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An Investigation to Evaluate the Feasibility of an Intermodal Freight Transport System.

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An investigation to evaluate the feasibility of an intermodal freight transport system.

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A thesis submitted in fulfilment of the requirements for the

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Abstract

The threat of greenhouse gases and the resulting climate change have been causing concern at international levels. This has led towards new sustainable policies towards reducing the anthropogenic effects on the environment and the population through promoting sustainable solutions for the freight industry.

The research was prompted by the growing concerns that were no mode-choice tool to select as an alternative to road freight transport. There were growing concerns that a large percentage of transport related negativities, related various costs and pollution costs, losses arising from traffic accidents, delay costs from congestion and abatement costs due to climate impacts of transport, etc., were not being borne by the user. Economists have defined them as external costs. Internalising these external costs has been regarded as an efficient way to share the transport related costs.

The aim of this research was to construct a freight mode choice model, based on total transport costs, as a mode choice substitution tool. This model would allow the feasibility of choosing alternative intermodal system to a primarily 'road system'. The thesis postulates a novel model in computing total freight transport costs incurred during the total transit of goods along three North European transport corridors. The model evaluated the total costs summing the internal, external and time costs for varied mode choices from unimodal and the second level of intermodal transport systems.

The research outcomes have shown the influences of total costs on the shipper and the preferred mode choices from the available mode/route options with sustainable transport solutions. The impacts of such alternatives were evaluated in this research. This will allow the embedding of intermodal infrastructures as sustainable and alternative mode choices for the freight industry.

Declaration

I certify that this thesis, which I now submit for examination for the award of Doctor of Philosophy (PhD), 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 Institute's 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: 25th July 2016

Candidate: RAJA MAITRA

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I dedicate this to my Father and my late Mother.

List of abbreviations and symbols

- CBA — Cost-benefit analysis
- CES — Constant Elasticity of Substitution
- CNG — Compressed Natural Gas (can be used as transport fuel)
- CO_2 — Carbon dioxide
- CO_2e — Carbon dioxide equivalent. A measure of the environmental impact of a GHG in terms of the impact of one tonne of CO_2 over one hundred years. When the total impact of a range of GHGs is presented in terms of 'CO_2 equivalent' or CO_2e.
- ConRo — A vessel with combined of RoRo and LoLo Freight
- CT — Combined (freight) transport
- DG TREN — European Commission's Directorate-General on Transport & Energy. This DG was split in 2009 into DG Mobility & Transport (DG MOVE) and DG Energy.
- DWT — Deadweight
- EC — European Commission
- ECA — Emission Control Area (special zones SECA, NECA, etc.)
- ECMT — European Conference of Ministers of Transport
- EEA — European Environment Agency
- EMMOSS — Emission Model for inland shipping, Maritime transport and rail
- EPA — Environmental Protection Agency (USA)
- ETIS — European Transport Policy Information System
- ETS — Emission Trading System, Emission trading scheme

- EU European Union was established on 1 November 1993 with 12 Member States. Their number has grown to the present 28 through a series of enlargements:

  EU-12 (*1 November 1993- 31 December 1994*): Belgium (BE), Denmark (DK), France (FR), Germany (DE), Greece (EL), Ireland (IE), Italy (IT), Luxembourg (LU), Netherlands (NL), Portugal (PT), Spain (ES) and United Kingdom (UK)

  EU-15 (*1 January 1995- 30 April 2004*): EU-12 + Austria (AT), Finland (FI) and Sweden (SE)

  EU-25 (*1 May 2004 - 31 December 2006*): EU-15 + Cyprus (CY), Czech Republic (CZ), Estonia (EE), Hungary (HU), Latvia (LV), Lithuania (LT), Malta (MT), Poland (PL), Slovakia (SK) and Slovenia (SI)

  EU-27 (*1 January 2007 - 30 June 2013*): EU-25 + Bulgaria (BG) and Romania (RO)

  EU-28 (*from 1 July 2013*): EU-27 + Croatia (HR)
- EU-ETS European Emission Trading System
- EURO Euro (€)
- FEU Forty-foot Equivalent Unit container
- GDP Gross Domestic Product
- GHGs Greenhouse gases: Pollutant emissions from transport and other sources, which contribute to the greenhouse gas effect and climate change. GHG emissions from transport are largely CO_2.
- HGV Heavy Goods Vehicle (>3.5-ton gross vehicle weight)
- HFO Heavy Fuel Oil, a form of diesel fuel
- IEA International Energy Agency
- IEA (Ireland) Irish Export **Association**
- IMO International Maritime Organisation

- IMPACT ‘Internalisation Measures and Policies for All external Cost of Transport’, European Commission study (2007-2008)
- IMT Inter-Modal transport
- IPCC Intergovernmental Panel on Climate Change
- IRRT Intermodal Road-Rail Transport
- ITCM Intermodal Transport Cost Model – Research Model.
- IWW Inland Waterway
- Lden Perceived noise level weighted over day, evening, night
- LoLo Lift on, Lift off ships (container ships)
- LPG Liquefied Petroleum Gas
- MARPOL International Convention for the Prevention of Pollution from Ships
- MDO Marine Diesel Oil, a form of diesel fuel
- MT Metric Ton
- Mt, Mt CO_2 Mega-tons, million tons of CO_2 emissions
- NECA NO_x Emission Control Area
- NMVOC Non-methane volatile organic compounds
- NO_x Nitrogen Oxides
- NVOCC Non Vessel Owning Common Carrier operations include sales, stuffing and transport of containers to gateway ports.
- O/D Origin Destination
- OECD Organisation for Economic Co-operation and Development
- OR Operational Research
- PM Particulate matter: (PM_{10} particulate matter with diameter below 10 µm; $PM_{2.5}$ particulate matter with a diameter below 2.5 µm)
- PPH Pre-Post Haulage in intermodal system

- Reefer Points Electrical sources for cooling or freezing reefer containers
- RMG Rail Mounted Gantry for stacking/loading containers
- RoPax RoRo Vessel for passengers and cargo in trailers
- Ro-Ro Roll-on Roll off ships; primarily for unaccompanied freight
- RTG Rubber Tyre Gantry for stacking/loading containers
- RTR Road Transport and Intermodal Linkages (Rail)
- SB Swap body
- SECA SO_x Emission Control Area
- SO_x Sulphur Oxides
- SSS Short Sea Shipping
- ST Semi-trailer
- TEN-T Transport projects in the Trans European Transport Network
- TEU Twenty-foot Equivalent Unit container
- Tkm/tonnekm Tonne-kilometre
- TOC Terminal Operating Company
- Tonne-kilometre, tkm 1 tonne transported over 1 km distance = 1 tkm
- TRANSTOOLS, TOOLS for TRansport Forecasting ANd Scenario testing, TTv1, iTREN- 2030 model
- TREMOVE Vehicle fleet and emission model, iTREN-2030 model
- UIRR International Union of Combined Road-Rail Transport Companies
- Veh-km, vkm Vehicle-kilometre, 1 vehicle transit over 1 km = 1 vkm
- VOT Value of Time
- VSA Vessel Sharing Arrangement

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Chapter 1

An overview of the research project

1.1 Introduction

The threat of climate change, resulting from increased industrial activity and the anthropogenic pollutions, both environmental and socio-economic, is clear with widespread impacts on human and natural systems. National, supranational and international bodies have recognised the magnitude of the climate change challenge and the importance of global action and have been energetically pursuing the development and implementation of measures to address the reduction of anthropogenic emissions. The transport industry is one of the major users of fossil fuels.

An analysis of sustainable freight transport revealed a gap in the literature in respect of offering mode-choice tools, especially based on total transport costs. Generally transport studies, in policy and logistics, considered efficiency measures in improvements by lowering operating costs. However, this research considers total transport costs, with internal, external and time costs providing the tool for comparing mode alternatives to road transport.

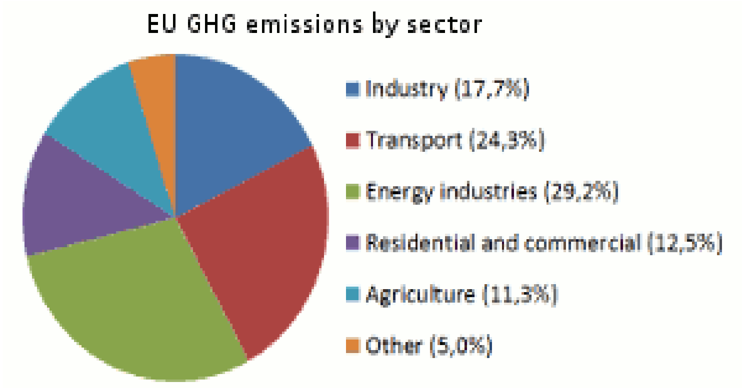
The aims of this chapter will be to present the context and reasoning for this research. It will present the research questions and justify the reasons addressing the questions by setting out the plan and process of this thesis.

On a personal level, this research was prompted by the researcher's long involvement and association with marine transport, and the perception of an economic need for sensible planning of integrated transport systems (intermodality) on a national and international basis.

1.2 Background to the research

Transport involves the carriage of goods and passengers and is crucial to international economic growth. There has been growing concerns regarding the climate changes resulting from the burning of fossil fuels and its threat to the world economies. Within the EU, pollution from transport related causes is about a quarter of the total EU GHG making it the second biggest pollution source after energy (EC DG Climate Action 2010).

Figure 1.1 shows the GHG by sectors and transport modes for 2012.



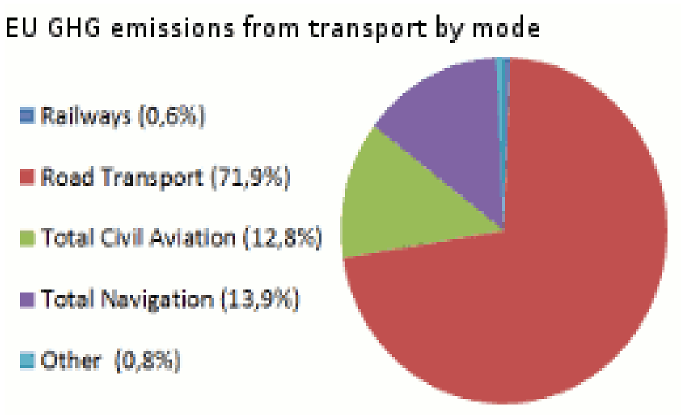


Figure 1.1: EU28 Greenhouse gas emissions by sectors and transport modes (2012)

Source: EC Climate Change[1]

[1] http://ec.europa.eu/clima/policies/transport/index_en.htm

Within this, road transport accounts for about two-thirds of EU transport-related GHG and over one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas (IPCC 2007). The report shows significant growth of emissions from the road, aviation and maritime sectors. The European Commission targets the reduction of carbon emissions in the transport sector of at least 60% by 2050 with respect to1990 level (EC, 2011; UNFCC, 1997).

About one third of the GHG emissions, shown in Figure 1.1; transport related GHG was over 70%.

Early studies linked strategic transport logistics decisions primarily to the operational decisions on types of vehicles, mode choices, routes, etc. (Abrahamsson and Aronsson, 1999). The threat of irreversible damage to the ecosystem prompted the European Commission (EC 2011) to incorporate the mitigation of industrial sourced pollution as a major priority in its roadmap for a competitive and resource efficient transport system. Intermodal transportation was proposed as the main solution by the European Commission[2]. The desire for environmentally friendly networks prompted new innovative research encompassing economic, environmental and operational factors within the network design (Harris et al 2011) allowing new insights.

Recent studies confirm the EU total GHG emissions and especially from the transport sector (See Fig 1.1). The transport sector is a major contributor to significant environmental pressures including climate change, biodiversity fragmentation, air pollutant emissions and noise. Climate change is one of the most

[2] European Conference of Ministers of Transport restricts the definition of intermodal transport to unitised transport. However, unitisation is but one possible, though important, means to facilitate the transfer of goods between modes. Regarding combined transport, the EU uses a more restricted definition (e.g. in the framework of Directive 92/106), aiming to promote only such types that limit road use in specified ways.
Intermodal transport: The movement of goods in one and the same loading unit or vehicle, which uses successively several modes of transport without handling of the goods themselves in changing modes.
Combined transport (ECMT): Intermodal transport, where the major part of the European journey is by rail, inland waterways or sea, and any initial and/or final legs carried out by road are as short as possible.

significant environmental issues and the transport sector contributed a quarter of the total GHG emissions in the EU in 2014. Transport GHG emissions have increased since 1990, despite a decline between 2008 and 2013. It is uncertain if transport-related GHG emissions will reduce before 2020 casting doubt over whether or not the sector can reduce its overall environmental impact by 2020.

The demand for both passenger and freight transport is expected to increase in the years ahead (EC, 2016a) making it challenging for this sector to reduce its overall environmental impact by 2020. Summing up in its 2016 policy document 'Reducing emissions from transport', the EU strategy will benefit European citizens and consumers by delivering improvements in air quality, reductions in noise levels, lower congestion levels and improved safety. Based on new technologies, intermodalism will offer improved and efficient transport systems with based on sustainable solutions.

Globalisation and increasing international trade have necessitated new transport solutions; competitive market forces introduced new performance indicators for managing, measuring and costing of freight systems. The growing concerns arising from increasing pollutions arising from the industry brought in new mitigating procedures. In transport based literature, there were very few total cost based studies comparing the total costs of the different modes, a sum of internal costs (out of pocket), costs arising from mitigating the externalities (effects of environmental pollution, noise, congestion, etc.) and the 'time costs'.

This reality is now broadly accepted by both national and internationally-recognised scientific organisations and governments. Rising global temperatures pose two major challenges for the transportation community:

- Ensuring that the transportation networks can withstand the climate changes that are already underway, and
- Reducing further contributions to greenhouse gas emissions.

1.3 Rationale for the research

There have been an increasing number of studies based on environmental issues associated with freight transport, mainly road, over the last few decades. There is a vast body of literature available on its external impacts such as air pollution, noise and vibrations, impact on land use and biodiversity, waste, congestion, accidents and even visual intrusion. Where available, the evaluations of freight transport (mainly road transport freight) economic activities have been based on the internal costs, ignoring the added costs in the mitigation of the transport related pollution costs and costs to the economic value of the cargo due to transit time.

In order to address this gap, this research seeks to explore and map the complex relationships between total transport costs and freight transport trends. The research will design a model, to provide a comprehensive framework model linking three parameters, to evaluate the total transport costs. This framework will be then tested over two other transport corridors. The transport corridors were selected from the TEN-T corridors, representing a relevant north-south route and an east-west route. There were extensive consultations with the main transport providers to obtain a realistic view of the present transport industry in order to surmise future changes in the transport, based on total costs.

Green and Wegener (1997) highlighted the problem areas of pricing and financing in sustainable transport and the potential towards achieving sustainability in urban transport (European Conference of Ministers of Transport 1995, Chapter 8). The authors suggested the need for innovative solutions on pricing congestion, air quality and the mitigating conditions. Green et al suggested the following issues for further research:

(1) The appropriate theory and methods for measuring external costs;

(2) Practical means for implementing effective externality taxes;

(3) Assessment of the impacts of comprehensive and practical full cost pricing both with respect to efficiency and equity; and

(4) The question of acceptability by the public of fundamental change in the pricing and financing of transport.

There is relatively little published literature on Irish transport options covering total transport costs for overseas destinations with intermodal options. This research offers a new Intermodal transport Cost Model (ITCM), based on total transport costs, which compares the costs of existing transport options with those of optimal modal combinations. This research model was then tested along two other transport corridors, validating the ITCM design to offer as a tool for the industry and the policy makers seeking sustainable transport solutions as an alternative to heavier polluting transits.

The contribution of this research is to:

- Re-evaluate the total transport costs, summing internal, external[3] and time costs;
- Evaluate the costs of transport externalities addressed in freight transport literature;
- Present a model of the total transport costs to assist the freight transport user/supplier on mode choice.

[3] External costs are the costs raised by transport activity that are not borne directly by the transport users.

1.4 The central research question

The research question posed is '*How can a comprehensive working model assess general freight transport costs, including economical and environmental costs, which allows transport stakeholders to make informed decisions on mode selection to achieve efficient freight delivery?*'

Hence, the primary aim of the research is to devise a model, evaluate it on appropriate freight routes and consequently offer it to all stakeholders as a tool to allow informed decisions on freight mode choice. *In consequence, two initial objectives must be realised.*

1. *In the light of current industry trends, it is necessary that the economical and environmental competitiveness of intermodal transport systems by comparison with unimodal systems is evaluated.*
2. *Given the consequence of the internalization, on intermodal competitiveness, relevant factors within total transport costs are determined. This will require:*
    a. *Evaluating intermodal transport choices and the determinants defining the multimodal markets within the transport corridors*
    b. *Investigating the main factors in respect of intermodal transport costs.*

In order to answer these questions, the research process was divided into the following stages:

1. A comprehensive literature review was conducted to establish the main factors influencing the environmental impact of road freight transport and their inter-relationships.
2. Different methodologies used in the past to forecast the environmental impacts of road freight transport were reviewed to identify the most suitable approach given the aims and objectives of this thesis.

3. Primary data was collected from a large sample of logistics specialists in focus group discussions. This was analysed using a range of statistical techniques.
4. On the basis of the earlier theoretical and empirical work, a spreadsheet model was constructed to facilitate the evaluation of the transport costs along the first route.
    a. Two further total cost evaluations were carried out with different mode choices with different mode distances.
5. This model was used to evaluate the costs on each of the routes. This allowed the transport buyer to choose the ideal mode combination route with lower costs and lower transport related negativities.

The ITCM model evaluates the total costs incorporating existing factors, (internal, external and time factors) on routes within European transport corridors. The model extended the intermodal transport solutions to the second level (e.g. truck – rail – rail – rail – truck). To date, knowledge optimization models and related network representations that allow the optimization of transport over all theoretically possible (unimodal and intermodal) solutions cannot currently be found in literature).

1.5 Thesis structure

A central focus of the thesis is the proposal of a transport model that allows the comparison of two routes with the same O/D to allow a comparison of different routes based on total transport costs. The thesis is centred on containerised freight on the European freight corridors linking Ireland, the Netherlands, Germany, Sweden and Turkey.

Existing literature on freight transport was reviewed to collect and collate the data on transport costs (internal, external and time factors), existing data on transport mode operations and usage. This analysis is very important, considering that price is a key determinant of users' choice.

(Figure 1.2) traces the nine chapters within the three sub-sections of theoretical, empirical and results. The theoretical part (Chapters 2 and 3) review the available literature and previous research on the freight transport and provides the academic background to this research. The methodology used in this research is outlined in Chapter 4. This chapter links the theoretical and empirical parts of the thesis and describes the procedures used to collect and analyse data necessary for the research. The empirical sections (Chapters 5, 6, and 7) present the research undertaken and discuss the empirical findings. Chapter 8 and 9 conclude the thesis, discusses its contribution to knowledge, outlines its limitations and indicates directions for future research.

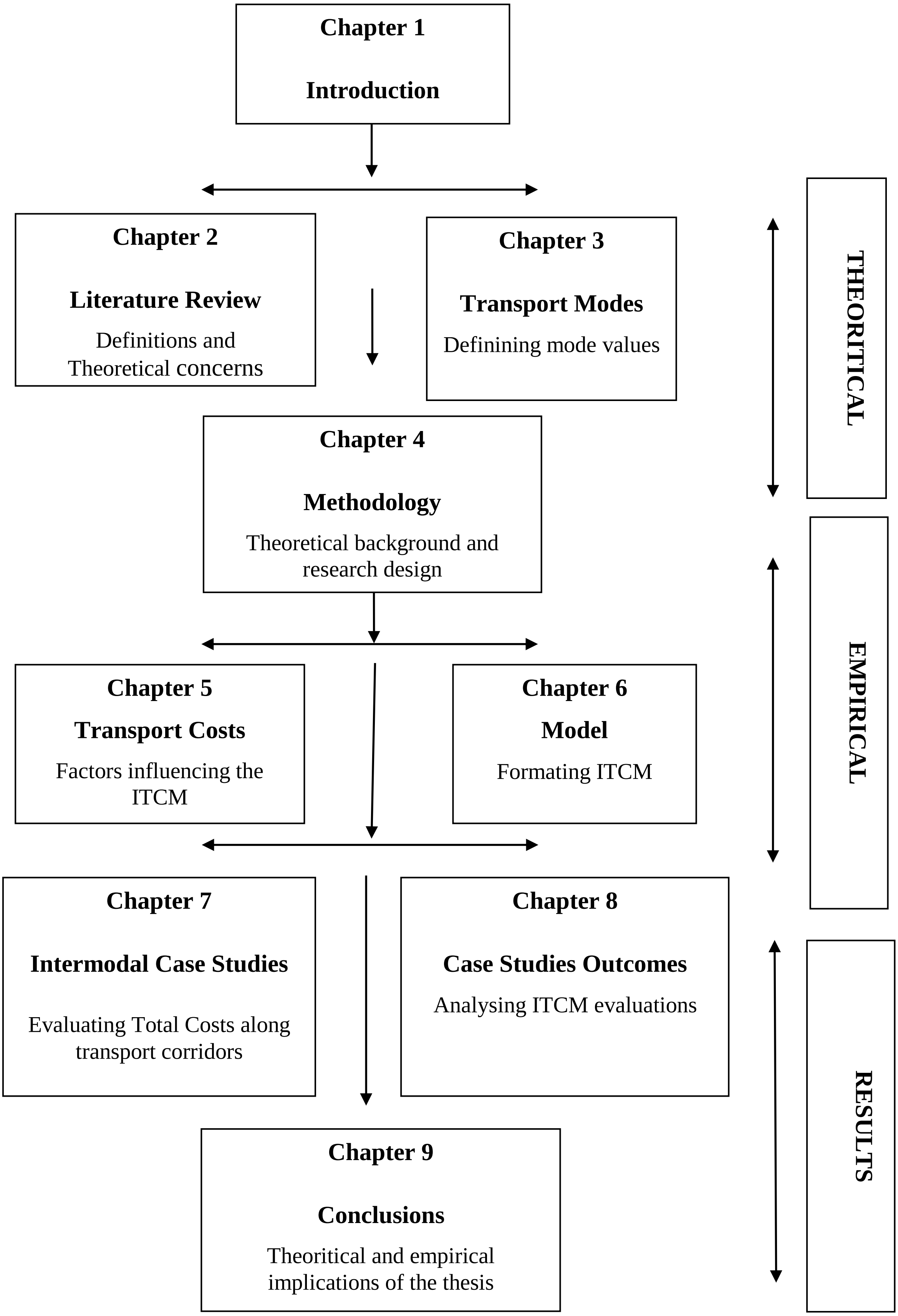
The chapters are structured as follows:

Chapter 1 introduces the background and the rationale for the research with respect to the existing theoretical and empirical knowledge with regards to mode options and sustainable alternatives. This section sets out the main research question and the consequent aims of the study.

SECTION 1: THEORITICAL

Chapter 2 reviews the published literature relating to the competitiveness of intermodal transport, especially literature dealing with cost/price analysis, including external factors, and literature tracing the evolution and branching of intermodal concepts and their progression. This chapter reviews previous researches, articles and data that addressed transport issues, its competitiveness in comparison with other modes and its relevance to European transport and social issues.

Figure 1.2: The research flow chart



The aggregate data from the different sources are collected and collated for processing in Chapter 6, the model.

Chapter 3 describes the different transport modes, providing specifications and defining its characteristics. The various loading units used in the transport process are presented and including possible intermodal combinations are described. The transport data and factors provide the factors of the ITCM evaluation.

Chapter 4 presents the methodology used to address the research objectives using both quantitative and qualitative techniques. The philosophical assumptions underpinning this research and the research design are discussed here. The chapter justifies the critical realist paradigm research approach, which is adopted as the philosophical stance of this thesis' ontological and epistemological foundations. Subsequent sections present and justify the research methods applied throughout the project.

SECTION 2: EMPIRICAL

Chapter 5 describes remit of the research in respect of freight transport costs in its various applications, as in definitions, general modelling assumptions. This chapter defines the different aspects of the research model's basis of total transport costs, as a sum of internal, external and time costs during the transit.

Chapter 6 presents the overviews and the concepts leading to ITCM and its design. The design incorporated the various aspects of generalised transport costs collated from the literature. The design was completed based on the selected parameters laid out in the methodology. The ITCM design summed the generalised costs, both internal and external, with the time components leading to the outline of the ITCM.

SECTION 3: RESULTS

Chapter 7 presents the nine case studies on three selected European transport corridors for the model. Data for each of modes are interpolated on the nine routes on the three transport corridors between Rotterdam to Ballina, Rotterdam to Stockholm and finally Rotterdam to Istanbul. The results of the total transport costs, associated with the different modes of transport, are analysed using an Excel tool developed for the purpose. The full data representing the costs of the different transport mode combinations were analysed primarily based on the road mode, with very few intermodal alternatives.

Chapter 8 discusses the results of the case studies by comparing the similarities and the dissimilarities between the literature reviews and the case study results. The analysed data are then used as the basis for an industry-wide feedback with the industry (truck owners, shippers,' freight forwarders). It discusses its contribution to knowledge, outlines its limitations. The results of the ITCM case studies showed clearly that routes offering intermodal alternatives to road-heavy systems had comparatively lower total costs.

Finally, **Chapter 9** summarises the main issues of the research and reiterates the main issues rose in the introduction. The chapter offers possible suggestions for interventions and trends for future works and research development.

1.6 Summary

Chapter 1 has provided a brief introduction to the topic of the research and has set out the background of the research. It has postulated a hypothesis that addresses the research question and described the methodology for testing this question during the research. A central issue in this research is to explore the impact of environmental factors on intermodal transport systems. The research proposes a model for evaluating the costs of alternative transport modes for typical international routes to and from Ireland. The structure of the thesis has been outlined and an introductory overview of the methodological approaches has been provided.

