respondents could access it without the need to be logged into a Gmail account as was the case with the Google forms.

6.2 Response Rate

From the data collected, out of 30 questionnaires administered, 17 were filled out and returned which represents a 56.66% response rate. Such a response rate is considered adequate according to Mugenda and Mugenda (2003) who mentioned that a 50% response rate is adequate, 60% good, while 70% was rated very good. This also collaborates with Bailey's (2000) assertion that a response rate of 50% is adequate, while a response rate greater than 70% is very good. This infers that the response rate in this case of 56.66 % was an adequate representation of the entire targeted population. After an interval of three weeks a reminder was sent out and one extra participant responded. Generally, there are many reasons that some respondents do not participate in the survey, such as a lack of interest in the topic under study, the respondents' company policies of non-participation in external surveys, and the respondents being too busy (Tivesten et al., 2012).

Table 22 Response Rate

	Frequency	Percentage
Questionnaire administered	30	100%
Questionnaire completed and returned	17	56.66%
No Response	13	43.34%

6.3 The Survey Questionnaire

The questionnaire is based on prior knowledge on port attractiveness. This prior knowledge suggested large number of different attributes of attractiveness. As defined by Fink (2003), surveys are a system for collecting data which is used for analysis. Survey design can be divided into experimental design and descriptive design (cross-sectional design). The cross-sectional is a simple survey that provides a cross section of the group's opinion and experimentals are characterized by the comparison between two or more groups, at least one of which is experimental (ibid). The research presented here is cross-sectional and examines the individual shipping operators and freight operators' opinion on container terminal operations. Fink (2003) states the following characteristics are important for good surveys; specific objective, straight forward questions, sound research design, reliable and valid survey instruments, appropriate management and analysis, accurate reporting of survey results and reasonable resources. The questionnaire can be found in Appendix VII. The questionnaire was kept as respondent-friendly as possible by ensuring it was reasonably short, easy to understand but at the same time professional in style. The questionnaire consists of four parts; labelled A to D. A was designed to obtain information about the respondents taking part in the survey. Part B consisted of questions on the background of the company. In part C the respondent rated the container terminals in terms of the attributes affecting port attractiveness. Part D was for any additional comments the respondent wished to make. The rating matrix question was in Likert Style and the respondents were asked to rate the questions in an interval e.g. from one to five, where one represents strongly agree to five strongly disagree or in the case of the grade question where one represents excellent. The Likert scale was developed by Rensis Likert in the 1930s to assess people's attitude towards various different questions. The research applies Likert scale in all rating questions. The questionnaire was distributed to freight operators in the lift-on/ lift-off section in the shipping industry. In order to send the survey to the right person, a telephone call was made to the companies involved. The "right person" to answer the survey was the person with the highest knowledge of strategy and operations in a container terminal. This was to ensure an accurate and honest answer by the respondents on the survey.

6.4 Result of Findings

An important factor is that the emphasis was on rating the importance of the elements rather than judging the performance. However, it was discovered that freight operators were found to be open to change with a strong emphasis on quality of service. Moreover, this research highlighted the emphasis on service quality; with particular regard to speed, flexibility, and reliability (see Figure 21).

Table 23: Question 1. What is your position/job title?

Position	Frequency	Percentage
Owner Manager	2	12.50%
General Manager	4	31.25%
Line Manager	5	31.25%
Other	4	25.00%
Total	**15**	**100%**

The findings from Table 23 indicate that 12.50% of the respondents hold the position of Owner Manager, 31.25% of the respondents hold the position of General Manager, and 31.25 % also hold the position of Line Manager while 25% holds other positions. The latter 25% are possibly shipping clerks but according to Figure 25 below all have over ten years in the shipping business indicating they are highly experienced. Two respondents declined to answer this question.

Table 24: Question 2. What shipping qualifications, if any, do you have?

Qualifications	Frequency	Percentage
None	5	35.29%
Diploma in shipping	3	17.65%
Advanced Diploma in shipping	4	23.53%
Degree in shipping	4	23.53%
Masters in shipping	0	0.00%
Total	**16**	**100%**

From the descriptive statistics shown in Table 24, 35.29% has no qualifications in shipping, 17.65% of the respondents were Diploma holders, and 23.53% were holders of Advanced Diplomas. 23.53% of the respondents were holders of a Degree in Shipping while none of the respondents held a Masters Degree. One respondent declined to answer this question.

Table 25: Question 3. How many years' experience do you have in Shipping?

Years	Frequency	Percentage
Over 10 years	13	86.67%
6 – 9 years	2	13.33%
3 – 5 years	0	0.00%
Less than 2 years	0	0.00%
Total	**15**	**100%**

Table 25 shows that 86.67% of the respondents have worked in their respective jobs for over 10 years while 13.33% of the respondents have worked between 6 – 9 years. None of the respondents worked between a period of 3 – 5 years and less than 2 years respectively. This shows the majority of respondents have worked as freight operators for over 10 years, indicating a highly experienced profile. Two respondents declined to answer this question.

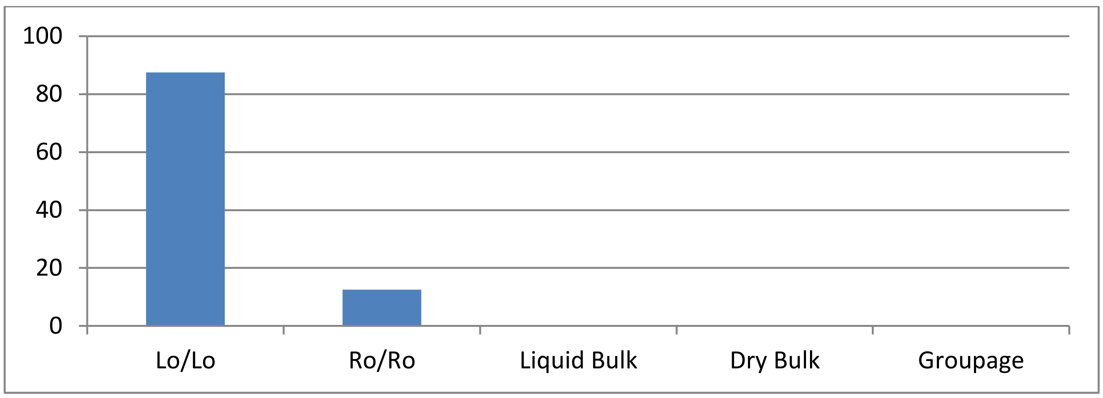
Table 26: Question 4. In what year was the company was established?

Year	Frequency	Percentage
1960 -1980	6	54.55%
1981 - 1987	1	9.09%
1986 - 1992	3	27.27%
93 to present	1	9.09%
Total	**11**	**100%**

The findings reveal that the majority of freight operators at 54.55% are in the shipping business for thirty six years or more which shows that these companies are well established in the maritime industry. This well established sector has seen continuous change. The industrial unrest of the 1970s and 1980s was a particularly hard time for these companies wher all too frequent strike disruptions were evident during this period. Then came the Celtic Tiger from the mid -1990s to the mid -2000s a period of rapid real economic growth fuelled by foreign direct investment. This was followed by the Irish economy entering a severe recession in 2008 and then an economic recession in 2009 from which it is still recovering. Business strategies play an important role in the daily operations of all companies. Strategy has been defined by various authors within the field of strategy.