Chapter 2

Literature Review

2.1. Introduction

Chapter 1 set out the objectives of the thesis and provided a brief introduction to the problem posed. This chapter provides a background to the problem by reviewing the literature relating to the role of logistical structure in freight modal choice and aims to identify gaps in the literature. Specifically, this review summarises selected material on the scope and extent of intermodal freight transportation with a view to identifying the key impediments and barriers to intermodalism, possible strategies to overcome these barriers and impediments, knowledge gaps and topics for further research.

Economists have considered transport freight as ‘derived demand’; it is the demand that drives the transport of goods or transport services to locations. Transport freight is heavily influenced by geographic domain issues: international, national, regional and city. The majority of freight demand research has been through quantitative modelling (e.g. input-output methods). On the other hand, shipper behaviour research has included surveys of shippers or carriers and has relied on qualitative analysis (Thomas 2010). Traditionally, freight transportation has been described through vehicle movements or freight/commodity movements. Typical models include an origin-destination (OD) matrix that contains both the type and quantity of goods moved by a combination of mode systems.

2.2. Background

Increased volumes and tonnages in freight transports have witnessed new freight transport models and systems. However, there has been a huge increase in transport related pollution, environmental and socio-economic. The increased pollution, both environmental and socio-economic, has caused concern amongst the policy makers and the research communities. European transport policies have promoted improved transport infrastructure (Harmonised European approaches for transport costing and project assessment" HEATCO, 2006 and Roadmap to a Single European Transport Area" (European Commission, 2011). This has directed the studies on European transport modelling and the inherent limitations of the transport policies (Tavasszy, 2011).

Freight transport models are used to assess the impacts of different types of policy measures, such as changes in national regulations and taxes or infrastructure investments in specific links, nodes and corridors (de Jong, et al 2013).

2.2.1. Rationale for the review

Analysing the recent trends in EU freight transport coverage indicates increasing share of the road freight[4]sector. These increases impose significant negative impacts on the society, the economy and the environment. They are primarily air pollution; climate change; noise; disturbance to nature, the landscape, water and ground sealing; separation in urban areas; scarcity of space in urban areas; reduction in natural visibility; accidents and additional secondary upstream/downstream processes (DG MOVE Update of the Handbook 2014**).** A key policy objective of the European Commission has been working towards a form of mobility that is sustainable, energy-efficient and environmentally friendly. The key aims have been to reduce the transport related externalities. On a policy level this has been by promoting co-modality, which is by optimally combining various modes of transport within the same transport chain, as a solution in the case of freight. Technical innovations with a shift towards the least polluting and most energy efficient modes of transport, especially within urban environ and in the case of long distance, will greatly assist in the lowering of transport related

[4] The 2013 estimate for the total inland freight transport in the EU-28 was over 2200 billion tonne-kilometres (tkm); some three quarters of this freight total was transported over roads. Source: Eurostat (road_go_ta_tott), and Directorate-General for Mobility and Transport 2014

negativities. Legislative measures incorporating the ‘polluter pays’ concept has been by introducing the charging of freight transport across Europe[5].

Analysing the literature review on intermodal transport, reveal definite gaps in the literature, especially those relating to mode choices (and routes) based on total transport costs. In view of the importance of the environmental co-efficient within the overall sustainable transport aggregate, it was important to develop the ITCM as a discriminatory tool for the transport users. A substantial work of research addresses the dilemma of environmental impacts and efficiency of urban freight transport focusing on urban deliveries and city logistics (Anderson et al 2005) as well as seaport gateways (McCalla 1997 and Roso et al 2009). There were not very many studies on transport systems, based on total transport costs, providing the transport alternatives to shippers connecting with receivers. This paper examines the relationship of total transport costs and the mode choice alternatives to road transits.

2.2.2. Layout of the chapter

The literature review of the freight transport covered early freight transport practises, its relevance to this research’s issues and transport costs. The literature on transport models were reviewed, especially with its influences on mode choice modelling (behaviour mode choice model, inventory based model and discrete choice model), shipper’s behavioural models in North West Europe including Ireland.

Chapter 2 is set out in eight sections (See Fig 2.1); following the introduction the second sections sets out the background of the scope of the research’s literature review. The third section outlines the specifics in conducting the review.

[5] Legislations:
Directive 1999/62/EC of the European Parliament and of the Council of 17 June 1999 on the charging of heavy goods vehicles for the use of certain infrastructures
Directive 2006/38/EC of the European Parliament and of the Council of 17 May 2006 amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures
Directive 2011/76/EU of the European Parliament and of the Council of 27 September 2011 amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures

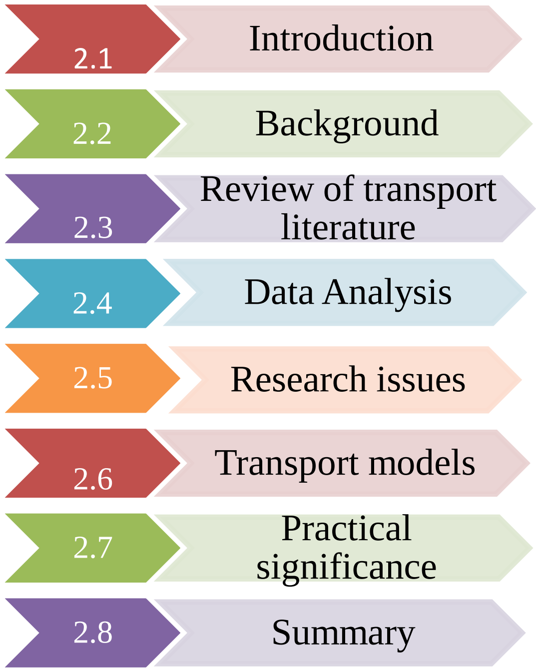


Figure 2.1: Chapter 2 flow chart

The fourth section reviews the collection, collation and analysis of the data prior to the application onto the research model. The fifth section reviews the literature relevant to the research issues in way of transport costs and mode choices. The sixth section reviews the transport models, in general and research related models. The seventh section reviews the practical aspects arising from the literature reviews, crucial to identifying the knowledge gaps, and the manner the study contributes to the theoretical and empirical perspectives of the research. The eighth and the final section summarises the literature review.

2.3. Review of transport literature

The three main sources for the literature are detailed out in Fig 2.2.

The two main reasons for reviewing literature as presented by Saunders et al (2009 pp. 58) citing (Sharp *et al*. 2002) are as follows:

- It forms the preliminary search that helps to generate and refine the research ideas

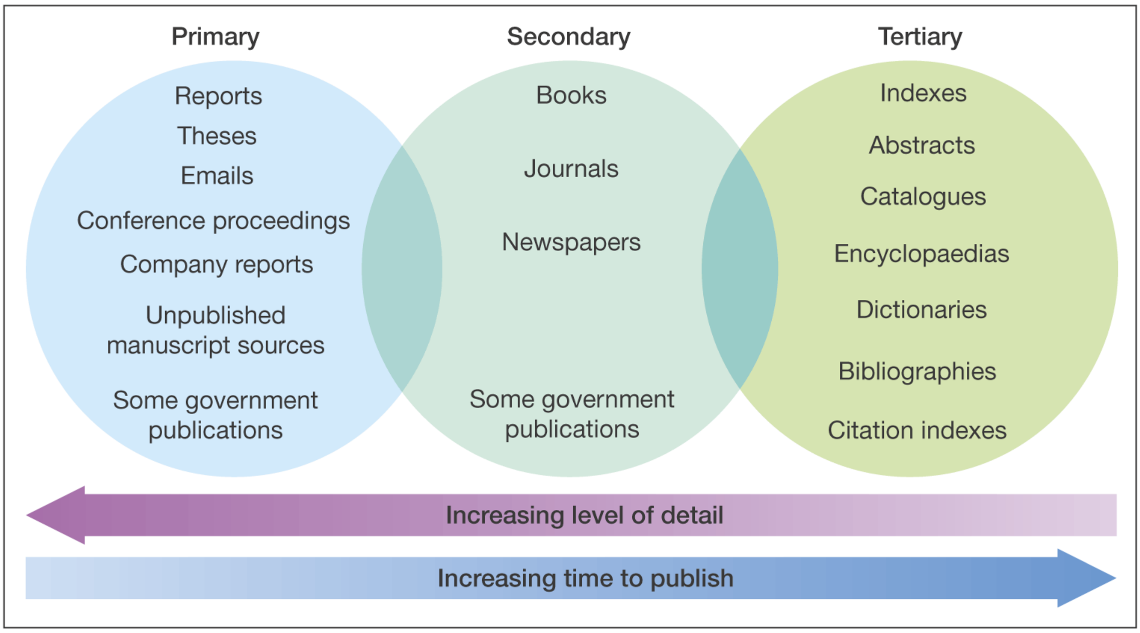


Fig 2.2 Literature sources available

Source: Saunders, Lewis and Thomhill (2009)

- The critical review of literature is part of the research project proper. It traces the relevant ‘knowledge’ with respect to the research topic, already completed or in progress that is relevant to the particular subject area, measures its relative strengths and weaknesses and prevents the researcher from duplication of existing knowledge.

Establishing what research has been published in the chosen area supports the research design process by identifying the key approaches, data collection and analysis methods best suited for the topic. It also helps to identify gaps in the existing literature, which can be translated into research questions providing an explicit justification for the research project (Saunders et al., 2009).

The following sources were used to conduct the literature review:

- Dublin Institute of Technology library: SearchAll-LibraryResources
- E-Resources
    - *E-Journals*

    - *E-Books*
    - Databases: Online journal databases (Emerald Full text, Science Direct, EbscoHost, IngentaConnect and JSTOR)
    - Conference proceedings and working paper collections
    - Arrow@DIT
- Other Libraries
- Internet

The literature review commenced started with ‘keyword searches’ in several academic journal databases and the library catalogue. Examples of key words used included: ‘transport models’, ‘transport costs’, ‘transport related pollutions’ ‘GHG emissions’, ‘road freight transport’, ‘intermodal utilisation’.

There have been a few publications exploring the value of the application of intermodal transport and yet fewer papers addressing environmental aspects. Bauer et al. (2010), Goel (2010) presents a transportation model combining shipment and route choices to improve on-time delivery performance. An intermodal system could easily be adapted to include green metrics such as carbon emissions, energy used, spoilage and losses etc. These kinds of models assess environmental effects of transforming a large airport into a real multimodal transport node and connecting the airport to the high-speed rail transport network (Janic 2011). The system, with intermediate stops along its route, is a possible choice, as it satisfies a wider range of options for a larger market area than conventional origin/destination terminal solutions, with a smaller emissions footprint and lessened social negativities (Kordnejad 2014). Intermediate terminals could also offer shorter road feeder transport.

2.4. Research issues

Earlier studies on the choice of transport mode or combination of transport modes have found the direct impact on the overall transport efficiency (Liberatore and Miller, 1995). These studies compared unimodal systems based on operational costs over distances.

Basic comparisons between road and rail were common (Fowkes *et al*., 1989; Hayuth, 1992; Marlow and Boerne, 1992); on national routes between air and sea modes (Hayuth, 1986; Jung, 1994) and extending to intercontinental routes. Study models based on international transport found multimodal choices were central to international trade (Beresford and Dubey, 1990; Beresford, 1999; Minh, 1991; Barnhart and Ratliff, 1993; Yan *et al*., 1995) to aid transport decision makers in choosing the most effective transport mode or combination of transport modes that not only minimises cost and risk, but also satisfies various on-time service requirements. Previous freight transport studies mentioned intermodal transport systems[6] in passing (Morlok and Spasovic, 1994; Feo and Gonzalez-Velarde, 1995; Nozick and Morlok, 1997; Powell and Carvalho, 1998; Newman and Yano, 2000). These mainly pointed out the main differences between the main road mode and intermodal mode combinations the general conclusions were that the intermodal system chain may be considered as the sum of separate unimodal systems having three broad sections, namely drayage, long-haulage, and terminal operation. Intermodal concepts were considered within the broader freight study as a transport subset (Ashar, 1993; Adjadjihoue, 1995; Jung, 1996; Woxenius, 1998; Beresford, 1999). However, there was reluctance to accept an intermodal system over the available unimodal, mainly road system (McKinnon 1989). Gradually, further studies combining other mode options extending to road/rail were presented by Jung and Beresford (1994); Drewry (1996) widened the scope to include sea transport.

[6] An economic argument would be to select investment in intermodal transportation to be seen as a 'second best' alternative to more appropriate pricing models.

In the earlier research more than half of the studies reviewed were related (i.e. cited each other); Macharis and Bontekoning (2004) and Crainic and Kim (2007) reviewed many Operations Research (OR) studies dealing with a part or whole intermodal system. Some transport studies have suggested that intermodal transportation could provide a more cost-effective way of addressing some of the capacity and service limits of individual networks which have been built around individual modes (Blauwens et al., 2006a; Button, 2010; Frémont and Franc, 2010).

Analysing the literature allowed the determination of existing knowledge on intermodal freight transport revealed four main trends:

1. An increase in the number of articles, handbooks and reference literature on intermodal transport concepts, rather than unimodal studies in road, rail, sea and air (Coyle et al., 2000; Button, 1994). An increase in specific publications devoted to intermodal transport (Mahoney, 1985; Hayuth, 1987; McKenzie et al., 1989; DeBoer, 1992, Muller, 1995).
2. Improved technology and the economic recovery have resulted in increased transport activity with higher amounts of pollution, both environmental and social. There is an increase in the types of research quantifying the negative effects from transportation;
3. Increased influences dealing with the issues of pollution, environmental and social and solutions aimed at reducing the costs to the economy and the environment.
4. Increasingly intermodal transport is considered as a competing alternative system to the existing unimodal transport, which is mainly by road (Jourquin, et al 2014).

Earlier studies were based on premises, which invariably influenced the perspective and methodologies thus limiting the scope and influence of the results. For example, sometimes in total vehicle cost studies, the vehicle ownership and parking costs were ignored (de Jong et al 2008); on mode choice issues where operating costs are considered and yet the external influences are only casually considered (environmental impacts with air pollution, with noise and water pollution and various categories of land use impacts) but not included within the total costs. Woodburn (2003) acknowledged that the industry was acknowledging the importance of transport mode choice issues with the growing concerns about congestion, noise level and environmental pollution created new issues which influenced current solutions. The literature reviewed showed differing results, often significantly. These differences arose because scope, definitions and methodologies of factors were varied and not strictly defined in most of the papers (Quinet, 2004).

Bontekoning et al. (2004) reviewed over ninety published articles on the early research into intermodal transport and concluded that it was a new and emerging field of applied transport research and was still in a 'pre-paradigmatic phase'. Intermodality was generally seen as a subtopic within comprehensive freight research rather than as a specialised field in its own right. These authors categorised all the intermodal transport related studies into eight subcategories: drayage, rail haul, transhipment, standardisation, multi-actor chain management and control, mode choice and pricing strategies, intermodal transportation policy and planning and miscellaneous. The first five describe the different aspects of intermodal transport; the sixth is devoted to mode choice and pricing strategies; the seventh covered intermodal transportation policy and planning for optimal intermodal routing for a specific shipment (Barnhart and et al 1998; Boardman et al., 1999; Bookbinder and Fox, 1998) and the eighth reviewed the past and evolving nature of intermodal transport, defining the system and the shippers' perceptions of road-rail combinations. In the earlier research more than half of the studies reviewed were related (i.e. cited each other); Macharis and Bontekoning (2004) and Crainic and Kim (2007) reviewed many Operations Research (OR) studies dealing with a part or whole intermodal system.

There are a lot of issues in freight policy that demand the modelling of freight flows, such as the increase of freight volumes, pricing, logistics performance, changes in transport modes and the resulting external effects of transport. Tavasszy (2006) lists the linking of transport models to current freight policy issues: forecasting international freight growth, differentiating between goods with different logistic backgrounds, forecasting the impacts of mode choice, modelling critical global movements (containers, oil, dangerous goods, food).

Studies on passenger transport modelling have a higher of specialization as it has a longer history in academic research. In contrast, the evolution and the methodological concepts are a recent innovation (Tavasszy 2006).

Freight transport studies and especially those on transport costs form a relatively small part of total transport flows. Further, access to the sensitive data is difficult because of the reluctance of the freight transport market actors to divulge the operating costs (de Jong et al. 2004). The whole subject is complicated further with the due to the high number of different actors involved, such as consignors, shippers, freight forwarders, liner carriers and terminal operators, and their partly conflicting interests, the organization of international freight transport chains is very complex.

At present, there are no comprehensive tools, based on total transport costs towards selecting the most competitive transport network within a transport corridor. Consequently, it is difficult to estimate the expected advantages in selecting between two mode route choices. This research aims to offer an overview of the field of freight transport modelling and to develop a model to compare between two or three routes within a transport corridors taking into consideration different types of costs. Finally, the cost functions are applied to the ITCM and applied to two other corridors.

2.4.1. Transport costs

Recent intermodal transport studies on costs have favoured the 'general costs approach', which provides a common and useful tool for understanding variation in transport costs and factors that may influence shippers' behaviour (Grosso 2011). In the review the author expressed that the role of external costs and the cost of mitigating their negative influence were considered a low priority in influencing freight transport shippers. This was reoccurring theme found in the analysis of the prevailing transport literature. To analyse complete effects of freight transport costs, a model with accepted parameters will have to be developed, which includes all the three factors.

In passenger transport, pricing influences only one decision maker (the passenger). In freight transport, on the other hand, multiple decision makers are involved between the origin and the destination, including those involved in the operations of loading, transhipping (from one transport mode to another, e.g. from rail to road (Macharis et al., 2010; Macharis & Bontekoning, 2004) and unloading. For the purposes of this research, costs are defined as the amounts incurred by the owner of the transport unit. The term 'price' defines what the transport owner charges to provide a particular service.

Literature reviews show that transport cost was one of the key factors, namely transport cost, transport quality, transport time and reliability. Vehicle operating costs included the direct costs the transport provider paid out of his pocket to operate a transport unit; notably labour, capital, fuel, tyres, maintenance and depreciation cost of a vehicle (Widlert 1990; Widlert & Lindstedt 1992; Vannieuwenhuyse et al. 2003; Lundberg 2006; Punakivi & Hinkka 2006; Danielis & Marcucci 2007). However other studies indicated that although cost was important, it was not necessarily of paramount importance to achieve the lowest cost at the expense of other important criteria. Scandinavian studies (SIKA 2005 and Lammgård 2007) found that there was a lesser priority for low price / or being one of the lower prices and both of these are not rated highly in importance. In their study of the Irish freight sector (Mataer and Gray 1993), 'price attributed costs' was the ninth criterion (4.0) for the shippers and eleventh (3.8) amongst the freight suppliers. Lammgård's study asked the same respondents to prioritise the factors price, transport time, on-time delivery and environmental efficiency according to their importance when selecting transport solutions.

The responses showed that respondents attributed 58% of the weight to price, despite previously ranking price as a factor of low importance, as tabulated in Table 2.1.

There are three categories of vehicle operating costs: internal costs (with standing costs, running costs), external costs and time costs.

1) Internal costs cover two strands: standing costs and running costs
   a) Standing costs are defined as 'the costs of having a vehicle standing and available for work', 'are not subject to frequent change and are not generally affected by the amount that the vehicle is used' (RTITB, 1989, p.6). They are therefore closest to the definition of fixed costs. Examples of standing costs include vehicle excise duty, vehicle insurance, operator's licence fee, drivers' guaranteed wages, depreciation and overheads.
   b) Running costs are incurred only when the transport unit is in actual use. The costs of fuel, lubricants, tyres and repairs and maintenance are examples of running or variable vehicle operating costs.

Table 2.1 Service Attributes for Freight Suppliers

	Attributes	Shippers' mean scores
1	Fast response to problems	4.7
2	Punctuality of sea/air service	4.6
3	Avoidance of loss or damage	4.6
4	On time collection and delivery	4.6
5	Value for money price	4.5
6	Good relationship with sea/air carrier	4.3
7	Short transit time	4.0
8	Low freight rate	4.0
9	High frequency of sea/air service	3.7
10	Arrival time at destination	3.7
11	Departure time from origin	3.0
12	Special offers or discounts for sea/air service	3.0
13	Proximity of port/airport to destination of goods	2.9
14	Transport preference of shipper	2.9
15	Proximity of port/airport to origin of goods	2.4
16	Availability of freight space	2.4

Source: Mataer and Gray 1993

2) External costs associated with vehicle operations are those costs that are not directly borne by those who cause them; they include environmental, congestion and accident costs.

3) Time costs are generally considered 'commodity' related. These costs have been considered under several headings, but they all reflect the economic costs affecting the freight (commodity) during the transit time.

The earlier studies in transport methodologies had limited scope and influence. Woodburn (2003) traced the evolution of transport service choice issues in the increasing road sector and the growing concerns arising from the transport related pollution, as in congestion, noise level and environmental pollution, etc. Transport literature on divides the transport costs into two broad headings, ‘cost drivers’ (demands and modelling highlights) and ‘non-cost’ drivers. The following factors have an impact, either direct or indirect, on transport operating costs[7]:

1) Uncertainties related to the level of vehicle operating costs, including:
   a) Fuel: price and availability of conventional and alternative fuels;
   b) Labour: labour shortages and the cost of providing skills in the logistics sector;
   c) Impact of congestion in journey times on vehicle operating costs.
2) Government policies, including:
   a) Regulation of freight transport (e.g. through taxation);
   b) Valuation of external costs and policy measures to internalise them;
   c) Uncertainties related to the long-term direction of society and the implications for travel demand and transport provision.
3) Uncertainties associated with freight modelling, including:
   a) Uncertainty in accuracy and availability of data for freight modelling;
   b) Uncertainty of state or private policy objectives which influence model outputs and modelling needs.

[7] Logistics costs can be added. However, there is no agreement on a precise definition of logistics costs. Logistics is the process of planning, implementing, and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods and related information from point of origin to point of consumption for the purpose of meeting customer requirements. Logistics costs then encompass a much wider definition than transport costs, including transaction costs (those related to transport and trade-processing of permits, customs, standards), financial costs (inventory, storage, security), and non-financial costs (insurance).

Review of later studies on transport modal models on mode choices and alternative solutions have based their studies on generalised transport costs on fixed definitions (Jourquain et al 20014; Tavasszy and de Jong 2014)

Transport quality costs

The importance of cost is also shown by the fact that several studies use cost as a benchmark to value other factors against, e.g., how much is a shorter transport time worth (Floden et al 2010)? For the transport infrastructure, this is the sum of the efficiency and effectiveness of the services for the actual cargo volumes and the physical scale of the hardware. This 'cost' includes several factors, as in time, reliability, frequency, risk of damage, etc. Some studies have considered them as a single composite factor (Anderson & Browne, 1992; Björklund, 2002, 2005; Punakivi & Hinkka, 2006). Analysis by Lammgård (2007) considered that transport quality related factors are ranked as being most important. Some authors have not included transport quality as a separate factor, but rather in the analysis mentioned that the factors identified as most important related to transport quality. Danielis et al. (2005) argued that in freight transport one of the prime requirements was the delivery of the freight unit to its destination, in a proper way. It is difficult to imagine any situation where a transport buyer would request a low transport quality for its transport. This apparent vagueness of the term can be interpreted to include almost anything, which might explain its popularity. (Floden et al 2010).

2.4.1.1. Internal costs (Out of pocket costs)

Internal costs or private costs are those paid directly by freight transport owners/operators. These costs include the capital investments, in facilities and vehicles, which eventually need to be replaced and operating costs. These operating costs are closely related to the level of haulage activity and include fuel, labour, repair and maintenance, infrastructure charges, taxes, insurance and depreciation (Forkenbrock, 1999, Janic, 2007). In the UK, vehicle operating cost tables are compiled by the Freight Transport Association (2006), Road Haulage Association (2006) and industry publications.

Table 2.2 tabulates the literature reviews for the three modes for cost and attributes.

Table 2.2: Literature review of internal cost attributes for three modes

AUTHOR	COSTS	ATTRIBUTES
Boardman, B. et al, 1999	Total transport cost	Drayage, initial transfer, transport, inventory carrying cost.
RECORDIT, 2001	Internal cost	Personnel, fixed asset, maintenance asset, energy, stock turn, time, organization costs, taxes, insurance, charges, costs with external and internal parts
Blauwens et al, 2006	Transport costs	Interest and depreciation, insurance, taxes, driver wages, fuel, maintenance and repair, tyres, other costs.
Vil, 2006	Total logistics costs	Transport costs, loading/ unloading costs, time, stock costs, company costs, quality attributes
Vlaams Vracht Model 2009	Total transport costs	Transport cost, loading/unloading costs

Source: Grosso 2010

The total internal costs for an intermodal system are the sum of the pre-haul; the main haul and finally the post-haul journeys. They include the costs of transhipments at the intermodal terminal between the modes. The costs of each component includes the cost of ownership, insurance, repair and maintenance, labour, energy, taxes and tolls/fees paid for using the network. The network infrastructure and mobile plant are assumed to be in place to serve a given volume of demand. The additional costs arising from infrastructural costs/investments and rolling stocks are not included.