However the definition that includes all aspects is derived from Johnson et al. (2008, p.7) who define strategy as “*the direction and scope of an organisation over the long term: which achieves advantage for the organisation through its configuration of resources within a changing environment, to meet the needs of markets and to fulfil stakeholder expectations*"

Figure 9: Question 5. What section of the shipping industry is your principal operation?



In the above Figure 9 the findings revealed that 87.50% of the respondents came from container terminal operations (Lo/Lo), while 12.50% were also involved in the Roll on / Roll off section. This implies that the majority of the respondents came from the container terminal operations section. This indicates that the correct respondents were targeted due to over 87% operating container services.

Figure 10: Question 6. Nature of activity/sector?

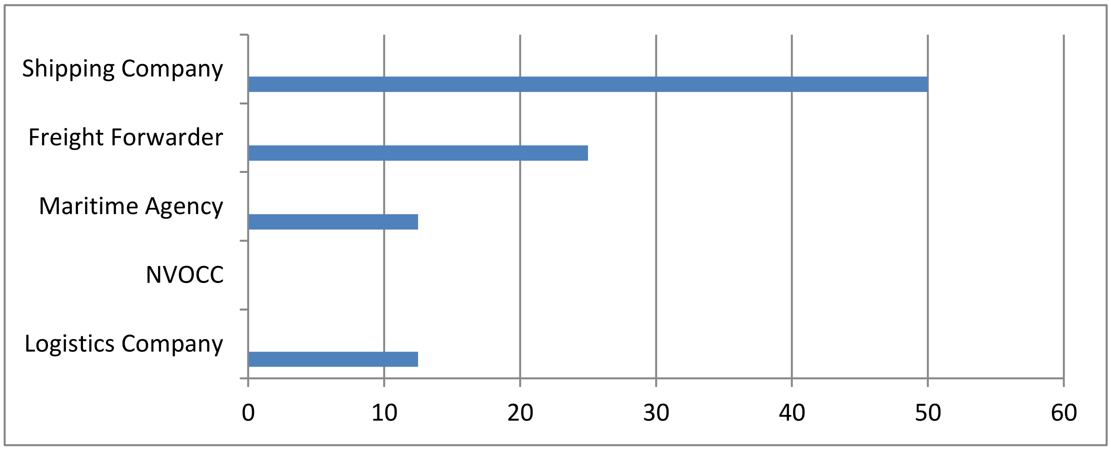


Figure 10 shows that 50% of the respondents came from Shipping Companies, 25% of the respondents are from Freight Forwarding Companies, 12.50% of the respondents work in Maritime Agencies. 0% is from NOVCCs' meaning non-vessel operating common carrier, while 12.50% work in a Logistics Company.

Figure 11: Question 7. Which port do you most frequently used?

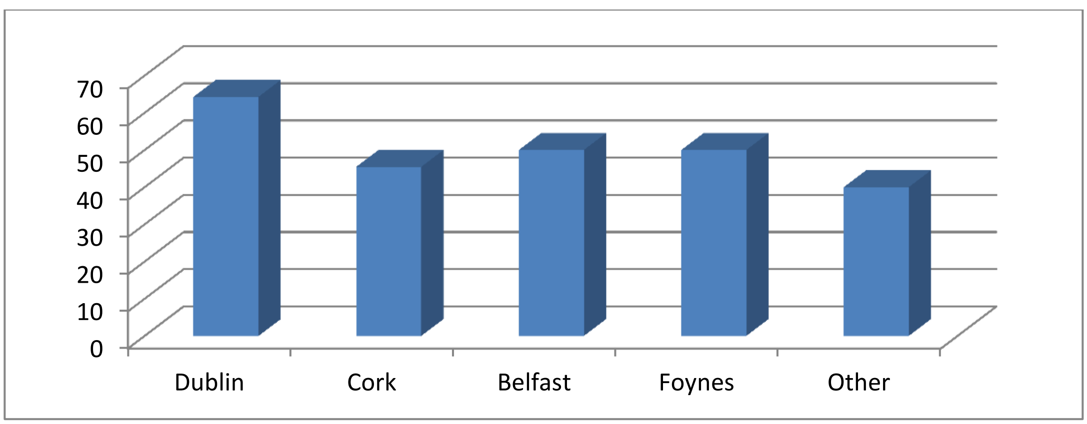
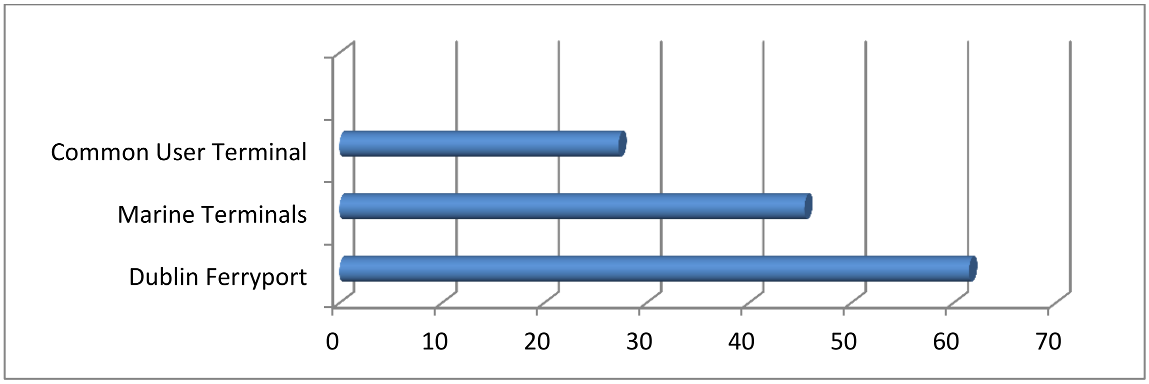


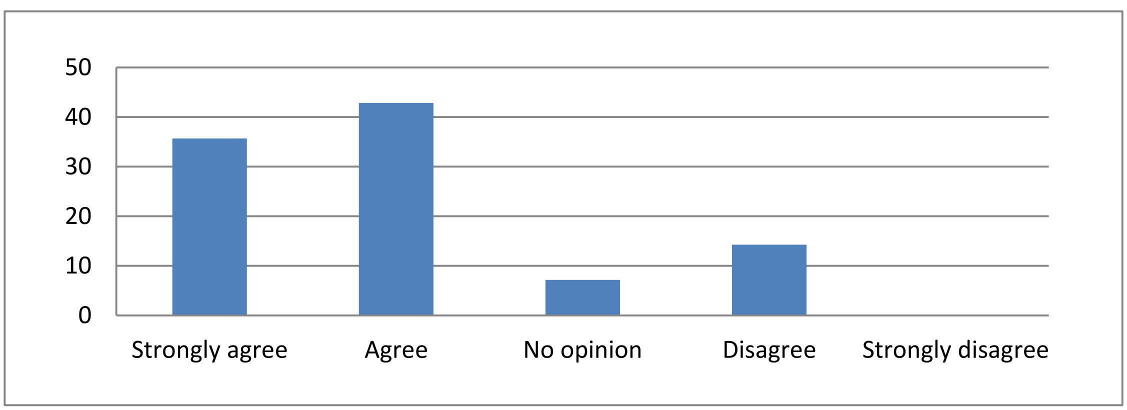
Figure 11 shows that Dublin is the most frequently used port for container operations with 64.29%, Cork is the second most used port with 45.45%, Belfast is third, Foynes, Shannon is the fourth most used with others coming in fifth.