2.4.1.2. External costs[8]

The current trend in public policy and legislation is to incorporate the external costs of transport into the total costs for transport users. For the transport company there are added concerns regarding the external effects on the environment and society. Table 2.3 summarises the early literature on the external costs. It is difficult to compensate the sections of the society affected along a specific transport leg by a particular transport mode. External costs are primarily the mitigating costs society pays arising from the effects of transport during the door-to-door delivery of commercial freight. These are the negativities defined as noise, air pollution, traffic accidents and congestion. Environmental pollution varies from one transportation mode to another. The full life cycle of the emissions of the hydrocarbon fuels must be considered, from production to consumption at the vehicle (well to the wheel) include exhausts from the oxides of carbon, sulphur, nitrogen (CO, CO_2, SO_2 and NOx) and others. Studies indicate that SO_2 and NOx are known contributors to acid rain, and nitrogen oxides contribute indirectly to the greenhouse effect and directly to smog (Stanners et al. 1995). Road transport produces about four times the nitrogen oxides, sulphur and carbon dioxide emissions per ton-km as transport by rail and inland waterways (Van Ierland et al., 2000).

[8] External costs are the costs raised by transport activity that are not borne directly by the transport users

The first external cost coefficients (for the Marco Polo programme) were calculated in 2004, and subsequent work was conducted by an Inter-service Group[9]. EU-led initiatives (i.e. Marco Polo) have promoted the shift from road freight transport to other more environment-friendly transport modes. In order to quantify the advantages of this modal shift, in terms of environmental and social benefits, external cost coefficients are used for each transport (sub) mode. The transport (sub) mode-specific coefficient calculated incorporates the external costs of air pollution, noise, accidents, congestion, and climate change per tonne-kilometre.

In subsequent updates (Brons and Christidis 2013; Korzhenevych, A., et al. 2014), external costs were calculated for different modes (road, rail, inland waterways and short sea shipping) and coefficients established to recognise their environmental (air quality, noise, climate change) and socio-economic (accidents, congestion) negativities (Martijn, et al 2013)[10]. The external costs of transport related issues include the cost of repairing the damage caused by pollution, congestion, noise and collisions.

Air pollution: The emissions from the combustion of all hydrocarbons cause pollution. The emissions from diesel and/or petrol engines damage surrounding buildings, green areas and people’s health. They mix with rain and fall as acid rain in remote locations, polluting wider expanses. In the case of vehicles that are electric powered, the air pollution is indirect.

The electric power is usually generated in remote power plants that may cause local air pollution. The air pollution generated by the operation of intermodal terminals is mainly indirect, because electric energy is generally used for the cranes transhipping the loads.

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9 The Interservice Group consists of representatives from the Directorates General for Mobility and Transport (DG MOVE), Environment (DG ENV) and Climate Change (DG CLIMA), and the Executive Agency for Competition and Innovation (EACI)

10 The European Commission strategy for internalising external costs of transport did not foresee the inclusion of external cost charges for infrastructure use and so did not cover these costs. Other factors for which there are no reliable and available estimates (scarcity costs of rail, inland waterways and costs of energy security and dependency on fossil fuel) were not covered either.

There is considered to be no pollution when the energy is supplied by hydro-electric generation.

Congestion: In densely urbanised and/or industrialised zones, freight is generally transported by truck. These trucks add to the road traffic load, causing congestion and consequent delays. These costs arising from 'transport induced delays on all the road users are regarded as externalities. An inter-terminal transport mode is assumed to be free of congestion.

Noise: Heavy goods vehicles are a source of noise; when this exceeds tolerable limits it causes annoyance and if persistent can affect productivity and may cause adverse health conditions. Noise from intermodal terminals is not considered since it is assumed to be just a part of ambient urban noise.

Traffic accidents: Traffic accidents cause property loss, damage network operators and third parties and may cause injury and death. The costs are usually calculated separately for each section and mode in the transport network due to the different frequency, nature and consequences in each. Accidents are rare at intermodal terminals.

Road network: The same external costs are used for the road transport network arising from the burdens, damages and associated costs which are included when diesel-powered trucks are used for the entire door-to-door journey. The two main issues affecting the impact of the road mode arise from its deployment. The first issue is that the trucks are the main mode to collect from the origin to the first intermodal terminal for the main haul: road, rail, air or sea (short sea or inland canals).

This section is predominantly within urban and industrial zones of a city. The second issue is the costs of operating on major motorways at optimal performances and efficiency. The effects of external issues do not directly impinge on society.

2.4.1.3. Time costs

There is a perception amongst shippers that ‘transport time’ is one of the most important factors. Time costs were evaluated as the product of time cost per hour and transport time and are commodity dependent. In practise, the transport mode of choice is dependent on the commodity.

The value of a commodity may be computed by the product of value per tonne, the interest rate per hour and the deterioration costs per hour (Hanssen et al 2012).

This can be found in the work of Fowkes et al. (1991); Hellgren (1996); Maier et al. (2002); SIKA (2002); Berdica et al. (2005); Punakivi & Hinkka (2006); Danielis & Marcucci (2007) and REORIENT (2007). However, the importance of transport time diminishes when expected transport times are longer (Danielis et al., 2005). Studies offering a faster transit time for an increased cost (Golias and Yannis 1998) found that the customers were unwilling to pay for added costs and willing to accept longer transit time for lower rates. Similar results were found by Fridstrøm & Madslien (1995). Widlert & Lindstedt (1992) and Engström (2007) also attribute a low value to transport time (Floden et al 2010). Value, interest rate and deterioration rate are all positively related to time costs per hour. In the computation of the main haul’s time costs there must be a declaration as to the number of drivers employed. For a continuous road journey, costs must include the salary for two truck drivers. In the event of nominating one truck driver, the rules[11] for resting times apply.

2.4.2. Mode choices

Historically, mode selection has been seen as a two-step process: the choice of mode is made first and the choice of carrier second.

[11] Regulation (EC) No 561/20061: establishes rules on driving times, breaks and rest periods for professional drivers

Table: 2.3 Literature reviews of published studies on external costs								
Project title, Pub. Year of relevant/delivery	Base year of results	Countries covered	External cost strategy	Costs included	Transport modes	Method used	Outputs	Differentiation of results
UNITE (2002)	1998 (1996, 2005)	EU 15, H, EE, CH	Accident	-material damages -administrative costs -medical costs -production losses/ human capital loss - risk value (pain, grief, suffering)	Road	Cost to transport system treated as external costs - Risk value considered to be internalised	Average costs of accidents - Marginal costs for specific countries (case studies)	- urban/interurban/ Motorway
INFRAS/IWW (2003)	2010	EU	Noise	-annoyance/ disutility - medical costs - fatalities		Bottom up approach	Marginal costs per decibel	- day/night - thin/dense traffic
INFRAS/IWW	2000	EU 15,	Noise	-annoyance/		Top down	Unit costs	- day/night

(2004)		H, EE, CH		disutility - medical costs - fatalities		approach	per decibel	- thin/dense traffic
INFRAS/IWW (2004)	2000	EU 15, H, EE, CH	Accidents	-material damages -administrative costs -medical costs -production losses/ human capital loss - risk value (pain, grief, suffering)	Rail	Risk value considered as external cost	Marginal costs of accidents	-
CAFE CBA (2005)	2000/2010 2002	EU 27	Air Pollution	- health costs - crop losses	Road, rail, IWW	Impact Pathway Approach (IPA), Extern E approach	Unit costs of NH3, SO2, NO2 and VOC	_
HEATCO (2006)	2002	EU 23	Air Pollution	- health costs - crop losses	Road, rail,	Impact Pathway Approach (IPA),	Unit costs of PM2.5,	Urban/rural

				- material damages	IWW	Extern E approach	PM10	
TREMOVE (2007)		EU 27	Air Pollution	-	Road, rail, IWW	-	Emissions per vkm	- fuel tech type - vehicle type - road network
EX-TREMIS (2008)		EU 27	Air Pollution	-	SSS	-	Emissions per tkm	- RoRo + RoPax/ container/gen cargo

The shipper's decision is made more difficult by the need to find the most competitive option from assorted commercially bundled solutions on offer (Murphy and Farris, 1993). The shipper's logistics management has to select the transportation mode and carrier for the firm's inbound and outbound freight. There are multiple criteria but the primary ones are the total costs and transit times. The 'decision tree' offers multiple options where the importance of individual factors often differs from industry to industry, company to company and even within a company from one facility to the next.

Brooke et al (2011) investigated the rationales of a mode choice study, examining the different factors and trade-offs (between price, transit time, frequency and reliability over different corridor distances and mode options is a necessary input to making sound regulatory and policy choices) in the Australian freight market.

They found in determining the ideal choices, that it was rarely 'an all-or-nothing decision but involves risk mitigation through route and mode allocation'.

Figure 2.3 shows the modal split percentages within the EU in 2012.

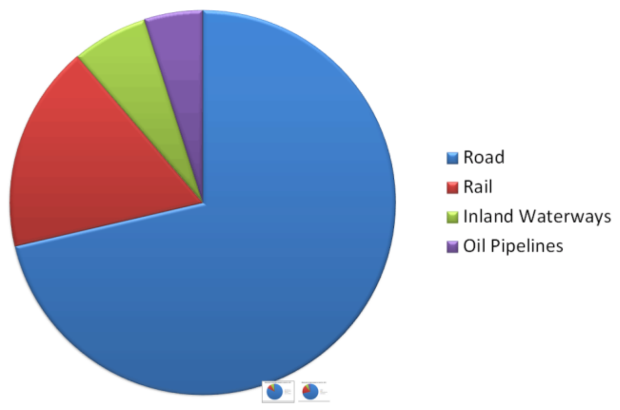

Figure 2.3 Modal split (percentage) EU 28 freight transport on land 2012.

Source: EU Transport scorecard (Facts & Figures)[12]

Mode choice decisions were a result of simultaneous preferences (of the shipper), with considering the available alternatives to the outsourcing to third-party logistics organisations. The modal split for Ireland is shown in Figure 2.4

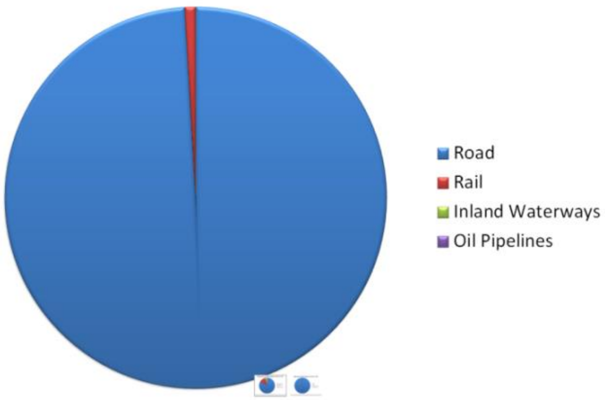

Figure 2.4 Modal split (percentage) for Ireland land transport 2012

Source: Mobility & Transport EU Transport score card (Facts & Figures) Ireland

2.5. Transport models

The basic transport European freight models in the early 1970s were based on the premise that a shipper's mode choice for the regular transport of freight between a set O/D, connected by various transport modes, tends to result in the best combination (Ferrari 2014). Generally, the shipper prioritises the transport alternatives based on transport costs per unit. This is a dynamic cost function, reflecting the relationship between average transport cost and freight flow, in a transport model, for each transport mode.

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12 http://ec.europa.eu/transport/factsfundings/scoreboard/countries/eu/index_en.htm#prettyphoto[charts]/0/

In many of the EU co-funded transport cost researches primarily dealt with long distance road transport. Research on middle distance studies revealed that around 50% of the transport demands are for distances up to 400 km (EUROSTAT, 2012) with significant challenges in the short-distance, around 400 km, intermodal transport market (Tsamboulas, 2008). Review of literature based on transport models describes studies comparing medium to long-distance services (e.g., Janic, 2007; Tsamboulas et al., 2007). Literature shows that there were opportunities in improving the competitiveness and innovation in the intermodal transport market over short-distance services (Macharis et al., 2010, Reis 2014).

Earlier freight network models considered mode split and the transport network using route choice models. National transport models (Belgium, the Netherlands, United Kingdom, Finland and Sweden) have considered them as modal split and network assignment simultaneously (Beuthe 2001), Swahn (2001). Subsequent transport model studies evolved onto multi-modal transport chains (Tavasszy et al, 2007, Pattanamekar et al, 2008). De Jong et al (2004) name 65 transport demand models for freight transport with 29 European passenger transport models. Liedtke's (2005) freight transport study, in Germany, found that based micro simulation model total logistics costs formulation for transport and trade decisions. De Jong et al (2007) model was based on a multimodal network that allows transhipment between modes of transport and different means of transport by mode (e.g. LTL-FTL).

Increased demands from globalisation required new modelling technologies for wider applications in transport modelling. Sivakumar (2007) refers to the earlier models predicting the choice of specific aspects (such as mode or route) of individual trips and these were deterministic in nature (the assumption was that behaviour was driven by lowering the cost or travel time) (Hägerstrand, 1970; Jones *et al*., 1983; Lenntorp, 1976).

Tavasszy (2006) identified three important trends in freight transport models, exploring network or hyper network modelling incorporating 'simultaneous trips' generation, modal split and route choice:

- Linking freight trips and networks
- Relationships between freight-economy
- Logistic decision making

The models were defined into different categories based on their properties. Summing their study of over 100 different freight transport models[13], further explanations of these categories are presented in Table 2.4.

Table 2.4 Model properties

Resolution	**Scale of analysis**	**Depth of aggregation**	**Measure variable**	**Method of modelling**
International	Macroscopic	Aggregated	Trip-based models	Econometric models
National	Mesoscopic	Disaggregated	Flow based models	Spatial equilibrium
Regional	Microscopic		Hybrid models	Network-based models

Source: de Jong G, Gunn H, Walker W (2004); de Jong G, Vierth I, Tavasszy L, Ben-Akiva M (2012)

Common classifications refer to their spatial resolution, scale of analysis, and depth of aggregation, variable measured or modelling method. In addition, there are

[13] Model refers to national freight models

other characteristics in order to differentiate models going beyond these main categories. Further examples can be found in their characterization due to their application, transport modes used, etc.

Reviewing literature on freight transport modelling traces the evolution of a non-structured, aggregate, engineering approach, primarily used for traffic management and routing to a structured disaggregate approach. The aggregated models used the global data available for shippers and shipments and identified general relations resulting from the underlying behavioural assumptions. Table 2.5 summarises the advantages and the disadvantages of the models.

Table 2.5 Summary of split modal models

Type of model	Advantages	Disadvantages
Elasticity-based	Very limited data requirements	Elasticities may not be transferable Only impact of single measures, no synergies
Aggregate mode split	Limited data requirements	Weak theoretical basis Little insight into causality Limited scope for policy effects
Neoclassical	Limited data requirements Theoretical basis	Hard to integrate in four-steps model
Direct demand	Limited data requirements	Hard to integrate in four-steps model
Disaggregate mode	Theoretical basis	Need disaggregate data

split	Potential to include many causal variables and policy measures	(shipper or commodity survey and/or SP)
Micro-simulation approach	Many behavioural choices Included links to theory	Either large data requirements or many assumptions on distributions
Multi-modal network	Limited data requirements Theoretical basis Can include elastic demand and policies affecting generalised transport cost.	Little insight into causality Mostly done with fixed demand

Source: de Jong, G.; Gunn, H.F.; Walker, W. (2004)

Economic globalisation introduced new trends where agile modern institutions have transformed freight transport influenced by major public concerns and policy (Ben-Akiva et al 2008). Academic research has reflected this trend and with the attraction of innovative and improved research into freight flows and market logistics. The review of the transport literature reflects the very heavy reliance on road transport and the very large share of the transport market[14] (EC EUROSTAT 2016). The new realities presented a shift in the existing paradigm; models were required to reflect new developments in logistics solutions. The models had to accommodate the differences in new markets, price pressures and available mode choices with a competitive infrastructure. This often led to a lack of consistency, which fostered

[14] Total inland freight transport in the EU-28 was estimated to be over 2 200 billion tonne-kilometres (tkm) in 2013; some three quarters of this freight total was transported over roads (http://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics).Road transport accounted for more than 90 % of inland freight transport in Ireland, Greece and Spain in 2013.

potentially contradictory model constructs that were unable to balance the needs of supply and demand (Tavasszy 2015). With the new empirical methods and a growing access to firm-level data, new freight models have favoured disaggregated analyses. Small and Winston (1999) pointed out *'economists have primarily, though not exclusively focused on mode choice'*.

The typical freight transport model structure comprised of four stages: trip production, trip distribution, mode choice and trip assignment (Tavasszy et al., 2012). Increased and improved applications brought about conceptual changes and were adapted to other freight transport applications dealing in trade flows, transport vehicle flows and expressed in monetary units (de Jong et al. 2012). The introduction of transport costs, of the various modes, also allowed for combinations of modal split. However the apparent reluctance in the shift over to another more suitable mode was surprising. Ferrari (2014) suggested that there were perceived issues that led to a limited confidence in the possibilities of the new intermodal transport, arising from the difficulties in adapting the logistical organisation and simple inertia in general.

There was a common perception, amongst the shippers, that intermodal services operated as single integrated services despite the increasing actor complexities within the intermodal networks (Bektas and Crainic, 2007). Studies in freight transport evolved from basic freight modelling research extended to strategic planning and subsequently to policy planning for intermodal networks and widening carriers and shippers' perspectives (Kordnejad 2013). This was a natural progression; usually it was logistics managers at shipping firms who were the actual decision makers regarding mode choice (Kordnejad 2014).

Increasingly, researchers have broken with this tradition. Huber, Klauenberg and Thaller (2015) found that the different intentions and their resulting characteristics of national freight models reflected the critical relevance and influence of the local logistical aspects and transport logistics hubs.

2.5.1. Mode choice models

Economic theory suggests several methods may be used for leveraging a shift to the optimal mode. What remain unclear, however, is which of these methods would yield the highest benefits at the lowest costs and whether the most feasible method would generate sufficient net benefits to justify a shift. In comparing two transport systems, the model must consider the total costs of both internal and external costs. Each mode provides mode related benefits, however those benefits typically entail a trade-off for some other cost. Advocates for road transport recommend its speed and flexibility factors whilst advocates for rail promote its safety and energy efficiency factors (Vanek et al 2008).

These models allocate freight flows (between each pair of zones) to the available transport services (supply). The transport services can be either single-mode (e.g., road, train or sea) or intermodal (e.g., road and train, or road and sea). A wide set of economic models are available; building on the transport agent's cost function where the available transport services are considered as one of the inputs. Demand functions, based on the costs function, can then be derived. Oum (1989) presents a model using neoclassical economic theory.

Disaggregated Modal Split Models represent the shipping firm's decision-making process. They are grounded in the assumption that shipping firms are rational and will opt for the transport solutions that maximise their benefits or utility. Utility functions are then built for typologies of firms, normally using the Multinomial Logit or the Nested Logit methods. These methods require a substantial amount of data which may not be readily available. Typical sources include: surveys of companies or transport companies and available statistics on freight flows. Ben-Akiva and De Jong (2013) present an aggregated–disaggregated–aggregated freight transport model in which logistic decisions are made at a disaggregated level. Blauwens et al. (2006b) present a model that deploys an inventory-theoretic framework to calculate the total logistics costs.

Aggregate Modal Split Models estimate the average market share of the transport services. Most models, rather than modelling the decision making of individual firms, rely on available statistics (modal share for a number of zones) to infer the utility functions, normally in the form of the Binomial or Multinomial Logit Models, of each transport service. The validity interval of the utility functions is therefore limited to source zone flows. These models have reduced data requirements. However, since they work with average values, they provide little information on the causal effects underlying the results. An example of this application can be found in Blauwens and Voorde (1988).

Mode choice models study freight flows (between each pair of zones) for the available transport services (supply), either unimodal (e.g., road, train or sea) or intermodal (e.g., road and train, or road and sea). Economic Models are based on the shipper's cost function, in which the available transport services are considered as one of the inputs; based on the available supply, the prospective 'demand functions' options may be derived.

The literature review offered here shows that there are several factors that influence freight mode choice: freight demand characteristics, cross elasticities; freight costs, commodity characteristics, modal characteristics and customer characteristics.

Consistently, it is found that trucks dominate short trip lengths and higher value goods, while rail dominates long trip lengths with bulky, low-value products. Cost benefits were weighed against customer service and satisfaction for many commodities where time constraints exist. For commodities with time constraints and/or service guarantees, road mode was the preferred option due to speed, flexibility, and reliability.

In one of the earliest reviews on dedicated intermodal transport studies it was reported that the use of Operational Research (OR) in intermodal transport research was very limited (Macharis et al 2004). The review concluded that intermodal transport research was an emerging field and considered still to be in a pre-paradigmatic phase and beginning to evolve into a legitimate branch of scientific research. For several reasons, modelling intermodal freight transport was considered more complex than unimodal systems as it involved three sets of paradigms.

Firstly, intermodal systems involved at least two modes, with their own specific characteristics in respect of transport units and infrastructure. Secondly, the control of the transport system had to be organised by a set of actors all of whom were responsible for only a part of the whole. Thirdly, complexity of assignment problems increased due to the large variety of load units (type and size) and options for intermodal load units (rail wagons and trailer chassis).

Mode Choice attributes

One of the earlier studies into transport models concluded that overall transport costs were divided into internal transport costs and external transport costs. Janic (2007) identified internal costs as collections, distribution, transhipment and handling of goods moved within a transport network as these were clearly identifiable and connected with the actual movement of freight between shippers and receivers.

The negative elements generated from each section of the intermodal infrastructure network place a burden on society. If these are intensive and persistent and not reflected in prices, these negative costs are defined as external costs. They are substantial costs that the transport network imposes on society and can be estimated using methods like willingness-to-pay for avoiding, mitigating or controlling particular impacts on society and the environment.

Traditional freight transport modelling approaches do have some limitations (Baindur and Viegas, 2011; Holmgren et al., 2012b; Liedtke, 2009) as they have been based on a set of statistical analysis and correlations between freight transport market parameters. Thus, disaggregated choices do not necessarily correspond to the actual decisions of transport agents. They are unable to consider the agent's specific individual case within the freight transport system. Consequently, behavioural aspects of the transport agents (such as decision making, individual preferences on modes of transport or variations on individual performance) and respective interactions (e.g., negotiation, communication or handling operations) cannot be modelled (Holmgren et al., 2012b). Also, in traditional modelling approaches results are restricted to the options initially included in the distribution. Thus, the emergence of new phenomena (e.g., implementation of new network structures such as transport corridors) cannot be forecast (Liedtke, 2009). Table 2.6 sets out cost factors: physical attributes distribution characteristics and modal characteristics. It is reasonable to deduce that policy interventions can shift the balance between these factors.

Commodities with high tonnage and mileage are of particular interest as it is those characteristics that make the commodity most suitable for a shift from truck to rail. Firstly, not all decision variables and their relevancies are fully described.

Secondly, the prioritising process of the mode choice factors appears to reflect more of the local issues and especially as viewed by the local transport manager. An earlier study stated that ‘it is not obvious that a competent transport manager thinks in terms of maximising a utility value’ (Beuthe et al 2008, pp. 159).

Table 2.6: Factors that affect freight mode choice

Total logistics costs [a]	Order and handling costs [a]
	Transportation charges [a]
	Loss and damage costs [a]
	Capital costs in transit [a]
	Inventory carrying cost at destination [a]
	Unavailability of equipment costs [a]
	Service reliability costs [a]
	Intangible service costs (e.g. Billing costs) [a]
	Shipment size [c]
Physical attributes of goods [c]	Package characteristics [c]
	Shipment shelf life [a]
	Shipment value [a]
	Shipment density [a]
Flow and spatial distribution of shipments [c]	Shipment frequency [c]
	Shipment distance [c]
Modal characteristics [a]	Capacity [a]
	Trip time and reliability [a]
	Equipment availability [a]
	Customer service [a b]
	Handling Quality – Damage loss reputation

Source: Collated from various authors: a: Cook, Das, Aeppli, Andreas, Martland (1999); b: Cullinane, Toy, (2000); c: Jiang, Johnson and Calzada (1999.)

It was possible that in the manager’s rationalising of the priorities, some of the total transport logistic costs that combined many internal and external logistic factors were minimised. These factors where the transport attributes and may naturally include some subjective judgment as to risk taking. Finally, in the analysis of the published literature for the full range of situations and conditions, it is a difficult proposition to identify attributes under a common reference framework. Nonetheless, the analysis does reveal a number of attributes, consistently ranked highest, namely: price, transit time, reliability, safety and flexibility.

This reflects the situation where some of the attributes will always be a part of the logistical process or equation, regardless of the case specificities. However influence and relevance are reflected in each case. Reis (2009) main mode choice attributes are tabulated in Table 2.7.

Table 2.7 Literature review Modal choice attributes

Attribute	Author
Reliability	Oum (1979) Shinghal and Fowkes (2002) Norojono and Young (2003) Cullinane and Toy (2000) GRUPO CLASS (2000) INRETS (2000) Murphy et al (1997) Jovicic (1996, quoted by De Mayer and Pauwels, 2003, pp. 27) Jeffs and Hills (1990) McGinnis (1990, updated by Murphy and Hall, 1995) McGinnis (1989)
Safety	Norojono and Young (2003) GRUPO CLASS (2000) INRETS (2000) Matear and Gray (1993) McGinnis (1990, updated by Murphy and Hall, 1995) McGinnis (1989)
Price	Garcia Mendez et al 2004 McGinnis (1990, updated by Murphy and Hall, 1995) McGinnis (1989)

	Jovicic (1996, quoted by De Mayer and Pauwels, 2003, pp. 27)
Transit time	Oum (1979) Shinghal and Fowkes (2002) Garcia-Menéndez et al (2004) Cullinane and Toy (2000) Murphy et al (1997) Jovicic (1996, quoted by De Mayer and Pauwels, 2003, pp. 27) Jeffs and Hills (1990) McGinnis (1990, updated by Murphy and Hall, 1995) McGinnis (1989)
Attribute	Author
Flexibility	Norojono and Young (2003) GRUPO CLASS (2000) INRETS (2000) Matear and Gray (1993) Jovicic (1996, quoted by De Mayer and Pauwels, 2003, pp. 27) Jeffs and Hills (1990)
Frequency of Service	Garcia Mendez et al 2004 Shinghal and Fowkes (2002) GRUPO CLASS (2000) Matear and Gray (1993)

Source: Reis 2009.

Though the table is neither extensive of exhaustive, it however shows the trends of published articles on preferred attributes. On the understanding that the numbers of the references reflect the main attribute's universality[15] on the modal choice process, it identifies two issues. Firstly, it seems to be of a nominal agreement on the main priorities for modal choices: reliability, transit time, safety, flexibility and price. Secondly, there are also other studies that mention additional mode choice

[15] Universality is understood as the attribute's presence in any modal choice process. The point here is that specific type of goods (or market conditions) may render some attributes as being important, while in most situations they are not taken into consideration (for example: in markets that are highly unbalanced, the availability of containers (equipment) may be a key issue). A universal attribute is thus an attribute that is always taken into consideration in the decision making process.

preferences but with no preferred priority choice. These are shipment size, shipment shelf-life, shipment value, shipment density, distance of shipment and carrying capacity (Delhaye 2010) may represent the local specificities (for example: goods, region or market) of the respective author's study.

There are new trends focusing on intermodal freight system choice[16] (Kim 2010). These studies highlight the shipper's financial preferences on the intermodal freight systems and deal with whether or not it should be chosen. Shippers' choices of the mode of transportation (air, sea, road rail, inland waterways or pipelines) are determined by the product (e.g. liquid, bulk or package) and the distance to be travelled. Each mode has different characteristics in terms of costs, transit time, accessibility and also different environmental performance. In intercontinental supply chains the choices are between deep sea and air and for continental chains or overland logistics the options are between road, air, rail, short sea ship and inland waterways. Air is often the preferred choice for time sensitive goods and types of high value goods (IT/electronics), while large volumes of commodities (like coal, iron ore) are economically transported by rail, inland barge or pipeline (in the case of gas or oils).

Intermodal transport systems offer the ability to serve smaller transport flows on relatively short distances. This could be achieved through implementing improved logistics, with frequent transport services serving more destinations. The downside of intermodal transport is that it requires more coordination than single mode transport (Dekker et al 2012). Multiple handling, especially at transhipment points, adds to costs and delays. Containerisation and other innovative infrastructural transport logistics have improved overall efficiency and reduced delays and other transport

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[16] 'System' choice is more appropriate than 'mode' choice in the context of this dissertation. Note, Cascetta et al. (2009) uses 'service' choice instead of 'mode' choice and 'system' choice

related negativities. An efficient transport concept should offer a stable and balanced flow of goods with optimised loading space utilisation along the route. The system should accommodate small flows over shorter distances for the system to be competitive and recognise both the internal and external components of transport logistics. Efficient management and bundling at transhipment terminals could offer an improved transport system, as the preferred sustainable choice, over unimodal urban services (Behrends & Flodén, 2012).

Managing the mixture of inland or dry terminals has improved the shift to rail based alternatives with a resulting reduction of road transit distances and a marked lowering in related negativities and environmental impact. Exploiting intermodal system' agility aspects have lowered the break-even distances to 400-600 km; where rail offered a competitive advantage over road (Klink & van den Berg, 1998; Nelldal, Sommar & Troche, 2008). There are a number of studies recommending measures of overcoming the perceived inefficiencies by adapting rail capacity, rescheduling departure times, using trucks parallel to rail lines, adapting train routes, assigning terminals dynamically, applying price incentives, improving information sharing and applying decision support systems (Davidsson, Persson & Woxenius 2007).

Norwegian freight transport studies revealed that about 50% of market tonnage was carried by rail (Hovi and Grønland 2011). The study compared transport costs for different commodities and the various modes; competitiveness was measured in cost efficiency and in NOK/ tonne-km (where km referred to the transit distance, while cost was the total transportation cost for the shipment. The factors defining the minimum rail distances, over road, depended on various factors, such as: commodity type, shipment size, consolidation possibilities, distribution distances and so on.

Figures shown in Table 2.8 reflect the Norwegian estimated costs (lead time and service effects, capital investment and inventory costs of alternative solutions, other time costs for goods, or external costs of transport, not taken into account).

Table 2.8 Minimum competitive distances for transport chains

Goods category	Rail	Ship	Railway direct access to Origin/ Destination	Ship direct access Origin/ Destination
Temperature-controlled goods	550	450	-	-
General cargo	250 (Vs. chain car-car-car, about 350 km)	600 (Vs. chain car-car-car, over 1000 km)	-	-
Manufactured goods	550	500	100	100
Dry bulk	-	-	100	100
Timber	550	650	150	-
Wet bulk	-	-	100	100

Source: Hovi and Grønland 2011

In the Norwegian coastal market, short sea has a high share in the dry and wet bulk sector. In order to transfer freight haulage from road to rail, the study recommended the following policy measures (in decreasing order):

- Increased taxes (fuel; emissions; congestion)
- Improved train infrastructure with better scheduling and longer trains;
- Lower terminal transhipment costs for road/rail/sea.

The measures that lead to the largest modal shift from road to sea were:

- Increased fuel taxes
- Removal of commodity tax at ports,
- Reduced port terminal costs,
- Removal of docking fee and port call charges and
- Improved port infrastructure (deeper draught, intermodal facilities)

The removal of commodity taxes and other port charges and increased maximum draught promote the modal shift from both road and rail, while higher fuel taxes and reduced terminal costs only contribute to the modal transfer from road transport. (Hovi, and Grønland, 2011)

North American studies in determining the mode swap from road to sea or rail (MariNova Consulting, 2005, 2009; Kruse et al 2010) were based on transit distances. The authors suggested that coastal shipping offered competitive options for distances greater than 1000 nautical miles. Shorter distances favoured the road mode, time and conditions (Bendal and Brooks 2011) and the shippers would pay for added frequency of services (Puckett et al 2011). This emphasises the existence of 'trade-offs'. An earlier study (Brooks and Trifts 2008) along the Bay of Fundy concluded that shipping options were competitive against trucks, for distances under 1000 nautical miles. The 'package' could include price, transit time, frequency and reliability over different corridor distances and mode options as necessary input for making sound regulatory and policy choices. In spite of the significant supportive rhetoric of short sea shipping by governments, US government findings show that local freight interests were reluctant to swap over from road to coastal sea shipping (GAO, 2005).

SteadieSeifi et al. (2014) literature reviews reflected the development of multimodal transport models, since 2005, showing the shift to sustainable transport alternatives with new transport performances. The new models incorporated the simulated impacts of internalizing the external costs on multimodal freight flows over a real-life network (Beuthe et al. 2002). Zhang et al (2015) summed up that the increase in the diversity of new transport models had a positive influence on the national and international policies. The increased volume introduced diverse and innovative transport mode networks of types, performance, reliability and security. The new paradigm, with the multiple actors, would bring about new parameters in freight transport designs, decision making with new corporate strategies in cooperation and competition. The main criteria were based on competitive costing.

Similarly, numerous European case studies (e.g., Paixão and Marlow, 2002; García-Menéndez et al., 2004) did not offer a clear understanding for shippers to change over from road to either rail or short sea systems (Bendall and Brooks 2011). Selection of mode systems involves risk mitigation by balancing mode and route delivery time with costs.

2.5.2. ITCM Models

An intermodal system reflects a hub-and-spoke network with the commencement of the journey beginning at the Origin (node) to the intermodal terminal (hub), where the ILU transhipped onto another mode (main haul) along the O/D route. The cost of each component comprises the cost of ownership, insurance, repair and maintenance, labour, energy, taxes, and tolls/fees paid for using the network. In intermodal transport, the total cost for each consignment does include time costs (such as waiting, schedule, congestion, etc., which are dependent on the mode) plus the handling costs involved in transferring from one mode to another. However, the costs of investment in any additional infrastructure and/or rolling stock are generally not taken into account by the shipper.

Considering operational reasons, the cost per tonne-kilometre for drayage (pre- and post-haulage, usually by road) is often more expensive than the long-haul road rates. Combining this with other commercial issues, the shippers (or receivers), who are not seriously concerned about reducing CO_2 emissions, seldom use the intermodal system.

There are four main types of intermodal transport operations:

1. Drayage operations: planning and scheduling of transport between the origin to terminal; and from the final terminal the final leg to the destination.
2. Terminal operators, responsible for the transhipment operations from road to rail or barge, or from rail to rail or barge to barge;
3. Network operations: responsible for the infrastructure planning and the organisation of network transport (rail, inland barge, air, etc);
4. Intermodal operations: users of the intermodal infrastructure and services and responsible for selecting mode/route along the whole intermodal network;

Figure 2.5 illustrates the concept of intermodal freight for a road/rail system compared with a 'road- only' system. Administration and planning costs accounted for 6% of the total. (A simple sales model was assumed with haulage companies and shipping agents).

There are other demographic and firmographic processes that influence the land-use configuration and indirectly influence the transport demand. With the increased building of transport infrastructures, the urban planners also recognised the complex interactions between the transport network and the rest of the urban system. The core is the transport system; this is influenced by land-use, needs of society (people and businesses) and finally regulated by government plans and controls. Transport supply changes directly influence society (residential and work location choices of the population; business location decisions) thus influencing the land-use configuration.

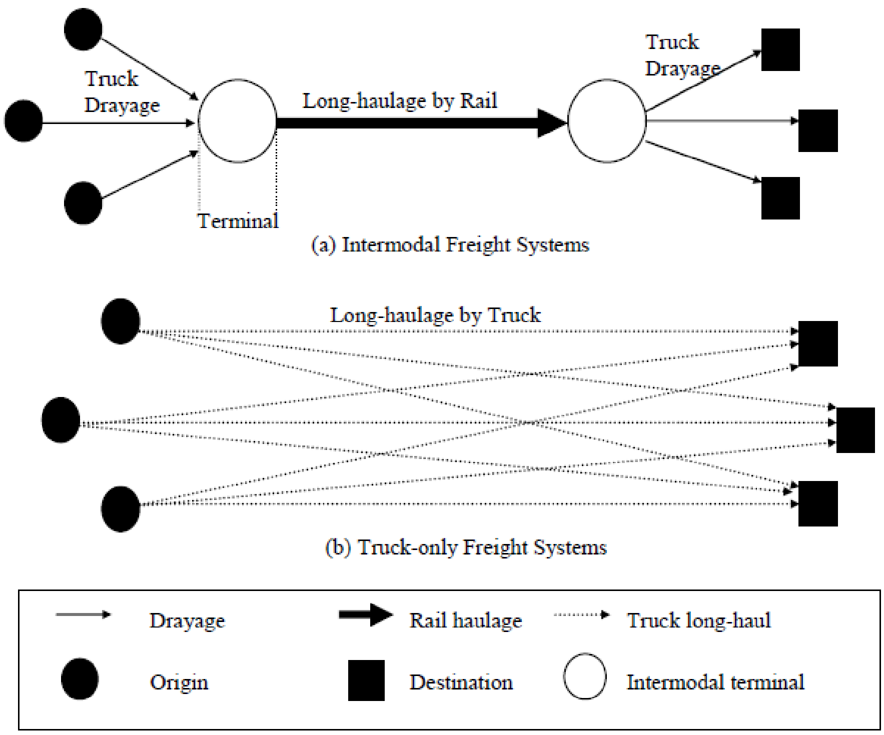

Figure 2.5: Intermodal system compared with road only freight Source: Kim (2010).

Figure 2.6 shows Southworth's (1995) assembly of the actors and stakeholders and complex interactions within the transport industry. A final piece within this interaction was environment, more so the negativities resulting from transport users (passengers and freight) from environmental emissions and socio-economic influences on the people themselves.

The environmental link was considered 'outside' the land use-transport system. However, it was recently asserted that in internalising environmental impacts that land-use and climate changes linkages became central (Sivakumar 2007).

2.6. Data Analysis

The research focuses mainly on the competitiveness of intermodality and its viability as the first choice for freight transport. EU research on freight records of tonnages, transit times and distances, the transport modes, etc. of the cargo flow database European Transport Policy Information System (ETIS) was addressed to determine the major O/D pairs for Europe. The ETIS database country resolution was at the NUTS-2 level and 10 NSTR commodity classes; it provided the distances between the ports of departure/entry connecting the major industry/population hubs within each specific NUTS-2 area. The sea distances used are the actual distances of shipping lanes, excluding the use of inland waterways (Kiel Canal, etc.).

The research literature sources mainly from the following sectors:

1. Published literature on transport models (Chapter 2.6)
    a. Transport models based on costs
        i. Models incorporating internal, external and time costs
2. Published literature on transport costs (Ch. 2.5.1)
    a. Data on transport cost factors of the available modes
        i. Collecting the relevant data
            1. EU 15
            2. EU 27
            3. Ireland
        ii. Collating the relevant data
            1. Sensitivity analysis
3. Published literature on infrastructure
    a. Transport corridors
        i. TEN-T
    b. International regulations and legislations
        i. EU regulations and legislations

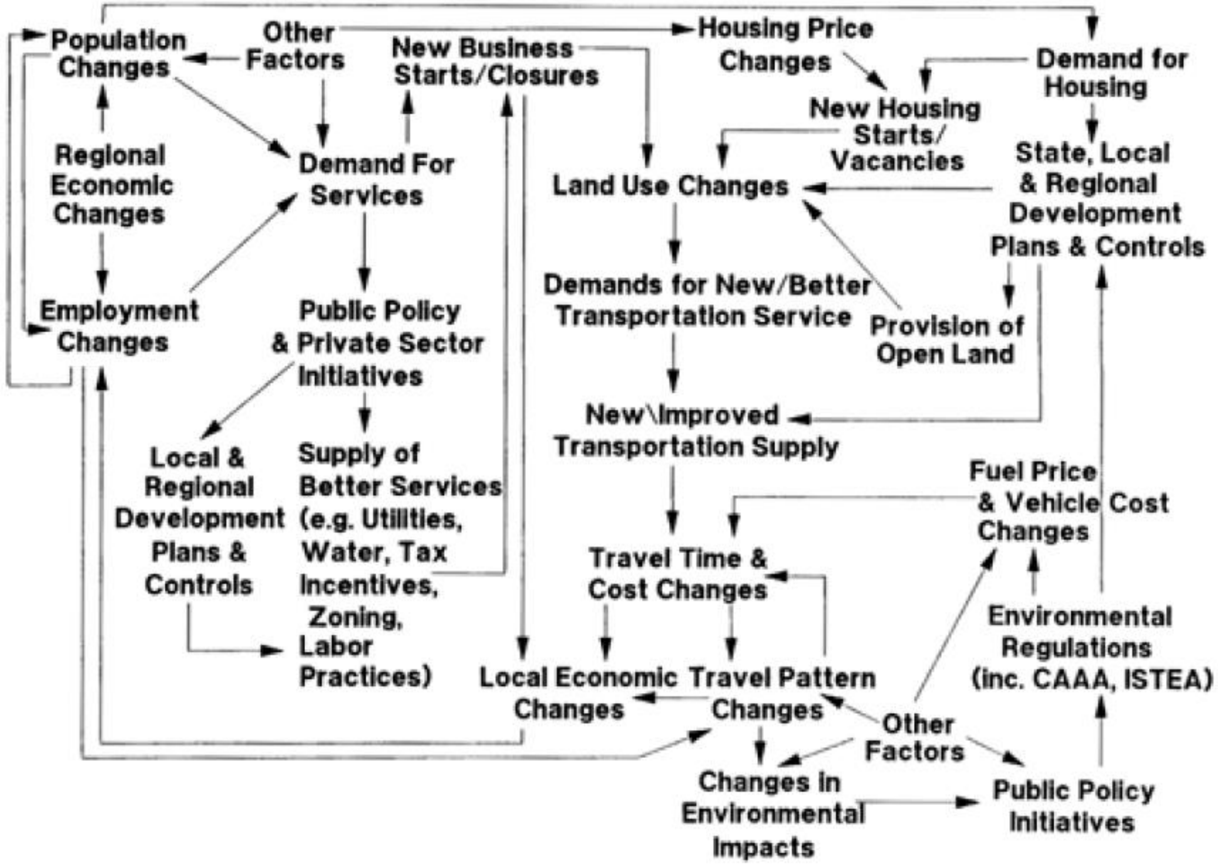

Figure 2.6: Complexity of functional linkages in urban system dynamics

Source: Referred by Sivakumar (2007) of Southworth (1995)

New trends Analysis of the data on freight transport costs reveals that the majority of the studies were based on road as the main haul mode (with general costs and efficiency) with a very limited number of studies on intermodal networks.

There was no literature dealing with the total costs (both internal and external) of the alternative modes available to shippers and stakeholders in the Irish freight market. This research aims to address this deficiency.

This ITCM considers the rationale for intermodal transport systems in its fullest application. The ITCM evaluates the total costs: internal and external (transport emission and social costs) and time components of freight transport costs. The research builds on the existing academic research concepts in transport economics of intermodal freight transport. The innovative element proposed in this thesis is analysis of the combined effects of general costs and the external costs and their influence on freight transport in Europe, especially in Ireland.

2.7. Practical significance

This section reviews the collected literature and analyses it with regards to the practical significance arising from this research. This research attempts to extend the existing definition of total transport costs by combining the three factors of internal costs, external costs and the time costs. The evaluated costs are used as a tool to seek alternative routes for the most competitive route/mode option. The literature is analysed under two broad remits and its influences on the theoretical and empirical remits of this research.

In the analysis of transport research there is a realisation of the outside influences on academic research, with the other main players being the policy makers and the market place. This thesis has several practical relevant influences.

Firstly it provides the transport users a new tool, based on total transport costs. It will allow the transport user (and in effect to the transport service provider) to select an optimal mode route and mode choice between one set of O/D.

This allows the ITCM to be an effective tool, with opportunity to select a sustainable mode and route combination along a route. Secondly, it provides policy makers with baseline projections of future transport infrastructure incorporating alternatives to road freight transport. This may provide a policy framework for assessing the likely changes (in tolls, taxes, incentives, etc) to reduce transport related externalities resulting from various policy measures. The research improves understanding of these trends which, from the industry perspective, are likely to exert the greatest influence on the Irish and North European freight transport sector.

The introductions of new regulations and legislations by the policy makers reflect the growing concerns of the environmental burdens arising from the transport related externalities. The recent changes to the EU Transport White Paper and the Irish transport policy changes confirm that the results have already entered the policy-making process.

The ITCM presented in this thesis can also be applied at the micro-scale, to serve the needs of an individual company. The research evaluates the total transport costs, along three routes, between the same O/D; it can be used to develop sustainable logistics through improved environmental performance. This might improve the future market practises by providing sustainable options over polluting mode/route combinations. This would provide the industry with a better base for a long term planning for the development of sustainable transport strategies.

2.7.1. Theoretical

The theoretical aspects of the research (Chapters 2 and 3), collated from the available literature and previous research on transport costs is reviewed to provide academic background to this research.The theoretical review was carried out based on two broad scopes: first scope was based on the commercial freight transport modes, choices and alternatives. The second scope was based on the theoretical aspects influencing policy issues of the transport industry governance and future of sustainable solutions.

2.7.2. Empirical

Reviewing the empirical aspects is set in Chapters 5 and 6. The analysis shows the difficulties arising from the earlier system dynamic (SD) models based freight transport models. Subsequent advances extended the SD model concepts to an infrastructural based freight transport model (Kuchenbecker 1999; de Jong et al 2004) and proposed new model structures that would allow detailed transport simulation and be instrumental as a forecasting tool. Thaller et al (2015) proposed that this methodology would enhance improved accuracy of the model's long-term forecasts or trend analysis abilities. The model could be manipulated and analysed at an infrastructural level. This linking approach would allow investigating impacts on the freight usage and the individual transport modes.

2.8. Summary

This section reviewed the available literature on intermodal transport, costs and efficiencies and finally the mode choice variables in medium to long-distance intermodal transport services. The overall available intermodal transport options were compared against a hypothetical road transport service. Competitiveness was assessed by measuring the performance of each transport option in relation to the mode choice variables in different demand scenarios.

The next chapter introduces the concepts of transport modes with its associated definitions of types, advantages and costs

Chapter 3

Transport Modes

3.1 Introduction

This chapter follows from the previous chapter reviewing literature related to the transport issues relevant to this thesis. The different transport modes and position within the freight structure and the various cost factors are presented. In the subsequent sections the sustainability concept is introduced and the magnitude of the environmental impact of all the freight transport is assessed. Overall, this chapter has a total of nine sections with four general divisions, as shown in Figure 3.1.

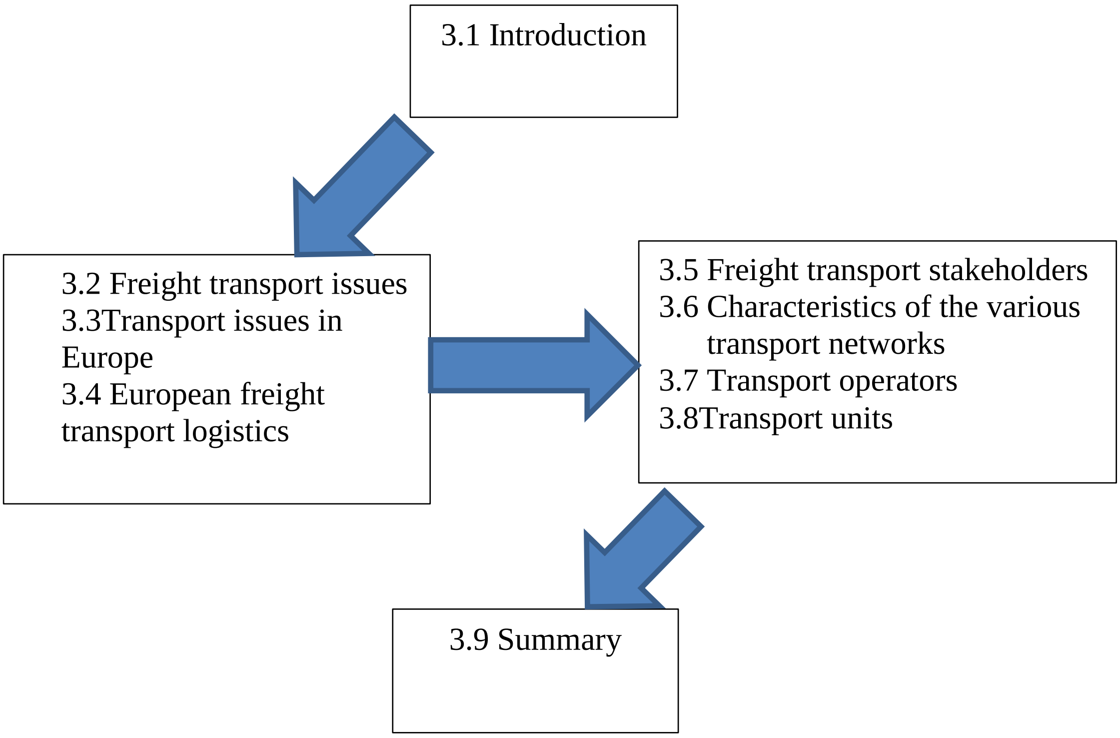

Figure 3.1 Flow chart of Chapter 3

This allows the ITCM to be an effective tool, with opportunity to select a sustainable mode and route combination along a route.

This section outlines the main freight transport modes and their characteristics (i.e. road, rail and water) within the context of this study. Each of the modes is assessed individually, explaining their main characteristics and how these modal attributes affect viable commercial operations. While this study considers each of the modes, it is important to recognise that the carriage of all the commodities is not considered, nor are the commodity flow-specific factors. This may give rise to an incorrect impression that certain commodities are not viable on certain modes for particular freight markets. A modern transport system is a key driver of a nation's industrial, economic development and prosperity. Efficient and effective transport facilitates the free flow of people, goods and services and contributes to productivity in all other economic sectors.

3.2 Defining freight transportation

In the EU, transport accounts for about 3.7% of GDP and about 5.1% of EU employment (EC 2012[17]) and connects the stakeholders and service providers in a globalised market. Radical changes brought about by the globalisation phenomena brought about a radical paradigm shift, especially in the supply chain premises within the freight transport industry. The challenge was to revaluate the existing systems and offer solutions for the market's new situation based on efficiency and corporate responsibility satisfying environmental and social concerns. The solution was to offer an innovative transport system for an international transport market incorporating the different operating and technical specifications of the transport modes in the EU transport sector. The concept of intermodal transport systems were promoted with stakeholders bearing the costs of the negativities caused by the ever increasing road based transport systems. It was necessary and responsible to consider procedures for shifting the main transport systems onto road and short sea through intermodal transport solutions. These required technological changes and were supported by EU legislation towards a cleaner transport and a responsible industry in the EU and Ireland.

[17] http://ec.europa.eu/competition/sectors/transport/overview.html

The freight transport records, measured in tonne-kilometres for road, rail, sea and total and real economic activity (GDP imports and exports) are collated from the available national and EU databases (CSO, Ireland and EUROSTAT, EU27). Road traffic congestion increased costs, delayed schedules thus affecting all the major industries by a total over €110 billion a year (Christidis and Rivas 2012) and its mitigation should be the main priority in planning traffic infrastructure, management and road charging measures.

Analysing the data in Table 3.1, shows very large variations of modal splits within the EU 28 countries, thus clearly reflecting the availability of an array of modal choices. The table shows the increase in the inland waters share of the freight transport in the Netherlands and the river transport along the Danube (Bulgaria and Romania).