Figure 12: Question 8. Which container terminal do you ship from in Dublin Port.



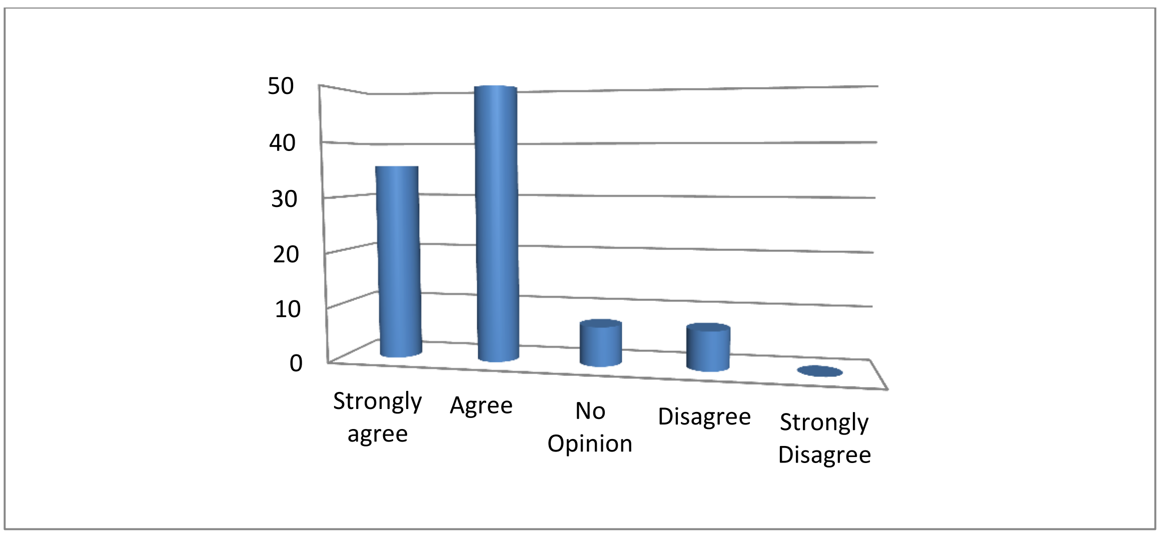
The above Figure 12 shows Dublin Ferryport Terminals as the most frequently used terminal with 61.54%, Common User Terminals is the second most used terminal with 44.44% with Marine Terminals coming third with 27.28%.

Figure 13: Question 9. Can the use of ITS increase efficiency and productivity considerably?



In Figure 13 the research sought to find out the extent of agreement or disagreement as to whether ITS, could increase efficiency and productivity considerably in container terminals. As the table indicates, 33.33% of the respondents strongly agreed, 46.67% of the respondents agreed, 6.67% had no opinion, 13.33% of the respondents disagreed while 0% of the respondents strongly disagree. The finding shows that ITS, could increase efficiency and productivity considerably in container terminals. This implies that freight operators require a seamless movement of goods through a port container terminal. This cannot be achieved in the absence of efficient terminal services.

Figure 14: Question 10. The customer will be the ultimate beneficiary of ITS in container terminals in Dublin Port?



In Figure 14 the research sought to ascertain if the customer would be the ultimate beneficiary of ITS in container terminals in Dublin Port. It reveals that 33.33% of the respondents strongly agreed, 53.33% agreed, 6.67% of the respondents had no opinion.

6.67% also disagreed, while those who strongly disagreed accounted for 0%. This implies that the customer would be the ultimate beneficiary. Similar to the previous question in Figure 12; this question highlighted the importance of customer satisfaction in the maritime industry. This is aligned with the current literature as discussed in Section 2.9.

Figure 15: Question 11. The prospect of ITS will result in greater efficiency for the customer?

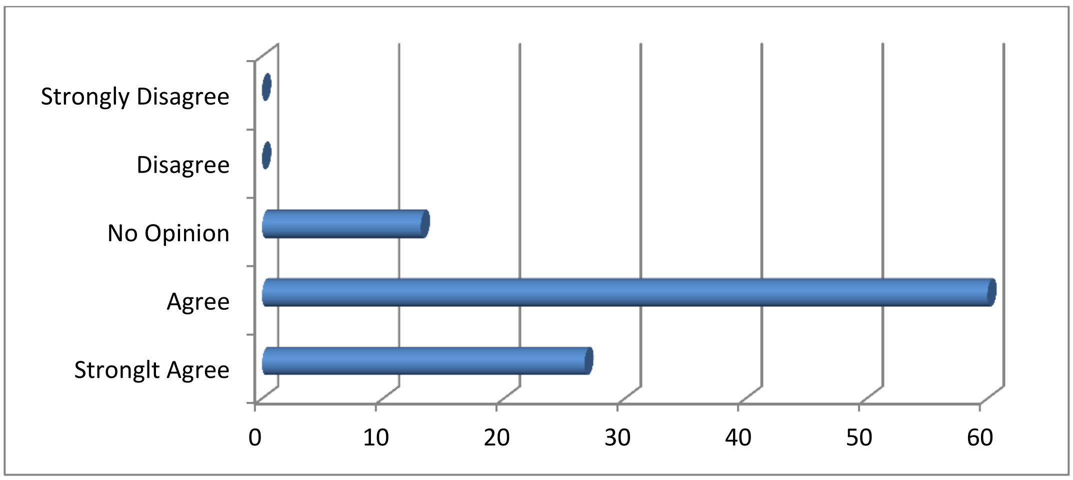
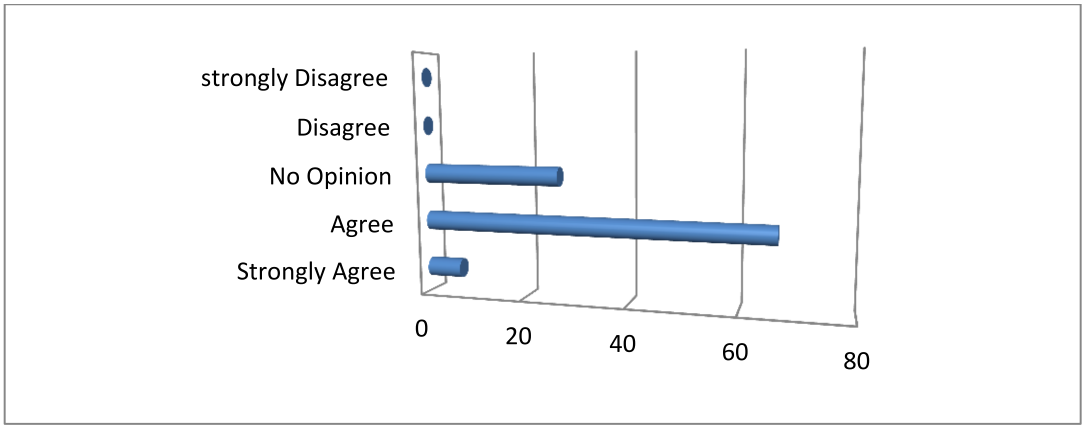


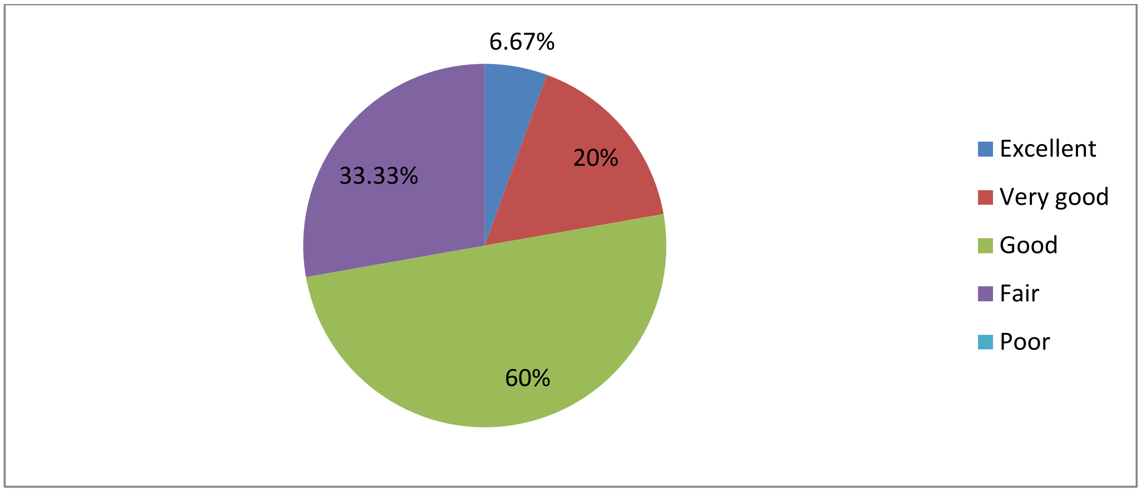
Figure 15 and Figure 16 dealt with the respondents' expectations with regard to ITS. Figure 15 sought to assess if ITS will result in greater efficiency for the customer. It divulged that 26.67% of the respondents strongly agreed, 60% agreed, 13.33% had no opinion, while 0% disagreed or strongly disagreed. This suggests that ITS, would result in greater efficiency for the customer.

Figure 16: Question 12. The prospect of ITS will result in greater productivity for the customer?



In Figure 16 the study sought to establish whether the prospect of ITS would result in greater productivity for the customer. While only 6.67% of the respondents strongly agreed, 66.67% agreed, 26.66% had no opinion and 0% disagreed or strongly disagreed. This shows that the respondents are fairly certain that ITS, could result in greater productivity for the customer. This emphasizes the freight operator's need for a coherent and smooth movement of their cargo. This cannot be achieved in the absence of quality services provided by a port container terminal.

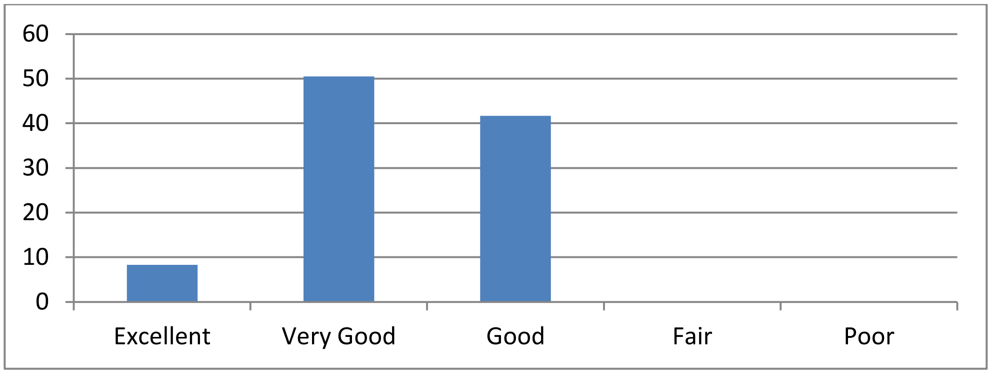
Figure 17: Question 13. How do you grade the current performance of container terminals in Dublin Port?



Note: Percentages do not total 100 due to multiple answer choices.

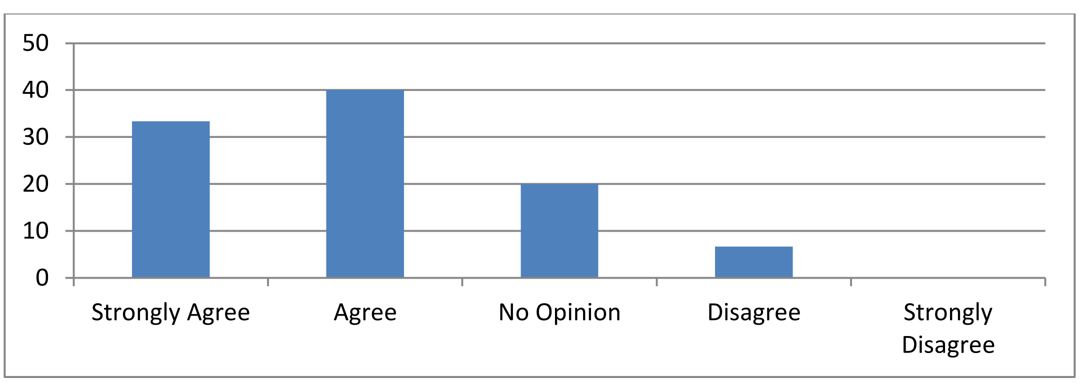
The next set of questions dealt with performance and efficiency in Dublin Port. In Figure 17 the research aimed to grade the current container terminal performance at Dublin Port. Out of the 17 respondents, 6.67% graded the current performance as excellent, 20% accounts for very good, 60% of the respondents graded the performance as good, and 33.33% of the respondents graded the performance as fair, while 0% of the respondent graded the performance as poor. This concludes that the current performance of container terminal in Dublin Port is good.

Figure 18: Question 14. How would you grade the operational effectiveness in container terminals in Dublin Port?



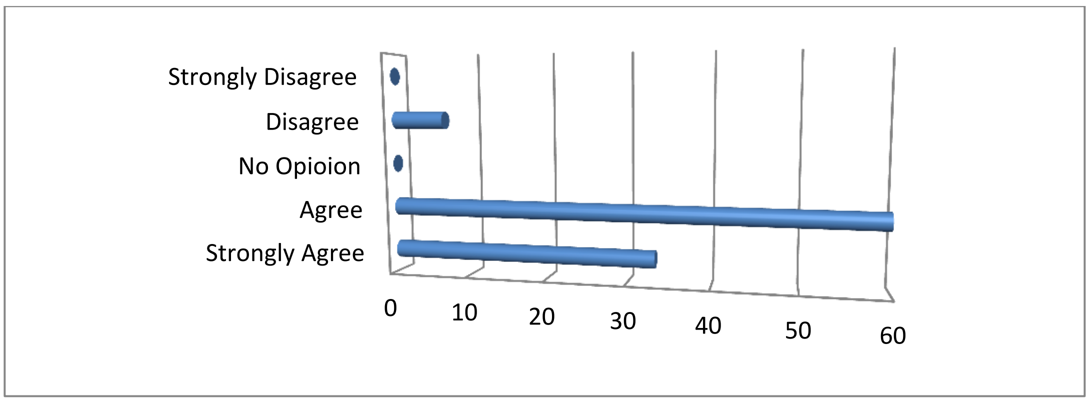
In the above Figure 18 the research sought to grade the operational effectiveness in container terminals in Dublin Port. The findings reveal that 8.33% of the respondents graded the operational effectiveness excellent, 50% of the respondents graded it very good, 41.67% of the respondents graded it as good, while no respondents graded it either fair or poor. This implies that the operational effectiveness in container terminals in Dublin Port is very good.