Table 3.1 EU 28 Modal Split of inland freight transport (% of total tonne-kilometres)

	2008			2009			2012[18]			2013		
	Rail	IWL	Road	Rail	IWL	Road	Rail	IWL	Road	Rail	IWL	Road
EU-28	16.1	6.3	75.5	16.9	6.1	77.1	18.5	6.8	74.7	18.2	6.9	74.9
BE	-	-	-	11.0	12.2	76.7	11.9	16.5	71.5	11.8	15.8	72.4
CY	-	-	100	-	-	100	-	-	100	-	-	100
DK	9.0	-	91.0	9.0	-	91.0	12.4	-	87.6	11.2	-	88.8
DE	19.3	10.7	70.0	17.9	10.4	71.8	19.1	10.2	70.7	19.1	10.2	70.7
ES	4.8	-	95.2	4.0	-	96.0	5.3	-	94.7	5.3	-	94.7
FR	11.5	2.5	85.9	10.6	2.9	86.5	10.8	3.0	86.2	10.5	3.0	86.5
IE	0.7	-	99.3	0.8	-	99.2	1.0	-	99.0	1.1	-	98.9
NL	6.7	43.7	49.6	6.2	39.5	54.3	6.0	46.5	47.5	5.9	47.1	47.1
PT	9.7	-	90.3	9.4	-	90.6	12.8	-	87.2	12.7	-	87.3
SE	31.9	-	68.1	33.3	-	66.7	35.8	-	64.2	33.5	-	66.5
UK	11.2	0.1	88.8	11.7	0.1	89.0	11.6	0.1	88.3	12.8	0.1	87.1

Source: Eurostat Freight transport statistics (modal split Data from April 2015). Figures may not add up to 100%

[18] Belgium estimated values for 2012 and 2013

There has been a very marginal shift from road to rail within the UK and Ireland; this is in line with the trends across North West Europe, in both volume and tonnage.

The physical movement or transport of goods from origin to destination can be undertaken by one or more modes of transport. The different modes (air, sea, road, rail, inland waterways) have varying processes and information requirements. This partly stems from different infrastructures, different capabilities for handling larger or smaller amounts of cargo, but also from different international, national and even local regimes for a specific mode.

Transport modes and emissions are:

- Road, including private and commercial vehicles, buses, motorcycles, rigid and articulated trucks;
- Air, including domestic scheduled and general aviation and emissions arising from fuel uplifted for international travel (normally included under the category of international bunker fuels);
- Rail (passenger and freight), including electrified sources (though the emissions from electric powered rail are included in the stationary energy sector);
- Sea, including emissions arising from fuel uplifted for international travel (normally included under the category of international bunker fuels);
- Non-recreational off-road vehicle emissions.

The Central statistics Office (CSO) records the total transport emissions as the sum of all emissions from road and rail, domestic air and sea transport. Road transport emissions are categorised by vehicle type, including passenger vehicles, light commercial vehicles, rigid trucks, articulated trucks, buses and motorcycles. Air transport emissions are divided into domestic and international components, with the domestic component split into general air travel (charter services, helicopters, ballooning, emergency air travel, etc) and domestic air travel. Rail transport emissions are divided into passenger and freight sectors, with passenger rail travel divided further into heavy urban, non-urban, and light rail travel and the freight task divided further into government bulk, government non-bulk and private the freight task. Sea transport emissions are also divided into domestic and international categories.

Each freight transport journey may be divided in two sectors, primarily the pre main haul, or the ‘pre-haul’ and the ‘main-haul’. In the pre-haul section, the cargo unit is collected from the ‘origin’ to an intermediate of an intermodal hub terminal with access to a long distance carrier for the ‘main haul’. By its characteristics, the ‘main haul’ (road, rail or sea) delivers the cargo to the next/final intermodal/intermediate terminal; this section offers economical advantage over long distances. On the other end of the main haul, the final leg of the journey, post main haul, transports the freight to the destination. In view of the positioning of the industrialisation and carriage, often it is the road (truck) that does the pre-post haul transits. This intermodal and multimodal transport can lead to complications and trade facilitation issues such as the use of waybills for other modes of transport.

Transport by air and sea usually includes transport by other modes of transport for pre- and post-carriage (road, rail, inland waterways) modes. Multimodal transport consists of the use of more than one mode of transport, but also involves its own equipment, particularly in rail-road movements through specific equipment that can be transferred from truck to wagon.

International Transport Conventions settle the movement of goods through the different modes of transport, or in multimodal and intermodal transport. They define the legal framework in which transport operates and the liabilities between the parties involved in freight transport. For every mode of transport there is at least one International

Transport Organization responsible for the parties in that mode. These can be summarised as:

- **Air**: The International Air Transport Association (IATA) is a non-governmental organization representation over 240 airlines, comprising 84% of total air traffic. IATA has standardised the operations and documentation in compliance with the governmental regulations and requirements. The International Civil Aviation Organization (ICAO) is a specialised agency of the United Nations created to promote the safe and orderly development of international civil aviation. It sets standards and regulations necessary for aviation safety, security, efficiency and regularity, as well as environmental protection. The organisation serves as the forum for co-operation in all fields of civil aviation among its 191 members.
- **Inland Waterways**: ERI in Europe
- **Maritime**:
  - International Maritime Organisation (IMO) is a UN agency. Its mission is to develop and maintain international rules for shipping, which include safety, environmental concerns, legal matters, technical co-operation and efficiency in shipping for its 167 member states. The IMO's influence extends to trade facilitation and security in cross-border related trade.
  - International Chamber of Shipping (ICS) and the International Shipping Federation (ISF) are the principal international trade association and employers' organisation for merchant ship operators representing about 80% of the world merchant fleet (UNECE 2012).
- **Rail**: The International Union of Railways (UIC) is a non-governmental organisation representing the railway industry. UIC sets and publishes standards for the exchange of information between railway companies and railway infrastructure operators.

- **Road**: The International Road Transport Union (IRU) represents the interests of truck operators (as well as the interests of bus, coach and taxi operators) worldwide for the mobility of people and goods by road.

3.2.1 Road freight transport

Road freight transport is an indispensable sector for national economic activity. It has developed very dynamically in the EU. Inland transport covers all transport activities that go over land, i.e. all modes but air and maritime transport. It hence includes transport by road, by rail, on inland waterways and through pipelines. Transport by rail and on inland waterways suffered more heavily during the most recent economic crisis but is now recovering and this recovery is accelerating. The transport of bulky goods, which usually go by rail or inland waterway, appears to be more cyclical than the transport of other goods. Measured in tonne-km, rail freight transport activity in the EU lost 2% in 2008 and 18% in 2009 before growing by 8% in 2010.

In the studies on road freight, the following attributes are considered:

- Available network
- Capacity of mobile assets (both volume and cubic capacity)
- Assets required for handling goods
- Mobile asset costs and life
- Flexibility of equipment
- Speed and reliability

Road vehicles are usually the primary mode in the drayage stages (pre-haul and post-haul) and are an almost universally available option for moving goods between businesses and from businesses to consumers. The cost functions computed are based on Gross Vehicle Weight (GVW)-based truck classification. Typically, heavy-duty trucks (HHDT) used for intermodal drayage, produce higher engine emission characteristics compared with light and medium heavy-duty trucks (Floden et al 2010). The costs associated with a road-rail intermodal move, for example, can be divided into two drayage cost components (costs of drayage from point of origin to the intermodal terminal and from the intermodal terminal to the point of destination), line-haul cost and terminal handling costs at the two intermodal terminals. For distances exceeding the intermodal market area, the drayage costs relative to the total intermodal transportation costs become too prohibitive for the entire truck-rail intermodal move to be cost-effective.

Load capacity Heavy goods vehicles come in different sizes starting from a load capacity of 3.5 tonnes which more or less corresponds to a maximum permissible laden weight of 6 tonnes. Smaller heavy goods vehicles, those with a maximum weight of up to 20 tonnes, account for almost a quarter (22%) of all heavy goods vehicle-km. Roughly half of all heavy goods vehicle-km come from vehicles with a maximum weight of between 20 and 40 tonnes. Vehicles with a maximum weight over 40t account for 30% of all heavy goods vehicle-km. The heaviest vehicles appear to be slightly more used by EU15 hauliers than by EU12 hauliers: they account for 33% of all vehicle km of EU15 hauliers, but only 20% in the case of EU12 hauliers

3.2.2 Rail freight transport

In spite of the incentives for a conventional ‘wagonload’, growth has stagnated. However, road-rail combined transport (CT) has registered high growth rates (See Fig: 3.2). Big cities are linked by direct trains at competitive costs and speeds compared to road. The share of CT in the performance of freight transport (tkm) of European railway undertakings currently represents 25-40%. More than 1200 freight trains per working day, each with an average transport capacity of 25 truckloads, travel 500km on national and 950km on cross-border routes, which in comparison with road freight transport results in a 75% reduction of CO_2 emissions.

Figure 3.2: Road-rail combined transport (CT)
Source: Gesamtverband der Deutschen Versicherungswirtschaft e.V. (GDV), 2014

3.2.3 Marine transport sector

The water side of the intermodal transport system offers the inland water ways and the short sea services.

The use of intermodal sea transport is encouraged as is more environmentally friendly and often cheaper than road transport. In this framework many European measures have been developed, such as the Motorways of the Sea (European Commission Programme).

Short sea and feeder services

The modern terms short sea shipping, marine highway and motorways of the sea refer to the historical terms coastal trade, coasting trade and coastwise trade, which encompass the movement of cargo and passengers mainly by sea, without directly crossing an ocean (EC 1999b). Deep sea shipping, intercontinental shipping or ocean shipping refers to maritime traffic that crosses oceans. By definition, Short Sea Shipping (SSS) is the transport of goods and passengers in the European Union, or between the latter and non-European riverside countries in the Mediterranean, Black and Baltic Seas and Norway and Iceland. In Europe short sea shipping refers to coastal trade and the ‘marine highway’ in the United States (Brooks 2009).

The maritime transport exhaust emissions can be further reduced by two means; firstly, with better technologies related to fuel types, fuel systems and scrubbing the exhaust gases towards reducing the overall negativities per tonne kilometre and secondly through the promoting of an integrated intermodal system, with ecologically sound transport solutions. This would further improve the sustainability of short sea shipping through increased use of the mode. Shipping, in addition to its environmental advantages, offers a comparatively safe mode of transport.

The short sea sector is usually connected to the deep-sea international service, where mother vessels terminate their voyages allowing cargo to be transported onwards, either to the hinterlands or along coastal trade routes. Usually the mother vessel has bigger dimensions and only goes to the hub ports in which feeder ships operate. Short sea shipping operators provide national or continental connections between ports or for a door-to-door chain. In most cases short sea shipping offers alternatives to competitive road transport routes. The feeder service uses small vessels to connect the hub port(s) to the near local ports where the freight is unloaded to reach its final destination. In the case of a feeder service the feeder vessel is dependent on the mother vessel, both for operational activities and for the time schedule. Conversely, short sea shipping is a completely independent service that has fixed liner services and its own departures/arrivals timing. In several cases short sea shipping operators are also integrated into the land service provision for road or rail transport.

Short Sea Vessels: Lift-On Lift-Off (LoLo)

Lift-on/Lift-off (LoLo) vessels transport a range of different products as a result of their flexible cargo space, container capacity and on-board cranes. A LoLo operation is when containerised cargo is loaded and discharged, into the vessel's holds, using shore cranes or ship's derricks. The numerous types and application and the flexibility of services makes the feeder container ships often used in comparative studies[19]. Feeders collect shipping containers from different ports and transport them to central container terminals where they are loaded to bigger vessels. In that way the smaller vessels feed the big liners, which carry thousands of containers. Feeder vessels range in various sizes (lengths, breadths and draughts) but mostly with an average capacity of 1000 TEUs (6.1m twenty-foot equivalent units TEU). Feeder ships are often run by companies that also specialize in short sea shipping[20].

For this research, the common criterion was the vessel's sizes and the available data within the three transport corridors (Hjelle & Fridell, 2012, Mellin et al 2013). The characteristics of the container feeder selected were: 1000 TEUS with a gross tonnage (GT[21]) of 13000 and an assumed load factor of 70% (Mellin et al) Heavy fuel oil (HFO) containing 2.7 % sulphur was assumed to be used at 80 % and 20 % HFO with 1 % sulphur content for the 6 West to Istanbul transits. Meanwhile for the Rotterdam-Gothenburg route, marine fuel HFO with 1 % sulphur was assumed to be used (due to ECA regulations on sulphur content). Tier 1[22] was assumed for the emissions of nitrogen oxides (NO_x) from the vessel for both routes.

Short Sea Vessels: Roll-On Roll-Off (RoRo) and Roll-on Passenger (Ro-Pax)

Ro-Ro trade focuses primarily on national and continental markets and has no connection with deep-sea trade. In most cases Ro-Ro vessels characterized by accompanied transport and very often by Roll-On-Passenger (Ro-Pax) vessels are employed for combined freight-passengers transport. The intermodal sea transport

[19] Note that the environmental impact of short sea shipping is strongly dependent on ship type and size. For cases when small RoRo and container vessels are among those with the worst environmental performance, see Hjelle & Fridell (2012).
[20] Note that the environmental impact of short sea shipping is strongly dependent on ship type and size. For cases when small RoRo and container vessels are among those with the worst environmental performance, see Hjelle & Fridell (2012).
[21] Gross tonnage is the total of all enclosed spaces within a ship expressed in tonnes, expressed as equivalent of 100 cubic feet.
[22] Part of the MARPOL convention and regulates the allowed levels of NOx emissions from marine engines. Tier 2 was introduced in 2011, and Tier 3 will be introduced 2016 (IMO, 2008).

market is rather heterogeneous, since a large variety of operators are involved; which differ by geographical coverage, company dimensions or by the typology of services provided. Some big international maritime companies that provide deep-sea transport can decide to provide both feeder and short sea shipping services. In Europe, short sea shipping operators are mainly national or European companies that in some cases also provide road or rail services.

3.2.4 Inland waterways

In Europe inland waterway transport plays an important role for the transport of goods. In about 20 out of 27 Member states, with over 37000 kilometres of waterways networks, it offers a competitive alternative to road and rail However, EU inland waterways transport performance in millions of tonne-kilometres (Tkm) in 2011 was 4.9% lower than in 2010[23].

Figure 3.3: Inland canal barge with Lo-Lo containers

Source: Wikipedia

In a study of inland navigation (Buck final report PINE 2004) classifies the main factors in the classification of vessels [24] as river (canal) barges (see Figure 3.3); Lakers (designed and built to specific conditions for the lake area); River-sea vessels (sea-going

[23] http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-12-042/EN/KS-SF-12-042-EN.PDF
[24] http://ec.europa.eu/transport/modes/inland/studies/doc/2004_pine_report_report_concise.pdf

vessels equipped also for inland waterways).There are several other classifications and sub-classifications (i.e. hull material hull, structural and hydrodynamic particulars, type of the prime-mover (engine), commodity to be transported or type of service to be provided.

1. Installed machinery (self-propelled and non-self-propelled vessels)
2. Type of propulsion
3. Fleet operations floating regime when running
4. Type of the hull configuration (conventional mono-hulls, twin-hulls, trimarans)

3.2.5 Intermodal transports

Intermodalism has been defined by different segments of the freight transportation industry, for example, in the international seaborne shipping industry; intermodalism implies cargo transport in standard shipping containers. There have been several definitions offered (Hayuth, 1987; Rutten, 1998; Slack, 1996; Woxenius 1998) for intermodal transport systems involving intermodal loading units (ILUs) for transporting and transhipping on different transport modes (e.g. road, rail, inland shipping, short-sea shipping, deep-sea shipping and air). During the transport journey, at least two different transport modes have been utilized during the transit origin to the destination. The ability of carriers to provide the shipper with one bill of lading is also a crucial element of intermodal transport (Hayuth, 1987).

Here intermodal, multimodal and combined transport is defined by the European Commission (COM (97) 243 Final of 29/5/1997): *Intermodality* has been defined as ‘a characteristic of a transport system whereby at least two different modes are used in an integrated manner in order to complete a door-to-door transport sequence’. An efficient design of the transport logistical supply chain integrates the modes, the terminals, levels of infrastructure, ICT and hardware (e.g. loading units, vehicles, and telecommunications), operations and services, as well as the regulatory conditions (see figure 3.4). The Directive in 1992[25] aimed at establishing common rules for the sector, and promoting combined transport (CT).

Under its terms, CT is defined as: *"The transport of goods between Member States where the lorry, trailer, semi-trailer, with or without tractor unit, swap body or container of 6.06 m (20 feet) or more uses the road on the initial or final leg of the journey and, on the other leg, rail or inland waterway or maritime services where this section exceeds 100km as the crow flies and makes the initial or final road transport leg of the journey;*

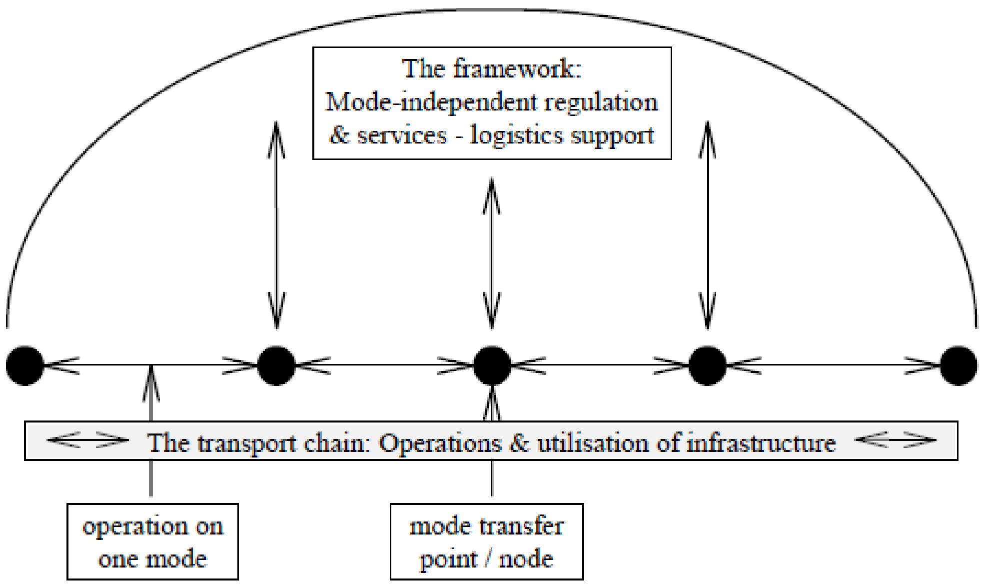

Figure 3.4 The Intermodal chain
Source: European Commission European Commission

- *Between the point where the goods are loaded and the nearest suitable rail loading station for the initial leg, and between the nearest suitable rail unloading station and the point where the goods are unloaded for the final leg, or;*

[25] Council Directive 92/106/EEC of 7 December 1992 on the establishment of common rules for certain types of combined transport of goods between Member States

- *Within a radius not exceeding 150km as the crow flies from the inland waterway or seaport of loading or unloading."*

Combined transport (ECMT): Intermodal transport, where the major part of the European journey is by rail, inland waterways or sea and any initial and/or final leg carried out by road are as short as possible.

Intermodal freight transportation involves the use of two or more modes of transportation in a closely linked network for the seamless movement of goods. There is a difference between multi- and intermodal transports; *intermodal* transport implies the use of a single intermodal load unit (ILU) to simplify the loading, reloading and unloading processes in all parts of the transportation. In the case of *multimodal* it is clearly stated that there is more than one mode of transport involved in the delivery. Intermodal freight transport is typically associated with containerization, or in more general terms the transport of goods involving direct transfer of equipment between modes without any handling of transported goods. ILUs allow the transportation and subsequent transhipments with simpler and faster handling and the avoidance of further 'stuffing and stripping of the containers' at the intermodal terminals. Stuffing takes place at the 'origin', prior to commencement of the transit and 'stripping' or emptying takes place at the destination.

Summarising the different strands that intermodal transport consists of:

- The intermodal system which utilises more than one mode of transport under this unique concept. There is a predominance in the usage of the rail mode, as the main transport mode and as an alternative to road only transport. However, road transport is still the primary pre-haul and post haul mode in the transport chain.
- The loading unit, with the goods, which are transported by the different modes along the entire door-to-door transport chain.

- The loading unit may be an ISO-container, a swap body, a trailer, a semi-trailer and termed an intermodal loading unit (ICU)

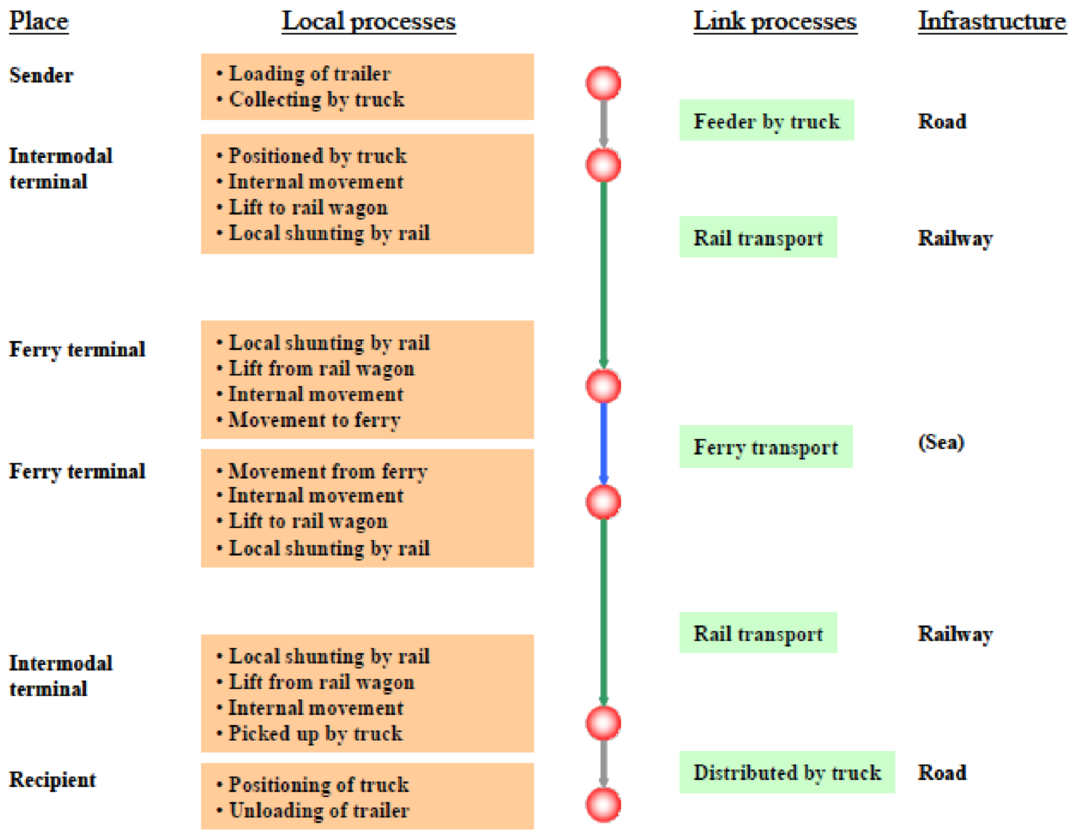

Figure 3.5: Connecting links with the various intermodal systems
Source: Troche (2009)

Within the logistics systems, links connect these nodes representing - highway segments, railroad segments, etc. and are a function of:

- Traversing cost (money, time, length, generalized cost)
- Capacity
- Mode
- Speed
- Flow, etc.

Intermodal transport solutions incorporated the cargo operations of freight units (containers transferred from a containership onto rail cars or a highway trailer from a truck to rail cars) within transhipment systems at intermodal terminals (See Fig 3.5).

3.2.5.1 Liabilities of the intermodal transport system

Technical incompatibility between the transport modes infrastructures were one of the main obstacles for a seamless operating system across Europe. Studies (Intermode Trans 2004) concluded that the main issues were:

- Incompatibility between the different available technologies and tools.
- Lack of terminal technologies to cope with increased demand from transport.
- Lack of standardisation and interoperability of transport technologies to allow easy handling and moving of goods.

A seamless platform would allow the manufacturers, the industry users and service providers improvements in total services (the–scheduling, savings in transit times) etc. For the industry, the priorities were: reduced environmental damage reduced road congestion and improved overall transit time with micro-economic advantages. Redesigning the transport supply chain with embedded intermodal terminals would satisfy both the users and the shippers. The Task Force on Intermodal Transport Statistics (TF IMTS 2011) identified the economic, social and employment impacts of intermodality 'to achieve a better use of existing capacities and infrastructures, notably in rail, inland waterways and short-sea-shipping'. The study identified very high local/urban congestion in the following countries: Ireland, United Kingdom, Poland and Hungary. The IMTS (2011) suggested that embedding intermodal concepts would extend sustainable policies of fair, efficient pricing and extend environmental and social benefits. Intermodal Transportation Systems (ITS) are logistics networks integrating different transportation services designed to move goods from origin to destination, in a timely manner and using multiple modes of transportation (Caris, Macharis, & Janssens, 2008; Macharis & Bontekoning, 2004). Following on, a process to manage ITS efficiently was based on a three-level hierarchy: strategic, tactical and operational. At the strategic level ITS design considered time horizons over a few years, requiring approximate and aggregate data. Tactical level planning involves the optimization of the flow of goods and services through a given logistics network.

Review of US literature highlights six critical factors relating to the implementation of intermodal transport system (Jones and Turner 2004) as shown in Table 3.2.