Figure 19: Question 15. The use of ITS would speed up operations in container terminals in Dublin Port?



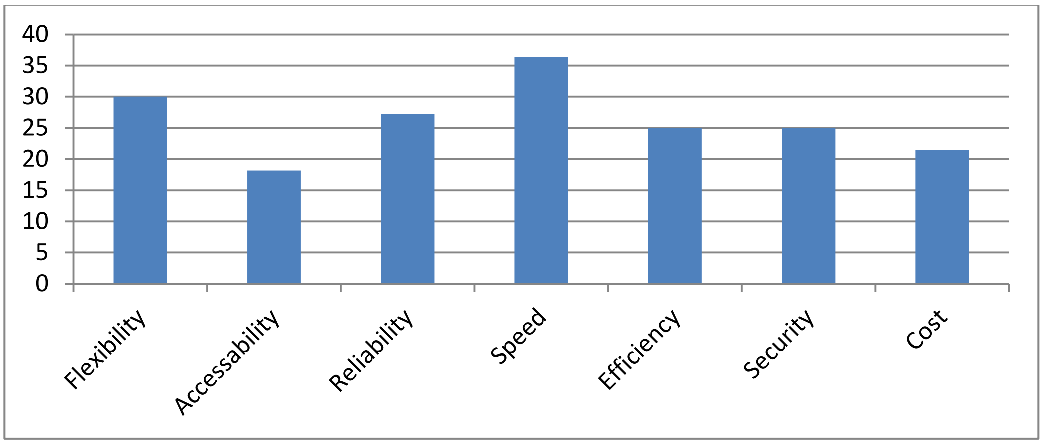
In Figure 19 the research sought to ascertain the opinion of respondents whether the use of ITS would speed up operations in Dublin Port. The findings show that 33.33% of the respondents said they strongly agree, 40% of the respondents said they agree, 20% had no opinion, 6.67% said they agreed, while 0% strongly disagreed. This infers that ITS, would speed up operations in Dublin Port. Today, port container terminals are investing in yard, gate and cargo handling equipment that is integrated with up to date IT technology (see Section 6.8) but according to the semi structured interviews, technology developments alone are not enough for sustainability in the maritime business. Ports are international gateways therefore need connectivity for competitive superiority.

Figure 20: Question 16. Customer satisfaction is an important element in a container terminal?



In Figure 20 the research sought to find out if customer satisfaction is an important element in a container terminal. The majority of respondents either strongly agreed or agreed with 33.33% and 60% respectively, while 6.67% agreed. 0% strongly disagreed. It can be assumed that customer satisfaction is definitely an important element in a container terminal. This issue is essential, both from the terminal operators' perspective which aim at higher traffic volumes and financial returns; and from freight operators' perspective who request quality services.

Figure 21: Question 17. Elements affecting container terminal choice?



Note: Percentages do not total 100 due to multiple answer choice

A 7-point scale was used to rank the elements affecting container terminal choice. The findings show that 36.35% of the respondents ranked speed as their first choice, 30% ranked flexibility as their second choice, 27.27% of the respondents ranked reliability as their third choice and 25% ranked efficiency as their fourth choice. Security was also ranked at 25%, cost was ranked sixth at 21.43%, while accessibility was ranked in last place at 18.18%. Therefore, the findings conclude that speed is the respondents' first choice. It is interesting that speed is ranked first and cost ranked sixth, because this implies that freight operators are willing to accept higher costs in return for more reliable and efficient services. This finding is opposite to De Langer (2007) findings, who conclude that freight operators are highly price sensitive.

Question 18 asked the participants what their views were on IAV's in container terminals. Eight of the respondents skipped this question. three stated 'none' while one wrote' no comment'. The remaining five respondents commented as follows:

i. *They cannot beat the human eye;*
ii. *IAV's have their benefits in large volume throughput environments, supported by high end computer systems with highly trained, skilled operators;*
iii. *They are used in all the main shipping port so they can only be an advantage;*
iv. *Complexity and reliability should be carefully weighed up against cost savings. There are always problems with plant in terminals and that is with minimum complexity and dedicated maintenance crew and;*
v. *Good idea.*

6.5 Key Informant Interviews

Terminal shipping operators are one of the main stakeholders, and they are pivotal players in port performance because they are the service provider to all port users. Therefore, terminal shipping operators were selected as the key informants. The aim of the terminal operator is to increase port productivity by achieving higher throughput with fewer berths and cargo handling equipment, while also serving and attracting more users (Imai et al., 2008, Beškovnik, 2008). The key informants were all from senior managerial levels. Senior managerial levels were targeted since these managers are familiar with container terminal problems and have good experience in the port industry. Therefore, they did not need a detailed explanation about the terminology used and the practical issues. In addition they are decision makers and have the authority to release any relevant important information. They are familiar with the major factors influencing port performance and the relationships between them. The main aim of targeting this group was to obtain their views and opinions.

Port performance is an important issue for all freight operators. The literature revealed that port performance could be measured by port productivity, efficiency and customer satisfaction. Recently, pressure has increased on transport operations due to logistics practices to minimise costs while enhancing service quality (Madeira et al., 2012). This can be achieved by improving port performance and enhancing efficiency (Clark et al., 2004). Container terminal operators face increasingly turbulent, fast-changing and uncertain situations. The port and shipping markets are no longer stable because the forces at work in the environment are rapidly changing. Technological advances, deregulation, logistics integration and associated new organisational structures, in particular, are constantly reshaping the port and maritime industries. Executive investment decisions recently undertaken by the key informants are examined in Section 6.9.

6.6 Discussion of Survey and Key Informant Interview Findings

The correct data collection method is crucial for the feasibility and accuracy of the survey and is influenced by the type of data required (Phillips and Stawarski, 2008). For this research, a '*Survey Monkey*' online questionnaire was used, as it was a rapid and appropriate method to capture the attitudes and opinions of experts in this field (Hair et al., 2000). The questionnaire consisted of nineteen structured questions. Each question discussed one issue. The questionnaire was reviewed and pilot tested by persons broadly representative of the type of respondent to be interviewed in the main survey before it was released on 6 September 2016. (Survey Monkey provides customizable surveys, as well as a suite of paid back-end programs that include data analysis, sample selection, bias elimination, and data representation tools).

Analysis of the data has revealed that port performance in container terminals in Dublin Port is considered good with 6.67% grading them as excellent, 20% accounted for very good while 60% graded the performance as good. In spite of this grade the respondents thought the terminals could improve by utilising ITS (see Figure 12). The respondents also thought that ITS would enhance the speed of operations with 33.33% strongly agreeing and 40% agreeing (see Figure 18) Port performance is assessed by the extent to which it meets the expectations of customers and/or by its productivity or efficiency (Haezendonck et al., 2011, Wu and Goh, 2010). These aspects of port performance include, but are not limited to accessibility, reliability, flexibility, speed, security, efficiency and cost. The main objectives of the research were to examine the use of ITS in container terminals in Dublin Port, discuss customer satisfaction and determine if container terminal operators are utilising ITS.

Customer satisfaction was an important factor with the majority of the respondents, 33.33% of them strongly agreeing and 60% agreeing (see Figure 20). The research confirms that customer satisfaction is a determining element influencing container terminal operations, by allowing a quick response to change in supply chain needs in an ever-changing market thus satisfying customer satisfaction (see Section 2.10).

In the competitive environment, such as between container terminals, where options for physical expansion are limited and cargo shipments and ship sizes are increasing, ports are under huge pressure to increase their productivity, performance and operational efficiency (Bichou, 2009).

As discussed in Section 6.8 all container terminals in Dublin Port have installed and are continuing to install new projects to enhance productivity and efficiency. The Irish economy has experienced a significant negative adjustment since 2007. The downturn and uncertainty saw a reduction in container freight throughput, profitability levels and ability to fund necessary development. This has led to very little investment by the container terminals in Dublin Port but times have changed with all three terminals investing in different projects.

Key informant (A) Dublin Port Company has disclosed that in 2015, world container traffic growth was lower than historical average due to an overall slowdown in the global economy. In spite of this, volumes through Dublin Port have increased for the third year running. Against the backdrop of three years of strong volume growth such that throughput is now 6.2% higher than at the previous peak in 2007, and consistent with the commitments set out in the Masterplan 2012-2040, the Company has commenced implementation of the first major project envisaged within the Masterplan – The Alexandra Basin Redevelopment (ABR) Project. The estimated cost to deliver this project over the next 5 years is in the region of €227m. The Port is pleased to report that it has been successful in securing

European Union funding and European Investment Bank support for the project. The European Union commission has approved grant aid totalling €22.8m in respect of the project under the Connecting Europe Facility. In December 2015 the Port signed a Finance Contract with the European Investment Bank in respect of a €100m project finance facility. This twenty year facility provides long term finance matching the long term nature of the infrastructural investment. It also provides certainty of funding on competitive terms and allows Dublin Port to finance the project conservatively, consistent with their strategic objectives. Dublin Port consider that implementation of this project will result in the most significant redevelopment of the Port's infrastructure in decades, providing additional cargo handling capacity and future proofing the Port in terms of being able to facilitate larger sized vessels into the future in terms of both length and draft. The ABR project is the first major project to be brought forward under the Company's Masterplan 2012-2040 and will make a significant contribution to the overall objective of the Masterplan to cater for a doubling of throughput to 60.0m tonnes by 2040 as discussed in Section 3.5.

Key Informant (B) one of the container terminals in Dublin Port has invested in *Navis N4,* a terminal operating system that has abilities to coordinate and optimise the planning and management of container and equipment moves in a terminal's complex business environment, from a single terminal to multiple terminals across multiple geographic locations, all within a single instance. Navis N4 is the only terminal operating system that claims to:

i. Increase Scalability – easily support future growth while reducing operational overheads;

ii. Seamless Integration – integrate, deploy and administer across multiple sites;

iii. Simplify and Accelerate Implementation – Focus on creating a more unified and integrated IT strategy and growth concept;

iv. Avoid Expensive Customization – create a highly configurable solution;

v. Reduce Administration and Support Costs – centralise back office administration and;

vi. Streamline Terminal Operations – keep up with technology advances (Navis N4, 2016)

Navis 4 is an example of the move towards the increase in automation of container terminals to enhance terminal efficiency and support future growth while maintaining customer focused services.

Key informant (C) another terminal in Dublin Port will be investing €6 million in installing automated stacking cranes. These cranes can deliver fast, accurate container stacking over a range of real world conditions (ARMG, 2016). This investment started on 1/9/2016 and it is expected it will be completed by 31/9/2017.

Automated stacking cranes are another example of advancing technologies in container terminals by enabling the highest possible capacity and stacking density. The ASC terminal optimises throughput and stack footprint.

Key informant (D) the third terminal in Dublin Port invested in a new terminal operating system (TOS) last year (2015) entitled *Tidleworks*. This new system claims to take efficiency in container terminals to an entirely new level. It employs the latest technology to help terminal operators manage and access data faster and more readily than ever before. The terminal has a five year plan that will see waste ground turned into an automated rail mounted gantry (ARMG) terminal. They also plan to automate their gate system. The new gate system will help support terminal efficiency and modernize the container collection and delivery process. The system will improve transactions for hauliers at the terminal entrance. It replaces the former gate-in gate-out procedure and will be the culmination of their five year plan objective.

Chapter Seven: Conclusion, Future Research, Summary and Recommendations

7.0 Introduction

This chapter draws conclusions based on the findings of the research. The conclusions are presented according to the research objectives and highlights possible further directions for research. The chapter ends with a summary and recommendations.

7.1 Conclusions

This section presents the conclusions of each of the research objectives.

7.1.1 Objective One

Identify the current intelligent transport systems offered by container terminal operators in Dublin Port and investigate the possibility of introducing new ITS.

With advances in technology and reliability of equipment, increased automation needs to be applied to container terminal operations. The technological developments in fast ship design, apparent at the start of the twenty-first century, have continued apace with the construction of the ultra-mega container vessels, providing increased frequency and speed of service. These large vessels require new configurations of port facilities to handle their specialist loading/unloading requirements and provision for manoeuvrability of these large vessels (see Chapter 1). For the container operations, advanced technology in ITS is required. The main commercial ports now have efficient motorway connections to the upgraded road network and, where appropriate, upgraded rail connections have been provided for specific trades (see Section 2.2.5). Due to lack of investment in container terminals in Dublin Port no new developments in ITS, has been carried out in recent years but, as the research has revealed, that is about to change with all three container terminals in Dublin Port presently investing in ITS.

7.1.2 Objective Two

Explore the factors that influence the customer satisfaction of freight operators provided by container terminal operators in Dublin Port and analyse their views.

Previous studies as discussed in Section 2.10 have revealed that container terminal efficiency is influenced by many factors which include, but are not limited to, accessibility, reliability, flexibility, speed, security, efficiency and cost. The research highlighted these factors and discusses the extent to which they influence container terminal efficiency within container terminal operations. The research showed that speed was the first choice with the freight operators, flexibility was second, reliability third, efficiency fourth, while security was fifth, with cost and accessibility coming in sixth and seventh respectively. However, the findings reveal that container terminal efficiency is mainly measured by the level of speed (see Figure 21). The findings also revealed the use of ITS can increase efficiency and productivity considerably (see Figure 15 and Figure 16). Additionally, the findings indicated the customer will be the ultimate beneficiary of ITS in container terminals in Dublin Port (see Figure 14). Moreover, the findings indicate the prospect of ITS could result in greater speed for the customer (see Figure 19). Furthermore, the results indicate that the prospect of ITS could result in greater effectiveness for the customer (see Figure 18). The key to efficiency and profitability for terminal operators will be the ability to analyse customers' needs and then respond quickly with differentiated and advanced ITS solutions.

7.1.3 Objective Three

Determine if container terminal operators are currently meeting the intelligent transport systems demands of consumers and explore their plans for the introduction of ITS in the future.