Table 3.2: Perceived critical issues in intermodal transportation planning

S. No	Issue	Percentage
1	Public/Private capital investment: Feasibility and development of pilot projects for intermodal terminals	26
2	Economics and land use a) Economic impact of multimodal/intermodal transportation on state highway construction program and economy b) Economics of truck/rail intermodal facilities c) Ability to assess freight-oriented capacity of highway facilities d) Transit-friendly development and local land use	20
3	External Data a) Climate change i) Emissions of CO_2 /other global warming gases b) Waste i) Vehicles, fluids, tyres c) Air pollution i) Local emissions of CO, PM, lead, VOCs, hydrocarbons and NOx d) Noise and related data	19
4	Capacity analysis: a) Improving the imbalance of inbound/outbound truck and rail freight shipments	18

	b) Opportunities for intermodal facilities c) Demand of intermodal transportation facilities with increasing capacity d) Cost/benefit analyses for comparison between modes passenger/freight system e) Reduced truck demands on highways	
5	Training and education a) Identifying methods to reduce shipper captivity by a single freight mode or single line service b) Methods for freight demand forecasting and freight network identification	10
6	Corridor definition a) Promoting connectivity among modes b) More effective planning methodologies, models, etc. that support integrated intermodal planning c) State-wide multimodal commodity flow study d) Commodity flows at individual corridor level e) Environmental streamlining alternatives for intermodal connectors f) Value of short line freight to state	7

Source: Jones & Turner 2004.

Concepts promoting intermodal solutions, especially for the 250-500 km range, failed to extend across the EU arising from the differing degrees of application of the principle of subsidiarity [26] (Woxenius 2008; Woxenius & Barthel, 2008). The four cases of intermodal transport below are competing with road transport, solely on freight operation factors.

- *Large flows over long distances* (LFLD): Intermodality is ideally suited, with trains (rail) linking the intermodal terminals, with regular, frequent scheduled links to improve turnaround.

[26] The principle of subsidiarity is one of the fundamental concepts in the decision making process of the European Union (EU). The principle of subsidiarity determines the most relevant level of intervention in the areas of competences shared between the EU and the Member States.
Subsidiarity and proportionality are corollary principles of the principle of conferral. They determine the extent EU can exercise the competences conferred upon it by the Treaties. By virtue of the principle of proportionality, the means implemented by the EU in order to meet the objectives set by the Treaties cannot go beyond what is necessary.

- *Large flows over short distances* (LFSD): There are two issues in productivity matters. Firstly, a very good transport link, between origin and destination is required to compete with road transport. Secondly, there are relatively short distances between the intermodal terminals with frequent short stops at these terminals. When embedded within the LFLD flows, this may offer efficient solutions in a network with the ability to handle large amounts of cargo.
- *Small flows over long distances* (SFLD): Intermodal solutions for small flows are not competitive; however, for longer intermodal distances combined with corridor flow and larger volume on parts of the distance, it is still competitive.
- *Small flows over short distances* (SFSD): The situation is the most difficult for an efficient model. Intermodal transport has a higher fixed cost than road transport and in the case of small flows these costs cannot be shared by enough shipments to be competitive with road transport.

3.3 Economic concepts related to EU transport

Globalisation of world economies underpinned the large increases in the real GDP of EU15 and Ireland, between 1960 and 2004, which spurred large increases in aggregate freight transportation activity. Early studies by the Intergovernmental Panel on Climate Change (IPCC 2007) indicated that global greenhouse emissions from the transportation sector increased by 120 % between 1970 and 2004.

Transport economics defines transport cycles as simple or complex. In its simple form, transport freight cycle completes one basic operation of loading/unloading cargo. The complex sector includes more than one mode of transport, thus more handling operations (Marchese 2001). Intermodal transport is defined as a complex transport’s cycle as it employs more than one transport mode during its whole journey with more handling activities needed. The additional operations allow further value added opportunities, offering employment benefits to the economy and society. Transport services accounts for about 4.2% of total employment and about 4.3% of total value added in the EU[27]. These figures do not include value added to the economies from the construction and maintenance of transport infrastructure and of transport means (i.e. road vehicles, ships, trains).

The proposed amendment of Directive 1999/62/EC allows for the introduction of charges to freight vehicles proportional to the damages they cause in terms of air pollution, noise damages and congestion. The amendment proposal outlines the areas of application, the methods for the calculation of the charges and the maximum charges to be applied on a specific road segment.

The European Commission's White Paper "European transport policy for 2010: time to decide" (CEC, 2001) laid out the three main pillars for transport policy; it required that transport be sustainable from an environmental, economic and social standpoint. These three tenets would be the main influence for the environmental goals of transport policy. A following document (EC 2006a), focused on the need for sustainable mobility and indicated the need for all modes of transport to become more environmentally friendly, safe and energy efficient?

Table 3.3 sets out the main expected impacts brought about by the supplementary road charges. Transport related external influences are directly related to the transport mode. Measures to mitigate the polluting effects may promote alternative options and stimulate new technological innovations, with organisational changes, that would lead to efficiency gains.

Alternative transport modes offering competitive options in some market segments and in most cases with lower levels of externalities, will reduce overall external costs.

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[27] Source: Eurostat 2012 DG MOVE transport urban freight

Table 3.3 Quantification of main expected impacts from road charges, EU-27

	Impact mechanism	Annual benefit (million €)
1	Modal shift (decrease in road traffic, increase in other modes)	295
2	Efficiency gains (increase in load factors, vehicle utilization)	200
3	Technology renewal (shift to EURO V)	100
4	Indirect benefits (better use of transport infrastructure)	60
5	Consumer welfare (mobility)	- 20
	Total welfare benefits	€ 635

Source: Christidis and Brons (2009)

In conclusion, the overall benefits of charging for external costs outweigh the limited negative price impacts on individual transport operators. There is though a possible future improvement that could increase the benefits for society as a whole even more: applying external cost charges for passenger transport and for other transport modes following the same principles of internalisation would provide a level playing field and stimulate sustainable solutions for the whole transport system.

European transport's "sustainable mobility" policy cornerstone has been the ability to offer alternatives to road transport. This policy promotes the concepts of intermodal transport between Member States (Council Directive 92/106/EEC 1992[28]). Subsequent initiatives expanded this concept ('Green freight transport corridors' launched as the 'Freight Transport Logistics Action Plan 2007;' Trans-European Transport Networks TEN-T; the Green Paper EC 2009) on to alternative modes as rail and water (inland canals and short sea shipping).

3.3.1 EU transport programs Marco Polo Programme

[28] Later amended by COUNCIL DIRECTIVE 2006/103/EC

EU Road freight transport is entirely dependent on fossil fuel and is thus a major CO_2 contributor. Therefore, greater recourse needs to be had to intermodality, which makes better use of existing infrastructure and service resources by integrating short sea shipping, rail transport and inland waterways into the logistics chain. It is in this context that the Marco Polo Programme (2003-2006) aims to shift freight from the roads to more environmentally friendly modes. The Marco Polo programme promoted three types of project:

1) Modal shift actions to shift road traffic to other modes of transport by providing start-up aid for new non-road freight transport services.
2) Catalyst actions; innovative measures to overcome structural barriers in the market. This would involve setting up alternatives, as motorways of the sea or high quality international rail freight services, operated on a one-stop shop basis. These actions should change the way in which non-road freight transport operations are carried out and use trans-European transport networks or pan-European corridors.
3) Common learning action to step up cooperation and knowledge transfer among operators in the freight logistics market to improve European environmental performance.

The Marco Polo II programme (2007-2013) extended the initial programme of (modal shift, catalyst and common learning actions) promoting a shift away from road freight transport, heavily dependent on fossil fuels, to a more widespread use of intermodality. The proposals for Marco Polo II had two additional new features:

1) Wider geographic scope: to provide for a better environmental performance of the transport system within the EU, intermodal options and alternatives to road transport must also be considered outside the EU;

2) New action types: the next Marco Polo programme needs to achieve an overall reduction of international road freight transport via the development of motorways of the sea and traffic avoidance actions.

The Commission's initiatives towards improving the infrastructure, cooperation between infrastructure managers and investment in rail infrastructure (COM 2007 608 final)[29] was encapsulated in the Trans European Network TEN-T programme;

The objectives of the Trans-European transport network (TEN-T) were to:

- Ensure the mobility of persons and goods;
- Offer users high-quality infrastructure;
- Include all modes of transport;
- Allow the optimal use of existing capacities;
- Be interoperable in all its components;
- Be economically viable;
- Cover the whole territory of the European Union (EU);
- Allow for its extension to the Member States of the European Free Trade Association (EFTA), the countries of central and Eastern Europe and the Mediterranean countries.

The European Commission (EC) Europe 2020 Strategy includes proposals for the Roadmap *for moving to a competitive low carbon economy in 2050*[30] (EC, 2011a – further referred to as 2050 Roadmap) and *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system* (EC 2011b Transport White Paper) were published in March 2011.

[29] European Economic and Social Committee Commission's opinion on - Freight Transport Logistics Action Plan COM (2007) 607 final, (2008/C 224/10)
[30] EC (2011a) A Roadmap for moving to a competitive low carbon economy in 2050, COM (2011) 112 final, European Commission. Brussels. http://ec.europa.eu/clima/policies/roadmap/documentation_en.htm

3.4 EU freight transport logistics

Trans-European networks (See Appendix 7) supply an infrastructure for projects of common interest and also improve the intermodality of transport. Specifically, they stimulate investment in order to foster the emergence of an integrated transport network covering all of the Community and encompassing all the different modes of transport.

A system choked by bottlenecks reflects the incorrect design of the transport infrastructure (intermodal platforms), operational efficiency and information exchanges. On-going measures concentrate on:

- Removing bottlenecks and reducing costs
- Exploring information and communication
- Facilitating efficient operations.

The successor of the Trans-European Transport Network Executive Agency (TEN-T EA) is the Innovation and Networks Executive Agency (INEA), managing the technical and financial implementation of its TEN-T programme in January 2014.

3.4.1 Ireland

Historically, the Irish economy was agriculturally based and freight transport was virtually confined to the movements of low value high volume products. However this has changed significantly altering the profile and structure of the goods requiring transport systems for high value products (Beresford et al 2002). Figure 3.6 shows the transport routes connecting Ireland to the UK and mainland Europe.

The OECD (1999) reported that Ireland’s phenomenal growth in the economy commonly referred to as “the Celtic Tiger” was not the result of a single issue. Many of Ireland’s major exporting sectors (pharmaceuticals, chemicals and food) were heavily reliant on Ireland’s maritime freight, with over two thirds shipped by means of combined transport, road freight and roll-on roll-off (Ro-Ro) services. There are four main Ro/Ro corridors connecting Ireland, with three corridors, northern, central and southern to Great Britain and the fourth corridor to France and the Benelux countries.

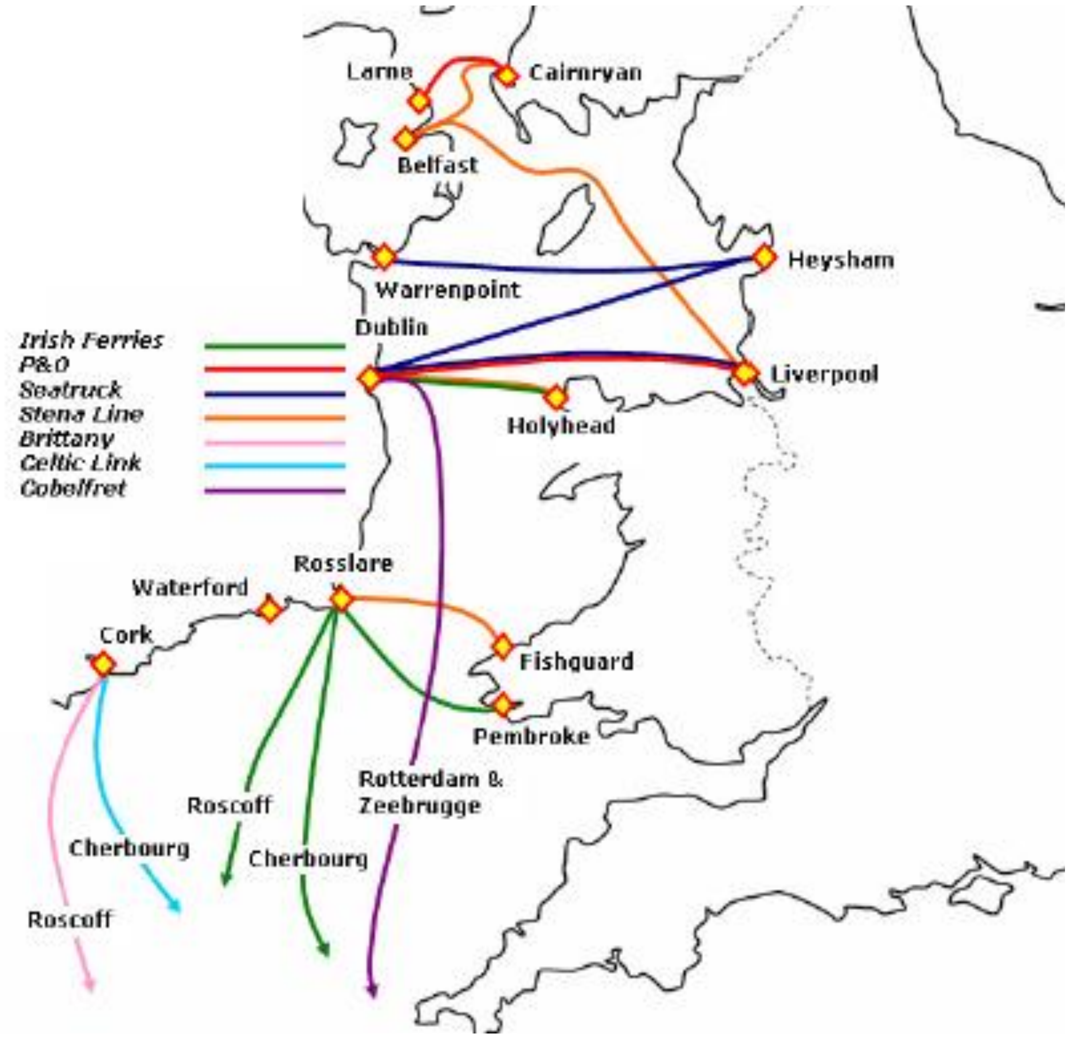

Figure 3.6 RoRo routes from Ireland
Source: Competition Authority 2012, Ireland.

The busiest RoRo routes are the northern corridor (46% of the market) and the central corridor (42% of the market) with about 83% of all Ro/Ro traffic having a final destination in Great Britain[31], a further 15% of all Ro/Ro traffic using the land bridge for accessing mainland Europe. On an all-island basis, 7% of Ro/Ro traffic is shipped direct to mainland Europe from Ireland (IMDO 2012). Ireland's continued economic

[31] Some Irish exports are ferried by Ro/Ro and connect with international flights out of London

growth was driven by its export-orientated economy, exporting 84% per cent (by volume) of all it produced[32]. The new demand for freight transport systems, driven by goods with modern logistical profiles, required complex transportation chains; within a growing global logistics market economy. Table 3.4 shows the maritime trade between Ireland and its trading partners.

Table 3.4: Irish maritime freight handled in 2007, 2010 and 2013 ('000 tonnes)

Total Maritime freight	2007	2010	2013
Great Britain & Northern Ireland	20351	18002	17028
Other EU economies	18118	14948	15944
Non EU economies	4482	3355	2769
Foreign trade	9264	7028	8167

Source: CSO 2014

Great Britain's geographical proximity, similarity of cultures and advanced distribution networks contribute to the importance of this market.

3.4.2 United Kingdom

The main network corridor crossing the North Sea-Mediterranean Corridor connects Belfast and the Irish ports (Cork and Dublin) to the UK network and onto Belgium, with branches to Amsterdam and Rotterdam. Figure 3.7 shows the transport connections of rail, road, airports, ports and the inland water-ways embedded within the Seine-Escaut inland waterway connecting to the southern French ports of Fos/Marseille. In the late nineties, the United Kingdom (Department of Transport DfT 1998) published its policy document on better transport in the White paper 'A new deal for Transport: Better for everyone' .

[32] Based on data from Irish Exporters Association (2012), Trade and Transport Analysis

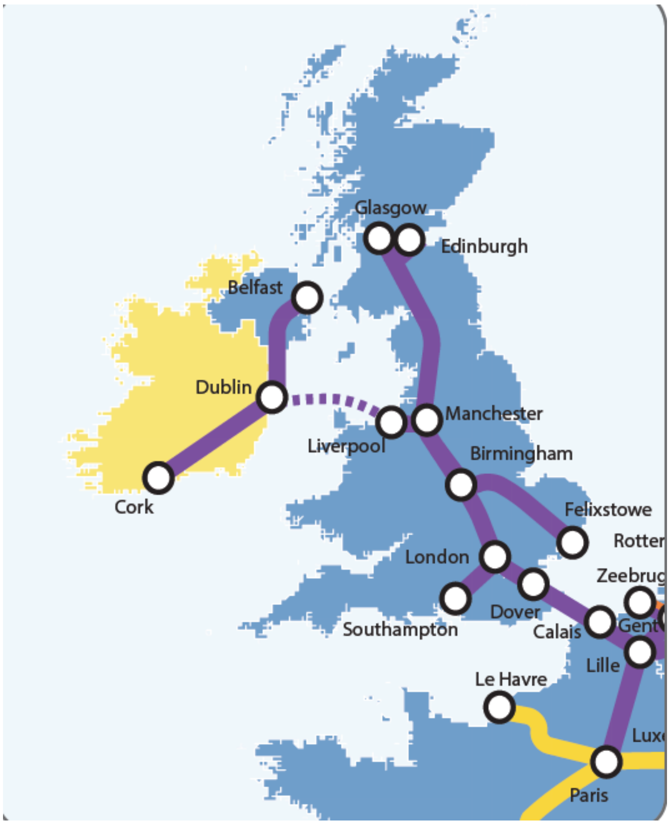

Figure 3.7 Ireland/UK corridors with NW Europe

Source: TEN-T 2014

The policy document was in response to the growing problems of pollution, congestion and noise through an integrated transport system. In a follow-up study 'Freight Modal Choice' (DfT2010a) presented the different factors of the modes, their mode-specific transporting costs, with different types of freight and patterns of UK freight transport.

The study highlighted the importance of intermodal flows and with it the gaps in knowledge of services costs in the rail and water sectors'; available transport corridors with scheduled services and connections. A subsequent review (AECOM 2010 with ITS Leeds) summarised the existing research on modal choice as:

- Commercial issues affecting modal choice decisions;
- External factors influencing such decisions;
- Optimising the transport flows, which have greater modal shift potential, especially on capacity and alternative modes?

3.5 Freight transport stakeholders

Freight transport combines several stakeholders across a very wide section of the industrial supply chain. The major players in intermodal transportation are the shippers who generate the demand; the carriers who supply the transportation services to satisfy the market demand along the intermodal network infrastructure. Table 3.5 sets out the general types of transport stakeholders. Studies detailing the efficiencies of the interactions, prioritising the issues and the subsequent redesigning of the infrastructure determine the efficiency of the whole system (Crainic and Kim 2007; Macharis and Bontekoning 2004; Sussman 2000).

Table 3.5 Different parties in the intermodal transport logistics

Description	Specific party	Roles	Commercial designation
Origin/ Source	Consignor	Sends goods	Product Supplier
Destination	Consignee	Receives goods	Product Customer
Management	Transport Co-ordinator	Co-ordinates transport services	Forwarder third party logistics provider, agent
Link Operator	Transport Operator	Moves goods	Road hauler, rail operator, ship owner, shipping line
Node Operator	Terminal Operator	Tranship consolidate goods	Port, airport, intermodal terminal operator

Source: Several sources and Author

There are sections within the stakeholders that are not directly involved in the freight transport movements (public authorities, residents, tourists/visitors) and those that are the actors in the supply chain. The latter can be categorised according to the demand for goods (receivers), the supply of goods (shippers or producers) and finally the transport of goods (transport operators). Generally, as the freight forwarders' are not bound by 'loyalty'; this brings about a level of uncertainty into a complex non-linear paradigm in the transport 'choice bundles' (mode, route and distances); often without any specific consideration for the local environment (Crainic and Kim 2007). This gave rise to the situations of conflict between the stakeholders' commercial efficiency objective and the policy makers objectives for the wider sustainability objectives pursued by city authorities on behalf of residents and tourists/visitors.

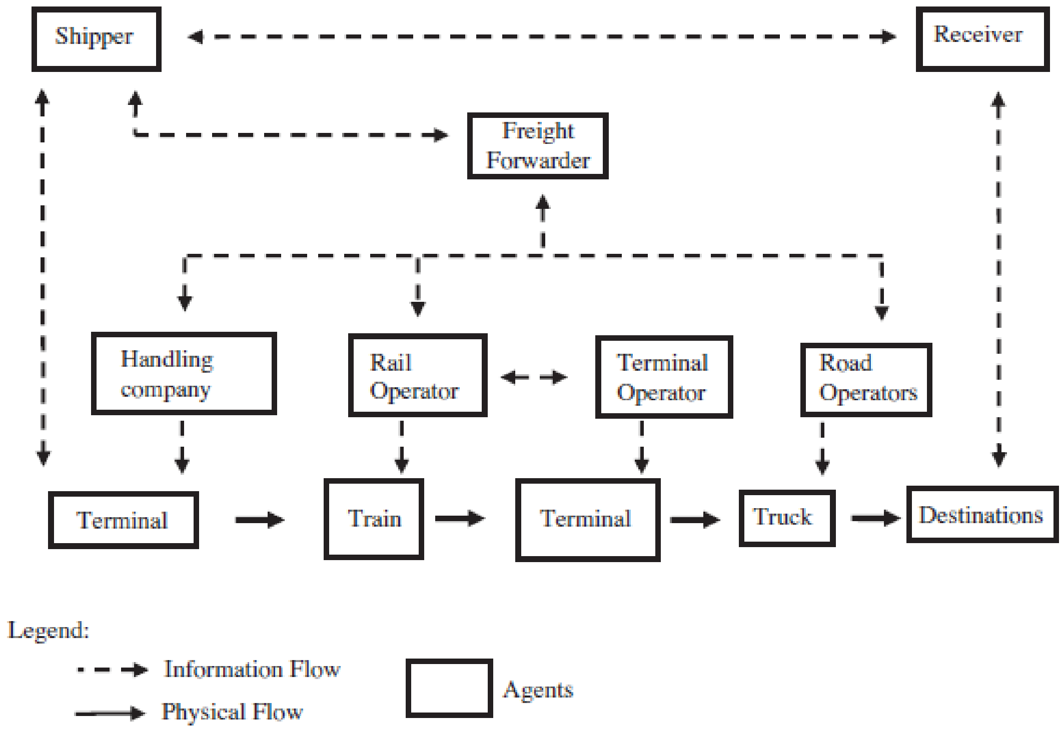

Figure 3.8: Conceptualisation of the freight transport services
Source: Reis (2014)

The shipping company (shippers) hires a freight forwarder to manage the intermodal transport service. The freight forwarder then contracts the transport services from carriers.

Freight is handled at each intermediate intermodal terminal. Transhipment volumes are regulated by the capacity of the carriers and transhipment handling productivity. Transport demand is determined by the shippers' orders and the containers already stored at the terminal of origin. Initial instructions: Shippers, under instructions from the receiver, direct the freight forwarder of each delivery detail (delivery information of the number and destinations of the containers).

The two land transport modes considered are:

- Road carriers who provide services to the initial terminal and then to the final destinations.
- Rail Carriers who provide transport services between terminals.

This is important for the logistic supply chain as planned logistics ensures the balance of incoming numbers of containers with those outbound. Failure in managing the logistics leads to congestion. The terminal then becomes a temporary storage facility. The uncertainties arising from the freight forwarders past choices thus influence the restraints presented by present choices and thus the subsequent future options. The freight forwarder makes the mode choice decisions (scheduling, destinations, length of train, etc.). These choices (of the freight forwarder) are directed by shipper's requirements (e.g., destinations or transit time), the carrier characteristics (e.g., speed or capacity), demand and their own previous choices (e.g., train schedules or capacity or stored containers).

The private and public sector institutions are given in Table 3.6.

Table 3.6: List of Private and Public institutions in the maritime transport sector

Private Sector	Public Sector
Shippers	Port Authorities
Freight Forwarders	Maritime Authorities and bodies
Logistic Operator	Customs Authorities
Haulage transport Operators	Revenue Authorities
Rail/river transport operators	Other Public agencies
Shipping Lines	-
Shipping Agents	-
Terminal Operators	-
Customs Agents	-

Source: Vrenken et al (2005), Author

These operators have evolved from the global terminal operators into operators servicing the entire door-to-door transport chain providing cover to all risks, commercial or physical, along the transit passage (Vrenken, et al. 2005). These operators reflect the paradigm shift in the supply chain concept where the nature of competition will not be between companies, but rather between supply chains.

The demand side are the users who ‘buy’ the services to transport their cargo or cargo interests. The main parties are:

- Shippers, who are commercial companies that move national and multinational imports and exports by the services of a freight forwarder. They are the owners of the cargo and they ‘buy’ a service to transport/ship/deliver the freight from its origin to a specific destination. The shippers may organize the transport procedures directly or delegate or outsource to other operators who act on their behalf.
- The freight forwarders who act on behalf of the shippers and take the responsibility for the management of the entire transport chain. The forwarders try to find the best solution for each particular shipment case and interact with all the supply actors. Presumably the forwarders will not have any transport asset and will just manage the operational phases as organizers of the service.
- Maritime links: Increased competition and consolidation witnessed the shipping lines extending their services to the port’s surrounding hinterlands. Competing maritime companies transformed into international logistics supply chains. These corporations expanded from services buyers into complete service providers that included maritime shipping services and terminal operators with inland hinterland connections. The global terminal operators integrated the freight supply chain with links between markets, ports and hinterlands.