The size of a container terminal plays a crucial role in the level of ITS implementation. The small to medium size terminals are more likely to have constraints in financial, human resources and ITS expertise leading to their not being able to afford appropriate solutions in contrast to the larger terminals. This could lead to a loss in confidence and reduce the overall use of ITS. Furthermore, the economic and financial factors such as large investment requirements, the cost of implementation as well as management and maintenance costs can be another constraint. The research shows the delay in implementing ITS in container terminals in Dublin Port was due to the downturn in 2007 and its effects on container terminals (see Section 5.10). However, the research also shows that all three container terminals in Dublin Port are now engaging in the latest developments in technology. This is a definite step in the right direction. Furthermore, the research reveals that the application of new ITS will connect the container terminal environment to the real world which will help to assist in better efficiency and productivity.

7.2 Further Research

Further research in order to improve the efficiency of container terminals in Dublin Port system needs to examine possibilities to enhance competitiveness and explore ways to support transport growth and efficiency. In order to expand the research of ITS implementation in maritime and other modes of transport, it is necessary to explore the new possibilities of simulation models in the study of intelligent transport systems. In order to improve the operation of the container terminals in Dublin Port, ITS implementation is an important segment and needs to be further examined.

Furthermore, further research can follow a similar approach and examine new ITS for other regions or other transportation segments and compare it to the situation discovered in this research.

Finally, a new challenge is posed by advanced security issues. These will entail more versatile planning tools for optimization. Usage of techniques such as, e.g., transponders and certain security procedures and their impact on the logistic chain have to be taken into account.

7.3 Summary and Recommendations

Governments and legislators all over the world view port container terminals as vital infrastructure assets, as they play a critical role in economic growth by attracting and generating trade. A port that does not have the ability to cope with rapidly advancing technologies will not be in a position to foster the development of the trade sector. The future is bringing increased demands for greater efficiency and for more sustainable designs in cargo handling technologies. Moreover, the scarcity of land is forcing port operators to realise higher area utilizations. With the arrival of the next generation ultra-large Triple-E vessels carrying 18,000 + TEU, it is important to investigate the opportunities to introduce innovation in the development of terminal operations and the logistics chain. The crucial terminal management problem is how to balance the integration of the current technology with new technology such as the IAV (see Section 3.6). Traffic management and space optimization is a problem with the future development of container terminals. The problem can be solved by having a remote 'traffic control centre' directing vehicles to marshalling areas where the containers are handled by ITS. The challenge is to find innovative solutions to balance service requirements while integrating automated and non-automated cargo handling equipment in container terminals to ensure sustainability, safety and security.

Port terminal automation is no different from any other form of technological disruption, which almost inevitably leads to displacement of some segments of the workforce. However, in the long run, technology ends up creating better jobs and expanded opportunities across broad spectrums of the economy for e.g. Port of Rotterdam. Managing the transition is hard, often requiring social safety nets from government, as well as concessions from those who stand to benefit from the new technology. The advent of automated handling of containers is expected to result in reduced labour requirements. This problem could be addressed by educating the users of the new system about its benefits by including the users in the planning stages. The automatic elimination of jobs with the implementation of ITS should not be necessary. There is much work the cargo handling equipment personnel can be retrained to perform. By doing this, container terminals will actually be saving money by not having to hire additional personnel.

Shipping technology advancements have shown themselves time and again to be capable of creating a more prosperous world. Difficult as the transition toward port automation may be, one cannot afford to shy away from the challenge.

This research aimed to determine the components of assessing new ITS in container terminals in Dublin Port. It contributes to knowledge by presenting the first study of container terminals in this region. The attributes of port competitiveness identified include flexibility, accessibility, reliability, speed, efficiency, security and cost. This evaluation structure could be used to rank container ports elsewhere and could be beneficial to practitioners as it advances and updates knowledge of the use of new ITS. It could also provide guidance and inspiration for the management and use of existing and emerging ITS.

It is expected that in the near future ITS will have a major impact on how container terminals are operated. ITS systems such as the IAV are not yet integrated enough to meet

European-level (Vienna Convention on Road Traffic, 1968) requirements; and well-structured, well organised inter-modal transport chains do not exist. New technological developments will need to cover these gaps and inefficiencies in today's container terminals operations. The integration of new ITS within the overall European ITS will be the challenging area of research and policy formulation activity for ‘‘intelligent’’ freight transport in Europe.

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Appendices

Appendix I

Quay Crane

Appendix II

Shunter (terminal tractor)

Appendix III

Straddle Carrier

Appendix IV

Reachstacker

Appendix V

Automated Guided Vehicle

Appendix VI

Dear Colleague,

I am a lecturer in Maritime Operations in the Dublin Institute of Technology, Bolton St. I am currently completing an MPhil in Intelligent Transport Systems (ITS) in Dublin Port. I will be looking at how new ITS could possibly improve container operations in the Port.

I would be very grateful if you would complete the survey, which can be accessed by clicking the following link:

https://www..com/r/R2Z78JR

The survey should take in the region of five minutes to complete. Please respond before the 30th of September and bear in mind that the information collected in this survey will be treated in the strictest confidence, and will only be used to produce statistical tables, it will not be possible to identify the responses of any individual from the results produced.

I would very much appreciate your cooperation with this survey. If you have any queries, or require any further information, please do not hesitate to contact me at the following e-mail address: kay.mcginley@dit.ie

Kind Regards,
Kay McGinley

Appendix VII

Questionnaire

Section A. Demographic Information

1. What is your position/job title?

- Owner - Manager
- General Manager
- Line Manager
- Other (please specify)

2. What shipping qualifications, if any, do you have?

- None
- Diploma in shipping related area
- Advanced diploma in shipping
- Degree in shipping related area
- Masters in shipping related area

3. How many years' experience do you have in shipping?

Section B. Background

4. In what year was the company established?

5. What section of the shipping industry is your principal operation?

- Lo/Lo
- Ro/Ro
- Liquid Bulk
- Dry Bulk
- Groupage

6. Nature of activity/sector?

- Shipping Company

- Freight Forwarder
- Maritime Agency
- NVOCC
- Logistic Company

7. Which port do you ship from?

(Which port most frequently used. Please rank 1 (Least Frequent) - 5 (Most Frequent)

Dublin

Cork

Belfast

Foynes, Shannon

Other

8. Which container terminal do you ship from in Dublin Port?

(Please rate from 1 (frequently) to 3 (seldom)

Dublin Ferryport Terminals

Marine Terminals

Common User Container Terminals

Section C. Container Terminal Efficiency.

The purpose of this section is to address the impact of intelligent transport systems in port container terminals.

Please indicate the extent to which you agree or disagree with each of the following statements.

Please respond to each statement.

9. The use of intelligent transport systems increases efficiency and productivity considerably.

- Strongly Agree
- Agree
- No Opinion
- Disagree
- Strongly Disagree

10. The customer will be the ultimate beneficiary of Intelligent Transport Systems in container terminals in Dublin Port.

(please choose one option)

- Strongly Agree
- Agree
- No Opinion
- Disagree
- Strongly Disagree

11. The prospect of Intelligent Transport Systems will result in greater efficiency for the customer.

(please choose one option)

- Strongly Agree
- Agree
- No Opinion
- Disagree
- Strongly Disagree

12. The prospect of Intelligent Transport Systems will result in greater productivity for the customer.

- Strongly Agree
- Agree
- No Opinion
- Disagree
- Strongly Disagree

13. How do you grade the current performance of container terminals in Dublin Port

- Excellent
- Very good
- Good
- Fair
- Poor

14. How do you grade the operational effectiveness in container terminals in Dublin Port

- Excellent
- Very Good
- Good
- Fair
- Poor

15. The use of ITS would speed up operations in container terminals in Dublin Port

- Strongly Agree
- Agree

- No Opinion
- Disagree
- Strongly Disagree

16. Customer satisfaction is an important element in a container terminal

- Strongly Agree
- Agree
- No Opinion
- Disagree
- Strongly Disagree

17. Elements affecting container terminal choice

Please rank from 1 (not relevant) to 7 (very relevant)

Accessibility

Reliability

Flexibility

Speed

Security

Efficiency

Cost

18. What are your views on Intelligent Autonomous Vehicles (IAV's) in container terminals?

Section D: Additional Comments

If you would like to make any additional comments about this questionnaire please write them in this section.
If you are referring to a particular question, please write the question number beside your comment.

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19. If you would like to make any additional comments about this questionnaire please write them in this section. If you are referring to a particular question, please write the question number beside your comment.

Appendix VIII

Layout of DFT

Appendix IX

Publications

McGinley, Kay, Shahin Gelareh, Rochdi Merzouki, and Roisin Murray, 'Scheduling of Intelligent and Autonomous Vehicles under Pairing/Unpairing Collaboration Strategy in Container Terminals', Transportation Research Part C: Emerging Technologies, Volume 33, August 2012, Pages 1-21.

Abstract: A new class of Intelligent and Autonomous Vehicles (IAVs) has been designed in the framework of Intelligent Transportation for Dynamic Environment (InTraDE) project funded by European Union. This type of vehicles is technologically superior to the existing Automated Guided Vehicles (AGVs), in many respects. They offer more flexibility and intelligence in manoeuvring within confined spaces where the logistic operations take place. This includes the ability of pairing/unpairing enabling a pair of 1-TEU (20-foot Equivalent Unit) IAVs dynamically to join, transport containers of any size between 1-TEU and 1-FFE (40-foot Equivalent) and disjoin again. Deploying IAVs helps port operators to remain *efficient* in coping with the ever increasing volume of container traffic at ports and eliminate the need for deploying more 40-ft transporters in the very confined area of ports. In order to accommodate this new feature of IAVs, we review and extend one of the existing mixed integer programming models of AGV scheduling in order to minimize the make span of operations for transporting a set of containers of different sizes between quay cranes and yard cranes. In particular, we study the case of Dublin Ferryport Terminal. In order to deal with the complexity of the scheduling model, we develop a Lagrangian

relaxation-based decomposition approach equipped with a variable fixing procedure and a primal heuristics to obtain high-quality solution of instances of the problem.

The completed article can be accessed at the following link;

http://www.sciencedirect.com/science/journal/0968090X/33

McGinley, Kay, Shayan Kavakeba, Trung Thank Nguyena, Zaili Yanga, Ian Jenkinson and Roisin Murray 'Green vehicle technology to enhance the performance of a European port: a simulation model: with a cost benefit approach' Transportation Research Part C: Emerging Technologies, Volume 60, November 2015, Pages 169-188.

Abstract: In this paper, we study the impact of using a new intelligent vehicle technology on the performance and total cost of a European port, in comparison with existing vehicle systems like trucks. Intelligent autonomous vehicles (IAVs) are a new type of automated guided vehicles (AGVs) with better manoeuvrability and a special ability to pick up/drop off containers by themselves. To identify the most economical fleet size for each type of vehicle to satisfy the port's performance target, and also to compare their impact on the performance/cost of container terminals, we developed a discrete event simulation model to simulate all port activities in micro-level (low-level) details. We also developed a cost model to investigate the present values of using two types of vehicle, given the identified fleet size. Results of using the different types of vehicles are then compared based on the given performance measures such as the quay crane net moves per hour and average total

discharging/loading time at berth. Besides successfully identifying the optimal fleet size for each type of vehicle, simulation results reveal two findings: first, even when not utilising their ability to pick up/drop off containers, the IAVs still have similar efficacy to regular trucks thanks to their better manoeuvrability. Second, enabling IAVs ability to pick up/drop off containers significantly improves the port performance. Given the best configuration and fleet size as identified by the simulation, we use the developed cost model to estimate the total cost needed for each type of vehicle to meet the performance target. Finally, we study the performance of the case study port with advanced real-time vehicle dispatching/scheduling and container placement strategies. This study reveals that the case study port can greatly benefit from upgrading its current vehicle dispatching/scheduling strategy to a more advanced one.

The completed article can be accessed at the following link;

http://www.sciencedirect.com/science/journal/0968090X/60

Appendix X

Different Types of Containers

Most cargos are carried in standard sized containers but different types of cargo will require different types of containers.

Standard Container

High Cube Container

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Ventilated Container

Flat Rack

Curtain Sided Container

Open –Top Container

Bulk Container

Refrigerated

Tank Container

Appendix XI

Key informant Interview Letter

Dear Colleague,

I am a lecturer in Maritime Operations in the Dublin Institute of Technology, Bolton St. I am currently completing an MPhil in Intelligent Transport Systems (ITS) in Dublin Port. I will be looking at how ITS could possibly improve container operations in the Port.

I would be very grateful if you would spare me some time in the coming weeks to conduct an interview with regard to your views on ITS in container terminals. The object of the interview is to gather your input on ITS in your terminal, benefit realisation, any issues encountered with ITS, and any potential improvements or interventions that could be made to improve the actual realisation of ITS benefits in practice.

As part of the interview a set of questions have been set out, see attached. Please bear in mind that the information collected in this interview will be treated in the strictest confidence and will only be used for the purpose of this research and will be completely confidential (neither you nor your company will be identified in the report or in discussions with other individuals). With your permission, I would like to record the interview to ensure accuracy and reliability.

I would very much appreciate your cooperation with this interview. If you have any queries, or require any further information, please do not hesitate to contact me at the following e-mail address: kay.mcginley@dit.ie

Kind Regards,
Kay McGinley

Key Informant Interview Questions

Experience with ITS

- Firstly, for how long have you worked with or been involved with Intelligent Transport Systems (ITS)?
- Could you outline your experience of (ITS), in terms of particular systems and ITS systems used or the companies in which ITS are used?
- If unsure of specific systems, I can follow up by email with you at a later time.

Key Benefits Expected and Realised

- From your perspective, what were the primary expected benefits of adopting ITS?
- Have the benefits been realised in practice to the extent originally expected?

Shortcomings/Issues

- Have you experienced any significant shortcomings associated with ITS in practice? If so, can you elaborate

Potential Improvements

- What interventions or improvements would you recommend to help further realise the benefits or alleviate any problems?

Customer Expectations

- What are your top (5) priorities for customers? How do you plan to meet them?
- Does your company set objectives? How do you plan to meet them?

Appendix XII

Conferences

i. The 13th International Conference on Harbor, Maritime and Multimodal logistics Modelling and Simulation (HMS), September 12-14, 2011, Rome, Italy.

ii. International Forum on Shipping, Ports and Airports (IFSPA), May 27-30, 2012, Hong Kong. China.

iii. Irish Transport Network Research (ITRN), August 29-30, Belfast, Northern Ireland.