The supply side level operators with transport solutions for the service buyers were the rail, road, inland waterways and short-sea shipping operators. These operators constitute the central part of the transport business, since they run the main physical transport operations. In most cases intermodal transport providers are managed and co-ordinated by forwarders or intermodal transport operators. This service has extended onto terminals. Conventionally, terminals were single assets within a port, where loading and unloading of service different types of vessels, like passenger ships, tankers, bulk carriers both dry and liquid and container vessels. The role of terminal operators (Stokland et al., 2010) altered when some of the terminal operators invested (own, lease or rent) in terminals chains along the main maritime routes allowing them greater agility of their vessels operations and a competitive advantages over their competitors by overcoming port related obstacles (congestion, crane services, etc) (Woxenius and Barthel, 2008). By merging and acquisitions, the global terminal operators (GTOs) extended their influence to exploit the synergies of the total transport delivery industry (Bärthel and Woxenius, 2004). The new generations of the GTOs have combined with the shipping lines and are offering a wider composite of solutions to the freight transport market.

The optimal positioning of the terminal influences the efficiency of a transport network (Limbourg and Jourquin, 2009). Comparative studies between the modes indicate that road is eleven times as expensive, per tonne-km, as rail (Ballou, 2004), prompting that intermodal terminals be closer to the shipper/receiver thus reducing the pre-haul and the post haul road distances (Hanssen and Mathisen, 2012). However, intermodal terminals need a critical catchment area for efficient operations (Bergqvist et al., 2010). By introducing information management systems, containerization and mechanization of loading and unloading activities, significant steps have been taken to make the terminal costs more efficient in the past few decades (Rodrigue et al., 2009), however a seamless interconnectivity between transport modes is not yet universal (Stokland et al., 2010).

3.6 Characteristics of transport networks

The EU and international transport networks connect the international logistical supply chains to national ports, which provide links to the hinterlands. These connecting links are gradually being joined to intermodal terminals with rail, motorway and sea port networks. In addition, the regional components of a network facilitate access to the core of the network or help to open up outlying and isolated regions. There are basically four types of network that can be summarised as:

- The combined transport network comprises railways and inland waterways which, combined where appropriate with initial and/or terminal road haulage, permit the long-distance transport of goods between all Member States. It also comprises installations permitting transhipment between the different networks.
- The air traffic control network comprises the aviation plan (air space reserved for general aviation, aviation routes and aviation aids), the traffic management system and the air traffic control system.
- The information and management network concerns coastal and port shipping services, vessel positioning systems, reporting systems for vessels transporting dangerous goods and communication systems for distress and safety at sea.
- The positioning and navigation systems network comprises the satellite positioning and navigation systems and the systems to be defined in the future European Radio Navigation Plan.

3.6.1 Road network

- Comprises motorways and high-quality roads and will be supplemented by new or adapted links;
- Comprises infrastructure for traffic management and user information, based on active cooperation between traffic management systems at European, national and regional levels;
- Guarantees users a high, uniform and continuous level of services, comfort and safety.

3.6.2 Rail network

- Comprises the high-speed network and conventional lines;
- Offers users a high level of quality and safety thanks to its continuity and interoperability and to a harmonized command and control system.

3.6.3 Inland waterway network and inland ports:

- The system comprises a network consisting of rivers and canals,
- A network of branch canals, port infrastructure and efficient traffic management systems;
- Technical specifications allow smooth transfer between other modes such as sea, road and rail.

3.7 Transport operators

In general within a transport delivery system, the long haul sectors are provided by rail, inland waterways, short sea shipping or ocean shipping and are influenced by economies of scale (Bergqvist and Behrends, 2011). Market and commercial demands dictate the choice of mode; where in some cases air transport may be the preferred alternative, particularly for highly deteriorating goods where transport time is critical. The costs of transporting freight vary greatly according to the modes. Studies indicate that for transport by unit tonne over a kilometre, sea mode is the most economical option with rail three times costlier than by sea/inland waters; road is about 35 times greater and air transport is 83 times higher (Ballou, 2004). However, the ‘down side’ of the sea mode is that it is the slowest of the transport modes, while the high cost air transport is the fastest (Ballou, 2004). High value, time sensitive and fragile goods will therefore, to a larger extent than low value, time indifferent and sturdy goods, be transported by air.

Initial studies indicated that intermodal transport solutions were attractive at distances in excess of 500 km (van Klink and van den Berg, 1998). However, subsequent studies showed that the break-even distance was dependent on the characteristics of the freight consignment and of the transport services (Janic, 2007). Competitive restructuring had reduced the breakeven point to about 400 km (Tsamboulas, 2008). Further trends, with the inclusion of the external components of congestion, environmental pollution, etc. suggest that the break-even distance could be reduced for medium to short sectors with the introduction of a rail network (Bärthel and Woxenius, 2004), with the road mode being the primary mode for the pre and post haul sectors (PROMOTIQ, 2000).

The next generations of evolving transport systems Northern Europe (North and Baltic seas to the eastern end of the Mediterranean Sea connecting hinterlands to the coastal areas for short sea feeder and international connections. Liberalisation of the short sea sectors brought about several EU incentives (Marco Polo[33], Motorways of the Sea) allowed new opportunities for the expansion of the intermodal maritime sector, thus

[33] MARCO POLO was introduced to promote the transfer to rail, short-sea shipping and inland waterways as a greener alternative to the unimodal road mode. Dynamic marketing, quality services with efficient layered customer care was the vital tools to overcome some of the concerns expressed by the forwarders. http://ec.europa.eu/transport/marcopolo/files/publi/brochures/bestof_2009_en.pdf

improving the maritime links, along the Motorways of the Sea areas[34]. However, in spite of the efforts to shift transportation away from road towards a sustainable transport solution, the initiative has not been a spectacular success. Despite the fact that intermodal maritime transport is an interesting business, it is still not always true that short sea shipping or Motorways of the Sea are the preferred options to road transport by freight forwarders or shippers.

3.7.1 Road operators

Road haulage vehicles form the backbone of most of the freight industry. In a very large number of transport operations all of the initial and final legs are undertaken by standard road haulage vehicles (either articulated or road-train combinations).

Evolved innovative technology in the development of the combined road-rail/waterway transport operations lays great emphasis on the initial and final road legs of all transfers on the rail and/or waterway networks. The choice of road vehicle is defined or restricted by the maximum load permitted on roads of the origin and destination sites. In particular, the fully loaded swap bodies and the standard ISO containers are restricted by the 44 tonne legal gross load limit. For example, Category A swap bodies weigh about 34 tonnes and the maximum loaded weight of a 12.2 m (40-foot) container is around 30 tonnes, hence the 44-tonne vehicle gross weight maybe legally permitted to be used on public roads.

3.7.2 Rail operators

The rail mode offers a competitive costs option for freight transport over land to tranship large volumes on long hauls. The disadvantages are that there needs an initial high structural investment and the establishment of a network system. Based on just

[34] Baltic Sea, Western Europe, Western Mediterranean and Eastern Mediterranean http://ec.europa.eu/transport/modes/maritime/studies/doc/mos/2006_reseach_good_flows.pdf

transportation costs and a functioning network allows a favourable shift from the road sector to the rail for the main haul of high volumes, with a reduced break-even distance from 500 km to around 250 km (Bacelli, 2001). The two values refer to economical convenience, without considering service quality or welfare costs.

The European Rail Freight Association (ERFA) promotes European rail freight transport and its stakeholders' to be active in that area through the complete liberalisation of the market. They include rail freight operators, wagon keepers, leasing companies, service providers, forwarders and national rail freight associations. These companies provide rail transport from maritime terminals in ports to inland terminals mainly on a national level, both for container transport and for swap bodies. The International Union of Combined Road Rail Transport companies (UIRR) provide services for the multimodal terminal operators (MTO) for mainly combined road/rail transport, both accompanied and unaccompanied. The operators are private companies and very often there could be a participation of national rail companies (see Table 3-9). The companies coordinate, integrate and manage the international operations through organization on a European scale. The common practise in UIRR is to provide a terminal-to-terminal service and the organization of the initial/final road part of the voyage is left to the forwarder. (Appendix Table A12.1: List of private and public European rail operators)

3.7.3 Intermodal inland waterways operators

Transport by inland waterways, short-sea and coastal shipping has taken on an important role because these modes offer great potential for transferring freight away from the congested roads in Europe. Inland waterway transport offers a reliable mode for transporting freight along Europe's integrated network of rivers and canals. It is energy efficient; its energy consumption is about one sixth of the road mode and about half that of rail transport (EC 2011).

The European Commission's commitment towards a less energy-intensive, cleaner and safer transport system was set out in its action programme promoting inland waterway transport called NAIADES (Navigation and Inland Waterway Action and Development in Europe)[35].

European intermodal inland waterway transport is spread throughout North and East Europe, along the navigable rivers. These waterways and canals connect the big ports of Antwerp, Rotterdam and Hamburg to the European industrial heartlands of Germany, Netherlands, Belgium and France. The Rhine with its 1326 kilometres serves as one of the main inland waterway highways connecting several destinations in central Europe. The Danube is the other European river connecting industrial centres, from Germany to the Black Sea, along its 2888 kilometres. However, there are operational issues of limiting low water levels arising from droughts, irrigational water usage, low population density and the low degree of industrialisation preventing a fuller effective development of inland waterway transport.

In Europe, inland waterway transport is almost fully liberalized; allowing operators to offer extended strategic transport services along the catchment areas.

3.8 Transport units

3.8.1 Containers (international ocean-going intermodal trade) and trailers

Containers are boxes that can be filled with cargo for transport. They were standardized as a result of two economic factors: the boxes had to able to shift between the different

[35] http://www.naiades.info/

transports modes across international boundaries and to compete with conventional road transport systems.

Figure 3.9: 6.06m (20'Shipping Container (TEU)
Source: Internet

The cargo carrying capacity varies, but may generally be stated as 27 tonnes for a 6.1m (20ft) container and 30 tonnes for a 12.2m (40ft) container. This makes the 6.1m (20ft) container (See Fig 3.9) attractive for high density cargo (e.g. steel products), while the 12.2m (40ft) container attracts volume cargo, as most consumables are less dense. Containers were designed to allow the loading of dangerous goods, which were stowed in accordance with the IMDG Code[36]. The design of the intermodal transport units and the international specifications are set out in ISO TC 104[37] and is given in ISO 1496[38]. Larger sizes offered quicker loading, handling and unloading for containerised cargo.

[36] International Maritime Dangerous Goods Code
[37] Standardization of freight containers, having an external volume of one cubic meter (35.3 cubic feet) and greater, as regards terminology, classification, dimensions, specifications, handling, test methods and marking
[38] Gives the basic specifications and testing requirements for ISO series 1 freight containers of the totally enclosed general purpose types and certain specific purpose types (closed, vented, ventilated or open top) which are suitable for international exchange and for conveyance by road, rail and sea, including interchange between these forms of transport

This gave a rationale for bigger and 'higher' boxes; 'Hi cube' boxes offered an increased cubic capacity (of 12%) over a standard 12.2m (40') container with the same operational handling equipment and road clearances[39]. The domestic containers in the United States[40] of 14.6m (48ft) and 16.1m (53ft) length, 2.6m wide and up to 2.9m high (equal to that specified by the ISO). In Europe it is found that the swap-bodies are of different length up to 13.60m[41], 2.50m wide and 2.67m high[42]. Detailed dimensions of the containers are set out in Appendix 1

The new EILU container dimensions would meet the European road and rail transport safety clearances, however the maritime shipping lines are strongly opposed because they have huge investments in current equipment and new ships under construction are optimized for existing ISO container sizes (Rodrigue, et al. 2013).

3.8.2 Swap body (SB)

Freightliner introduced these units in 1966. The swap-body units were lightly constructed units without rigid top frames, thus they are not for stacking (See Fig.3.10).

The swap-body is of light construction, optimised to fit European roads, with no over stacking and mostly it is not possible to top lift as there are grabber arm lifting areas in the bottom structure. The European Union is trying to implement a new container labelled the European Intermodal Load Unit (EILU) with a length of 13.72 m (45 feet) and a width of 2.59 m (8.5 feet).

This would allow two standard European pallets[43] o be loaded in containers side by side as existing containers are based on North American pallet dimensions. They are widely used in Continental Europe where they travel on truck-trailer combinations and on

[39] See Appendix 1 Container dimensions and specifications
[40] UTI-Norm (1999), "Current State of Standardisation and Future Standardisation Needs for Intermodal Loading Units in Europe", Contract no JC-98-RS.5039 – page 70-73
[41] Class A is 13.60m and Class C is 7.82m
[42] European standard EN 452:1995
[43] See Appendix 2 Dimensions for a EURO Pallet

railways. However, the added time for lowering and raising the legs has made theft/pilferage easier.

Figure: 3.10. Swap body
Source: NÄRPES TRÄ & METALL. Kristinestadsvägen, NÄRPES, Finland

Being the most commonly used transport unit for road-rail combined transport (CT) the swap body has its origin in the road system. Its main characteristics are as follows:

- Easily transferable on to road chassis and rail wagons
- Can be placed on fixed legs
- Generally covered and non-stackable
- Loaded/unloaded by crane - by the underside
- Better payload/deadweight ratio

The European Committee for Standardisation (CEN) has developed standards for the swap body. Two classes of swap body predominate:

- Class C with lengths of 7.15m, 7.45m or 7.82m (standard EN 284)

- Class A with lengths of 12.50m or 13.60m (standard EN 452)

3.8.3 Semi-trailer

Semi-trailers: Standard height semi-trailers may be carried in pocket wagons or Euro Spine wagon units, dubbed piggybacks. They are derived from road semi-trailers with added grab pockets and with a stronger frame and need additional ground personnel helping with the support props and guiding the king pin into the recess. The elements beneath the load carrying surface are prone to accidental damage and theft.

3.8.4 Intermodal freight equipment

The types of equipment used in intermodal transportation, as well as equipment ownership and lease issues had significant effect on the volume and distribution of freight flows, with the ILUs, in a region. Some of the characteristics of intermodal freight transport that are useful to understand from a freight modelling perspective are discussed here.

There is a great variety of unit types available, allowing a wide choice of cargo to be carried. The large number of intermodal units currently available does not allow fast changes to present technical details such as twist lock dimensions (top lift), grab pocket dimensions (bottom lift), bottom lock dimensions (road vehicle and rail vehicle connection via pins).

Intermodal transport units (ILU)

The intermodal transport units (ILU) are described individually with their specific characteristics and modal attributes and influences on commercial operations. Each mode, with its associated accessories, does limit the universal exploitation of each of the modes, within particular freight markets. The research model by focusing on tonne-based measures as defining freight activity, this may give rise to a distorted picture of the viable modal options for some flows, since some commodities have a large cubic volume but low tonnage. The flexibility of the ILUs[44] allowed them to be used at marine and rail intermodal terminals for terminal movement, stacking, loading and unloading of containers/trailers, which include packers (for lifting containers from the bottom), top lifts (for lifting containers from the top), yard/reach stackers (for stacking containers), rubber tyre gantry (RTG) or rail mounted gantry (RMG) vehicles used for moving containers/trailers and intermodal lifts and cranes for the loading and unloading of containers/trailers.

3.9 Summary

This chapter set out the different types of modes and the associated terminologies prevalent in the industry. The concepts of intermodal transport were introduced and the interaction of the modes and their impact on multimodality, intermodality and co-modality was discussed. Co-modality has not received much attention from the OR community as it could offer an improved utilization of transportation modal resources; a better consolidation of loads, flexibility and freedom to switch modes and synchronization of the services. EU studies showed that one of the most important obstacles was the incompatibility between the various carriers and the diversity of loading devices[45]. However, the lack of harmonisation and standardisation of the transport infrastructure has delayed the loading units and led to incompatibility between the modal hardware used, resulting in the failure of a smoother transfer between the modes during the transport of freight. These variations present the essence of optimized multimodal transportation planning, which consolidates the many practical aspects, such as the collaboration of the administrative bodies, traffic at terminals or en route,

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[44] COM (2004) 361 final

[45] http://ec.europa.eu/research/transport/projects/items/trimotrans_en.htm

resource limitations and modal capacities and finally uncertainties - weather, scheduling, etc.

Based on the transport research in this chapter, the aggregates are determined for the evaluation of the ITCM, are described in Chapter 6 within the concepts of the ITCM.

Chapter 4
Methodology

4.1. Introduction

The previous chapters established the theoretical context of the research project. This chapter presents the different philosophical perspectives that shape the researcher's perception and reflects the intellectual traditions that influence this research. Different research paradigms are introduced and their adaptations to the transport studies are reviewed. The logical process chosen reflects the researcher's stance and provides justification of the methodology chosen.

This chapter presents the theoretical foundations of the research and explains the methodology chosen. Earlier Chapters 2 and 3 established the theoretical context of the research project; this chapter is will set out the researcher's perception of the research process and detail the influences of these intellectual traditions on the present study. Subsequent sections detail the resulting research design process and choice of research methods.

4.1.1. Chapter layout

This section sets out the basic differences between two basic terms or concepts of 'research' or 'research methods' and 'research methodology'. In this research, the term 'methods' to refer to techniques and procedures used to obtain and analyse data. This, therefore, includes questionnaires, observation and informal discussions as well as both quantitative (statistical) and qualitative (non-statistical) analysis techniques and, as you have probably gathered from the title, is the main focus of this book. In contrast, the term 'methodology' refers to the theory of how research has been undertaken. This understanding is important as it allows an informed choice about this research.

This chapter is set out in seven sections, as shown below in Figure 4.1. It introduces the various acknowledged philosophies describing academic research. The third section examines the research paradigms and then explains the specific relevance to this research.

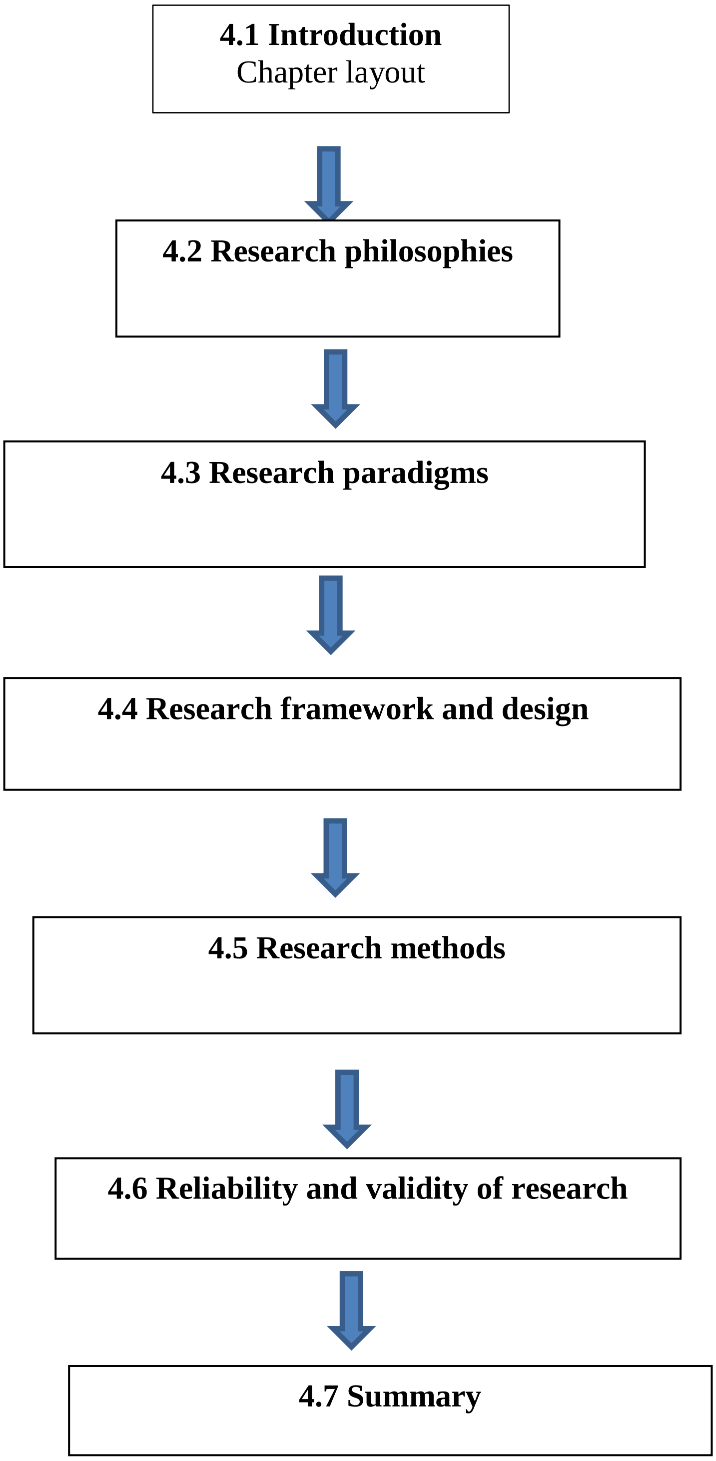

Figure 4.1: Layout of Chapter 4

The fourth section lays out the research framework and design. The fifth outlines the research methods and the selection of case study as the strategy. The research employed triangulation as research tool and quantified ITCM concept through the spreadsheet workings. The sixth section explains the reliability and the validity of the research. The final section sums up the chapter.

4.2. Research philosophies

The foundations of the social researchers' work are based on ontological and epistemological positions, where these positions are often more implicit than explicit, but reveal themselves in their methodology and approach. These stances are pivotal to a social scientist as the research primarily 'shapes the approach to theory and the methods' utilised (Marsh and Furlong 2002). Secondly, the values are intrinsic and grounded deeply within the researchers' beliefs about the world: "They are like a skin not a sweater: they cannot be put on or taken off whenever the researcher sees fit." (Marsh & Furlong 2002 page 17)

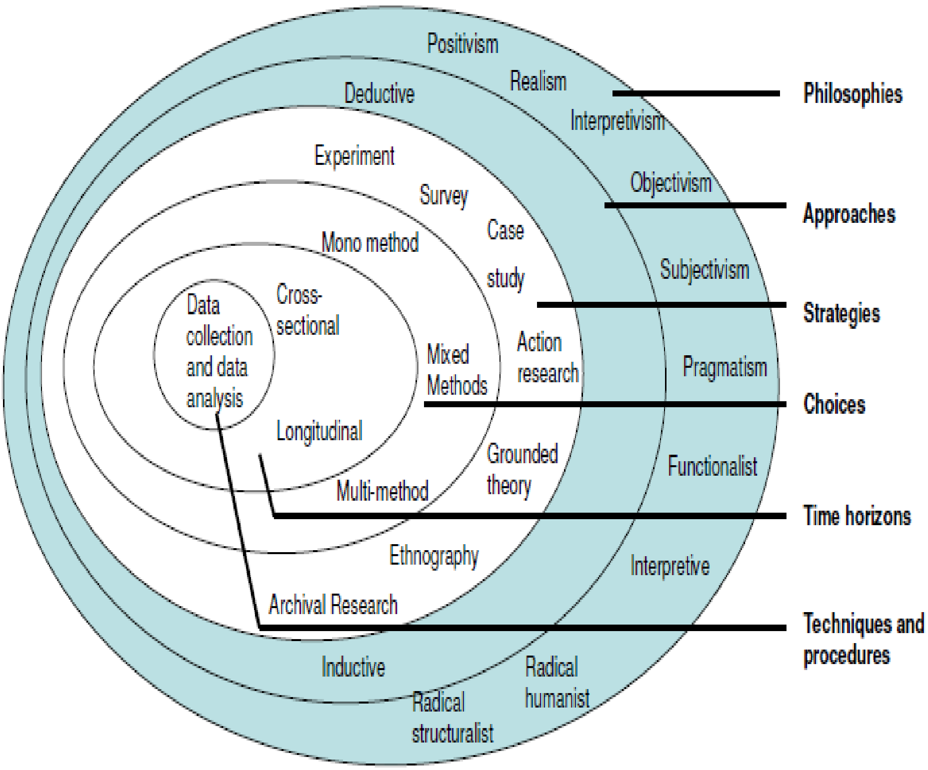

Figure 4.2 Research Onion

Source: Saunders et al (2006) cited in Saunders et al (2007)

In research, theory explains how 'something' works and can attempt to predict how 'something' will behave under specific conditions. Theory development follows formulating a consistent system of statements that unify, enlarge and deepen ideas, which had before, possibly been more or less intuitive and disconnected. In practice, the research involves alternating between two main approaches, deduction and induction. Crotty (2007) and Saunders *et al* (2007) presented their research methodology model based on 'the Research Onion'. The research model of Saunders *et al.* (2007) had six stages with philosophies; approaches; strategies; choices; time horizons; techniques and procedures (Figure 4.2), whereas Crotty's model narrowed it down to five stages: epistemology; theoretical perspective; methodology and methods (2007). The literature reviews for this research showed that the correct principles and choice of the research methodology was critical to discovering the main elements when considering different factors in transport costs (internal, external, time-costs and others) and the model that characterised the users' preferences in mode choice (Bryman & Bell, 2007; Saunders, Lewis & Thomhil 2007).

Based on the elements and concepts from 'Research Onion' (Saunders, *et al* 2007) the research options are highlighted below.as shown in Table 4.1.

Research methodology refers to the various sequential steps adopted by a researcher in studying the problem with certain objectives in mind. In short, it is the description, explanation and justification of various methods for conducting research (Bryman and Bell (2007).The research design includes the general plan of the research and how the research questions are answered (Saunders *et al* 2007).

The key elements are:

- Clear aims and objectives derived from the research questions
- Specification of sources from which data is collected

Table 4.1: Research strategies

Saunders et al (2007) Research Onion			Research Methodology
1	Philosophies	Positivism	
		Realism	Realism
		Interpretivism	
		Objectivism	
		Subjectivism	
		Pragmatism	
		Functionalist	
		Interpretive	
		Radical humanist	
		Radical structuralism	
2	Approaches	Deductive	Deductive
		Inductive	
3	Strategies	Experiment	
		Survey	
		Case Study	Case Study
		Action Research	
		Grounded theory	
		Ethnography	
		Archival Research	
4	Choices	Mono method	
		Mixed method	
		Multi method	Multi method
5	Time Horizons	Cross Sectional	Cross Sectional
		Longitudinal	
6	Techniques & procedures	Data: Collection & Analysis	

Source: Author, Several

- Consideration of the constraints that the researcher will have ~ access to data, location time and money

- Discussion of ethical issues

4.2.1. Approaches to research network

The general aim of this research was to design a transport model to evaluate total transport costs, which would allow the transport stakeholders to make an informed decision on mode selection(s) towards achieving a better freight delivery system.

An overview of the principal research methodologies (see Table 4.2) demonstrates the reasons certain approaches were adopted in this research. The model interpolated using both internal and external data from original databases of different sets of costs. The model compared total costs on three routes based on one set of origin/destination ports delivering a container unit. There were informal discussions with the transport providers, shippers and users regarding the route computations.

The survey-based technique satisfies the methodology as the questions addressed cover a wide range of issues. However, the main core of the hypotheses is essentially an understanding of the "why" type questions that a survey would have been unable to determine. There were informal meetings with the transport providers discussing the findings from the general surveys, to allow a more detailed and relevant study of the processes.

4.2.2. Philosophical foundations of research

Ontology and epistemology are branches of philosophy concerned with the nature of reality and the acquisition of knowledge (Saunders et al 2007). Ontology discusses whether the social world is regarded as something external to social actors or as something that people are in the process of fashioning through their actions and perceptions (Bryman, 2004).

- The philosophical study of the nature of being or the nature of reality
- Deals with questions about what exists or could be said to exist.

Table 4.2 Types of Research Methodologies

Research Strategy	Form of Question	Need control of behaviour	Focus contemporary issues	Advantages	Disadvantages
Experiment	How, why	Yes	Yes	Generally applicable to a statistical population	Limited focus, a priori theoretical commitment
Survey	Who, what, where, how many and how much	No	Yes	Generally applicable to a statistical population	Limited scope; may ask the wrong question
Archival analysis	Who, what, where, how many and how much	No	Yes / No	Interpret past events in light of new data; find errors in previous data	Cannot be generalised to a statistical population; may be subjective
History	How, why	No	No		Difficult to access subject of research
Case Study	Who, what, where, how many and how much	No	Yes	Ability to ask why and to narrate; uses range of methodologies	Cannot be generalised to a statistical population; may be subjective; may use small sample sizes; validity of results from interviews with actors may be difficult to establish

- Is the social world external to social actors or something that people are in the process of constructing
- Ontological assumptions underpin epistemological assumptions (or do they? – is there a necessary relationship?)

Epistemology relates to the nature and scope of knowledge and concerns what constitutes acceptable knowledge in a field of study (Bryman and Bell 2007)

Following from this, *ontology* is explained by question 1; the second, a question of *epistemology* and the third a question of *methodology*.

1. How does the world exist? In our case, how does the 'social world' exist?
2. How one comes to know what does exist?
3. Which method(s) we use to try to evaluate our theory (if we have one) will depend upon how we perceive the world.

The two main epistemological approaches which have underpinned research are objectivism and subjectivism. Objectivist epistemology holds that "meaning exists as such apart from the operation of any consciousness" and "there is an objective truth waiting for us to discover it", whereas in subjectivism "meaning is imposed on the object by the subject" and all knowledge comes from "an interaction between the subject and the object to which meaning is ascribed" (Crotty, 1998, pp.8-9).

The two main ontological approaches in research are realism and relativism. Realism asserts that realities exist outside the mind and are driven only by immutable, natural laws. Piecyk suggests that the 'real' social world exists independently of our perception of it and is essentially objective, quoting Denzin and Lincoln (2000).

Although ontology and epistemology are considered distinct studies, as theory of knowledge typically involve some assumptions about existence and what exists, they have strong similarities and can be seen as complementary disciplines (Solem, 2003).

Realism is often taken to imply objectivism and relativism is identified with subjectivism. However, there are also a number of writers in the research literature who reject this view (Crotty, 1998). In the next section it will be shown how different ontological and epistemological positions can be combined to produce the three main research paradigms.

4.3. Research paradigms

The concepts of a paradigm were introduced by Kuhn (1970). He described it as "an integrated cluster of substantive concepts, variables and problems" with corresponding methodological approaches and research tools. Saunders et al (2009, p.118) elaborated a paradigm is a way of examining social phenomena from which particular understandings of these phenomena can be gained and explanations attempted. A paradigm is a composite of ontological and epistemological assumptions and transports them into the methodological position of the person conducting research. There are two dominant paradigms in the field of business management and social science, namely positivism and Interpretivism. Within the research, the terms positivism and Interpretivism are described by other alternative characteristics used as substitutes (Table 4.3).

Table 4.3: Alternative attributes used to describe the main research paradigms

Positivism	**Interpretivism**
Quantitative	Qualitative
Scientific	Subjectivist
Objectivist	Humanistic
Deductive	Inductive
Experimental	Hermeneutic
Empiricist	Naturalist
Traditionalist	Phenomenological

Adapted from: Ticehurst and Veal, 2000 and Mangan et al., 2004

Positivism

The theory of positivism was developed by a French thinker Auguste Comte (1798 – 1857) who outlined features of his philosophical approach in six volumes entitled 'Course of Positive Philosophy' published between 1830 and 1842.

- Roots in Comte, Durkheim, and the development of the scientific method
- Associated with empiricism
  - Knowledge starts with our senses on the basis of direct experience we can develop general propositions about the relationships between phenomena
- Focus on causes and explanation
  - Flipside of explanation is prediction

Positivism research reflects the philosophical stance of the natural scientist (Saundres et al 2009). The researcher prefers 'working with an observable social reality and that the end product of such research can be law-like generalisations similar to those produced by the physical and natural scientists' (Remenyi *et al.* 1998:32). However, the are arguments against positivism by social scientists who emphasise that "physical sciences deal with objects which are outside people whereas social sciences deal with action and behaviour which are generated from within the human mind and that, furthermore, the interrelationship between the investigator and what was being investigated was impossible to separate" (Mangan et al., 2004, p.568).

It is often noted that the positivist researcher employs a highly structured methodology in order to facilitate replication (Gill and Johnson 2002). Furthermore, the emphasis will be on quantifiable observations that lend themselves to statistical analysis. Saunders et al (2009) notes that it is perfectly possible to adopt some of the characteristics of positivism aspects in the research, for hypothesis testing, using data originally collected in-depth feedback.

Interpretivism

Interpretivism developed as a result of criticisms of the positivistic philosophical position. Its focus is of the interpretive approach is on understanding a business or social phenomena rather than on measuring, explaining or predicting it (Mentzer and Kahn, 1995, Bryman and Bell, 2007). Crotty (1998) reflects that the persons who advocate this position argue that there is a need to focus social inquiry on the meanings and values of actors in order to understand what is happening and why it is happening. The research methods used in interpretative studies seek to "describe, translate and otherwise come to terms with the meaning, not the frequency of certain more or less naturally occurring phenomena in the social world" (Hussey and Hussey, 1997, p.53).

Realism

In special research projects there are other approaches to the positivism and Interpretivism, the two dominant paradigms in social sciences. They include critical realism, critical inquiry, postmodernism, etc. (Crotty, 1998). This section will consider critical realism in greater detail, as this approach provides a 'middle ground' between positivism and Interpretivism, allowing the synergies from combining aspects of these two philosophies.

Realism is another philosophical position which relates to scientific enquiry. Saunders et al (2009) explains the essence of realism is what the senses show as reality is the truth: that objects have an existence independent of the human mind. Realism is a branch of epistemology which is similar to positivism in that it assumes a scientific approach to the development of knowledge. This assumption underpins the collection of data and the understanding of those data. This meaning (and in particular the relevance of realism for business and management research) becomes clearer when two forms of realism are contrasted.

The first type of realism is direct realism. **Direct realism** says that what you see is what you get: what we experience through our senses portrays the world accurately.

The second kind of realism is called **critical realism**. Critical realists argue that what we experience are sensations, the images of the things in the real world, not the things directly. Critical realism, sometimes called post-positivism, can be considered as a 'bridging' theory between two extreme viewpoints, positivism and Interpretivism (Easterby-Smith et al., 2002). Piecyk cites earlier work by Mutch (1999) on this concept: "while social structures are dependent upon the consciousness which the agents who reproduce or transform them have, they are not reducible to this consciousness.

Saunders et al (2009, 115) identifies the distinction between direct and critical realism, both are important in relation to the pursuit of business and management research. The direct realist relates the capacity of research to change the world which it studies. Their perspective would suggest the world is relatively unchanging: that it operates, in the business context, at one level (the individual, the group or the organisation).

The critical realist recognises the importance of multi-level study (e.g. at the level of the individual, the group and the organisation). Each of these levels has the capacity to change the researcher's understanding of that which is being studied. We, therefore, would argue that the critical realist's position that the social world is constantly changing is much more in line with the purpose of business and management research which is too often to understand the reason for phenomena as a precursor to recommending change.

Within the research process, critical realism seeks similar objectivity to positivism. However, the positivists do believe it is possible to achieve neutrality of the researcher in the collation of data, while the critical realists acknowledge that their values and beliefs could bias the findings and it is only through the suitable methods that could mitigate this effect (Benton and Craib, 2001). Easterby-Smith et al., (2002) proposes that critical realism supports the case for "methodological pluralism" as it recognises the value of different approaches for dealing with problematic situations.

Table 4.4 *Comparison of three research philosophies in management research*

	Positivism	**Realism**	**Interpretivism**
Ontology: *The researcher's view of the nature of reality or being*	External, objective and independent of social actors	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple
Epistemology: *the researcher's view regarding what constitutes acceptable knowledge*	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions
Data collection techniques most often used	Highly structured, large samples, measurement, quantitative, but can use qualitative	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative

Source: Saunders, Lewis and Thornhill 2009 (pp. 118)

Saunders et al (2009) summarises the three research paradigms from ontological, epistemological and methodological perspectives, as shown in Table 4.4. It can be seen that the positivist, Interpretivism and critical perspectives and associated methodologies are different in their characteristics and they can be used in a complementary fashion, provided that their distinctive features are respected and the strengths and weaknesses of each are recognised (Saundres et al, 119 2009). Frankel et al. (2005) acknowledges that it is not whether the different paradigms are right or wrong but rather that the differences between them exist below the level of awareness of the researcher. As they will influence the researcher’s worldview and the foundations on which they build knowledge, the underlying paradigm needs to be made explicit to understand the limitations and potential of different forms of research and minimise the ambiguity of the research outcomes.

4.3.1. Research paradigms in transport models

Addressing the study on French freight transport demand, Jiang, Johnson and Calzada (1999) states that there has been decidedly less research on modelling freight demand with disaggregate discrete models than on modelling passenger demand. The principal reason for this imbalance is the lack of freight demand data. Freight demand characteristics are expensive to obtain and are sometimes confidential. Komini (2015) commenting on Beresford’s cost model for multimodal freight transport recognised that in view of greater transport demand, the service providers are obliged to ensure a wider array with higher quality of service, provided in low costs. These new demands allowed the shippers, carriers and Logistics Service Providers opportunities to innovate and improvise new solutions with the available transport assets and with competitive costs (Steadieseifi et al. 2014). Their review summarises that in view of the several policy measures lowering, both cost and carbon emissions, that mode choice with mode costs were worth studying. Komini (2015) suggested that in view of the increased demand for competitiveness on existing routes, new intermodal routes should be reassessed based on the strengths and weaknesses of services offered by each mode. This research extends the concepts of transport costs and fills in the gaps incorporating the costs of externalities within the remit.

4.3.2. Paradigmatic stance of the thesis

Referring to the earlier stance that it is researcher's position that largely determines the manner the study is viewed and conducted; which data collection and analysis methods are adopted and finally how the results are interpreted. Broadly speaking, it is the researcher's perspective on the ontological and epistemological suppositions that influence's the chosen topic to be studied and help to establish the focus of scientific interest. For the purposes and the nature of this research, and the researcher's preferences the preferred philosophy is grounded in critical realist paradigm. The challenge of employing critical realism was to adopt multiple perspectives and methods to gain insight into the phenomenon being studied, without compromising the objectivity of the research or over-simplifying the research findings (Easterby-Smith et al., 2002, Solem, 2003, Aastrup and Halldorsson, 2008).

The study of transport models with the aspects of mode choice and user behaviour is too complex to be explored in a strictly quantitative, positivist way. Logistic costs and freight distribution systems are linked within the wider business structures. They are business-context dependent and subject to external pressures from both other supply chain members and the wider economic environment.

Further, logistics systems are social creations and the human element cannot be ignored in the course of this research project. The views and experiences of large samples of individuals were collected and analysed using both quantitative as well as qualitative techniques to ensure the maximum 'realism' of the research findings. This concept of methodological triangulation, where both qualitative and quantitative methods are applied, has been identified as offering the greatest potential for an in-depth exploration of future developments in the sustainability of road freight transport.

This research consists of three elements: investigation of potential determinants influencing the intensity and direction of key logistics trends, quantification of likely future changes in the key trends and their determinants and, finally, modelling of the results to assess the magnitude of the environmental impact of road freight transport in the North West Europe and especially Ireland in the near future. Therefore, this study is both exploratory and explanatory in nature, what fits well with the critical realist paradigm.

4.4. Research framework and design

Saunders et al (2009) proposes that most research textbooks represent research as a multi-stage process that must be addressed in order complete the research project. The number of stages may vary, but the core processes usually include formulating and clarifying a topic, reviewing the literature, designing the research, collecting data, analysing data and writing up. In the majority of these the research process, although presented with rationalised examples, is described as a series of stages through which you must pass. It may seem that the research process is rational and straightforward; however the authors state that this is very rarely true. The reality is considerably messier, with what initially appear as great ideas sometimes having little or no relevance (Saunders and Lewis 1997).

Mentzer and Kahn (1995) provide a framework formulating "a comprehensive perspective on the logistics research process" (p.233). Basic research process consists of the following steps (Maylor and Blackmon, 2005):

1. Formulation of the problem
2. Development of working hypotheses or research questions
3. Planning the study

4. Data collection and processing

5. Analysis and interpretation

6. Presentation of results

The generic character of this outline may be applied to any research investigation discipline. Figure 4.3 represents the research concept framework. This shows the approach adopted for this research project and is divided in three stages:

1. Idea generation and substantive justification

The primary motivation to undertake this research project originates from the author's maritime experience and in freight logistics and personal interest in logistics, sustainability and the environment. The challenge of the project and particular relevance, practicality and applicability of the expected output were the additional incentives to undertake this research.

An in-depth review of transport literature on transport models and quantifying of transport related externalities revealed significant gaps in this field. Studies show the measures to improve the environmental performance of logistics, but there were very few studies to quantify their likely future effectiveness, particularly on a macro-level scale based on total transport costs. The second step involved identifying and attempting to fill the existing gap in the knowledge; the initial research idea evolved into a formulated research problem with and specific research questions.

2. Theory development and choice of methodology

Based on a systematic literature review, the theoretical framework for this research was developed. The complex interrelations between different variables determining future environmental impact of all the transport modes were identified in order to structure the research process. Chapter 3 describes this process. The appropriate research methodology was then selected, including philosophical considerations, as well as a selection of methods and tools to collect and analyse the necessary data

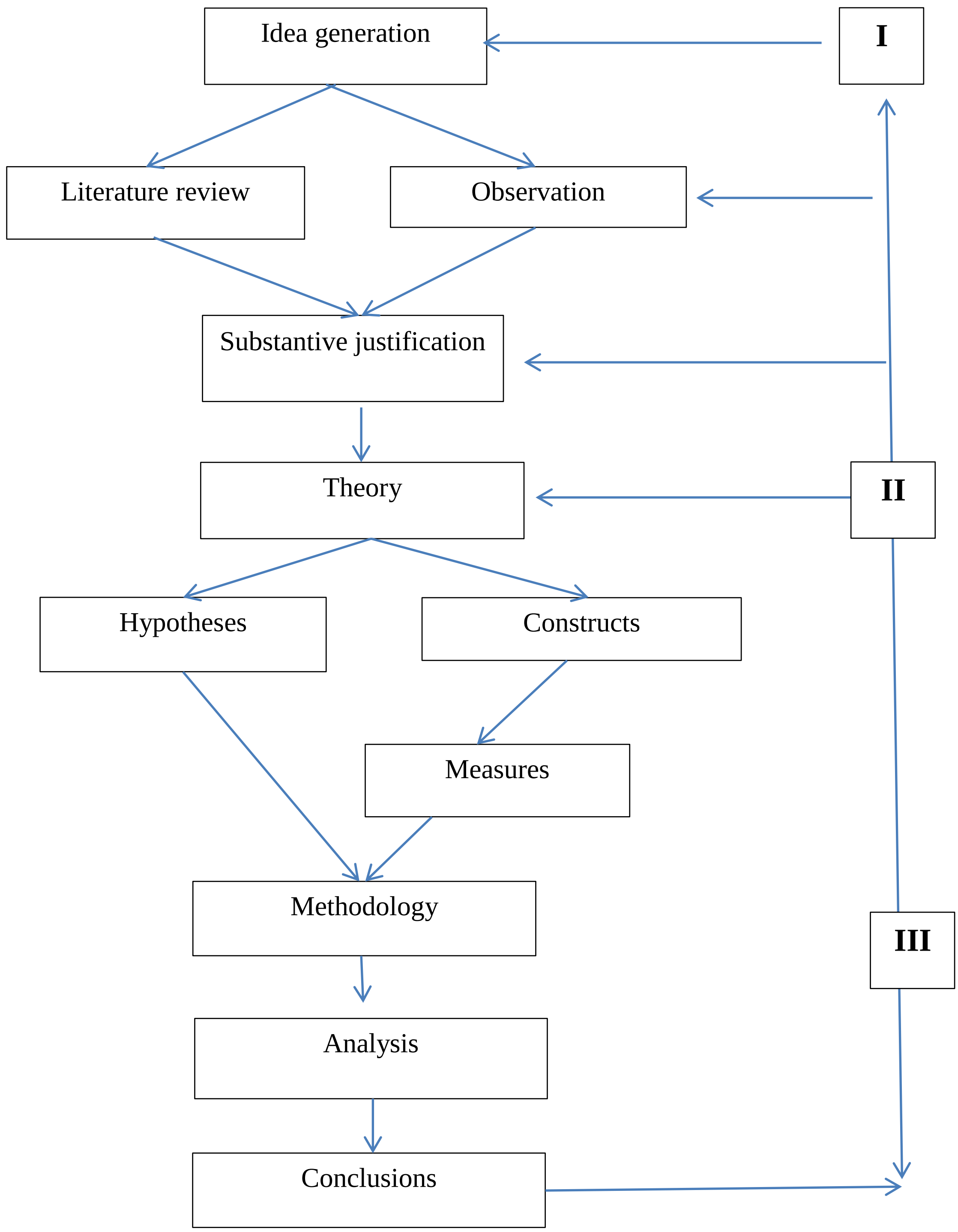

Figure 4.3: A framework of logistics research
Source: Mentzer and Kahn, (1995) cited by Piecyk (2010)

3. Data collection, analysis and evaluation process: The data for the research was in two parts: the first part involved the collection and collation of data from literature review. The second part was the collection and validating the recorded data with the actual industrial values. In the transport industry, often it is difficult to have access to sensitive operational costs, as in expenses for hardware, infrastructure and labour. The appropriate data was then collected and analysed. The interim findings were disseminated through taking part in conferences and workshops. In this way useful feedback and comments were obtained and incorporated into the final research findings.

The whole process was documented throughout to ensure maximum credibility and traceability. Finally, the last part of the analysis involved summarising the findings of the study and generating ideas for future research.

It is easy to appreciate that as commercial figures are sensitive data that companies are reluctant to provide and consequently academic sources are scarce or out of date. The data collection for this research was collected from several sources.

Distances: Each of the route transits EU- and non-EU-seas (Turkey), as the legislation cannot be applicable in non-EU seas. Some EU waters are considered to be ECA-zones. This means some maritime routes cross the ECA zones up to 6º West Longitude (distances between Rotterdam and Gothenburg, Kingston upon Hull. For practical purposes, the route Rotterdam to Dublin is considered with the ESA zone. The emissions evaluated for the transit to Istanbul is computed in two sections, the emissions up to 6º West Longitude (with low sulphur fuel oil) and the balance with the higher sulphur content fuel.

Transport Costs: Main internal (out of pocket) costs were collected and collated primarily from EUROSTATS Data was collected from different research projects performed for the European Commission, as well as stakeholder consultation. The main sources were the ETIS and Eurostat database (transport routes and volumes), the SKEMA study (specific information on maritime transport) and the TREMOVE (road and rail transport costs and emissions) and EMMOSS (shipping emissions) models.

External costs: There is a growing realisation that in spite of the huge benefits offered by the transport industry, studies show the transport related negativities are not fully borne by the transport users. The EU transport policies have been promoting for the internalising of transport related external costs (Directive 1999/62/EC). There have been several EU based studies suggest that implementing fair and efficient transport pricing, could yield considerable benefits (EC White Paper on Transport 2011). EC commissioned the IMPACT (2007-8) [46] to summarise the existing scientific and practitioner's knowledge. The results were published in 'The Handbook on external costs estimation' (Maibach et al., 2008[47]) and offered the state of the art with the best in practice on the methodology for external cost categories. There were have been several updates, of methods and the manner of evaluating external costs (European Commission 2009a; 'An inventory of measures for internalising external costs in transport European Commission 2012; External cost calculator for Marco Polo freight transport Brons M., Christidis, P. 2013). The aggregate values for the externalities for this research, the external costs were collected from Update of the Handbook on External Costs of Transport (DG MOVE Final Report 2014).

Routes: Based on the literature review of the transport corridors and the earlier mentions in (Chapter 1.3 and Chapter 3.3.1, and in Chapter 6.3etc) the selection of the research's routes were based on their TEN-T corridors. The first corridor selected was the Rotterdam to Ireland (North Sea to Mediterranean) corridor with the Origin at

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[46] http://www.cedelft.eu/publicatie/deliverables_of_impact_(internalisation_measures_and_policies_for_all_external_cost_of_transport)/702?PHPSESSID=c378bb001713d5baca60a6bb6979cc0d
[47] 2 http://ec.europa.eu/transport/themes/sustainable/internalisation_en.htm

Rotterdam and the Destination was Ballina (Ireland). The ITCM was design was based on the Rotterdam/Felixstowe/Holyhead/Dublin/Ballina route. The model was tested and verified. This was applied to two other routes between Rotterdam and Ballina was selected, each with different lengths of road transits.

In order to test its wider universal applications, the O/D of Rotterdam to Stockholm on the Scandinavian to the Mediterranean corridor was selected.

4.4.1. Research hypotheses

This sub-section describes the development of a series of linked research hypotheses, set out in Chapter 1, to test the three overall objectives after identifying key issues in the literature review. The three issues that required verification were:

1. Regulatory or operational infrastructure factors inhibit the fuller implementation of intermodal transport?
2. Intermodal transport faces several infrastructural problems, (inadequate intermodal infrastructure and insufficient rail infrastructure).
3. Transport cost rates high amongst the users' priorities in mode choice; although qualitative elements are relevant and some aspects influence the mode choice.

The research addresses the three perceived gaps highlighted in the literature, particularly as they relate to an improved set of modal choices in Ireland. These may require the restructuring of the transport infrastructure concerning the provision of intermodal (improved intermodal terminals, rail/sea infrastructure) freight services. The thesis is intended to provide greater knowledge and understanding of the interactions between infrastructure changes and from improved mode choice alternatives that can be understood and proposed.

4.4.2. The Relationship between Theoretical Perspective and Research Practice

This research proposal bridges the ‘relevance gap’ between researchers and the transport industry mode service providers. As the chosen research strategies have a direct influence on the outcomes, the research stance was both rigorous and appropriate in resolving the research questions. The strategy of the research design allowed the evaluated values from each of the case studies to provide both context-specific recommendations so that data that the model was potentially generalizable across a wider range of transport corridors (De Jong et al 2016).

The effects of environmental pollution and its effects on potential climate change have been attracting academic attention. This thesis extends the existing research undertaken in the emerging field of alternate sustainable transport solutions, based on total transport costs.

This research is based on existing research but introduces new concepts and theoretical knowledge onto a part of wider scientific and business reality. Transport logistics research, as in other supply chain logistics or even business or social science research, reflects the demands and concerns in the real world (Bryman, 2004, Remenyi et al., 2005, Bryman and Bell, 2007). The research is influenced by the academic traditions of the discipline, as well as by the researcher’s own set of intellectual beliefs and allegiances which in turn affects their perception of the nature of social or business entities and events (Maylor and Blackmon, 2005). Thus, academic investigation is influenced by the research design and especially by the way the researcher conducts the research.

Ontological and epistemological considerations underpin fundamental assumptions about the nature of social entities and knowledge. They form the philosophical stance; Crotty (1998) terms it as the research paradigm, which lies behind the chosen research methodology.

A framework illustrating how the theoretical base determines the researcher's approach, choice of data collection methods, analytical approach and interpretation of the results (Bryman and Bell, 2007) is shown in Figure 4.4.

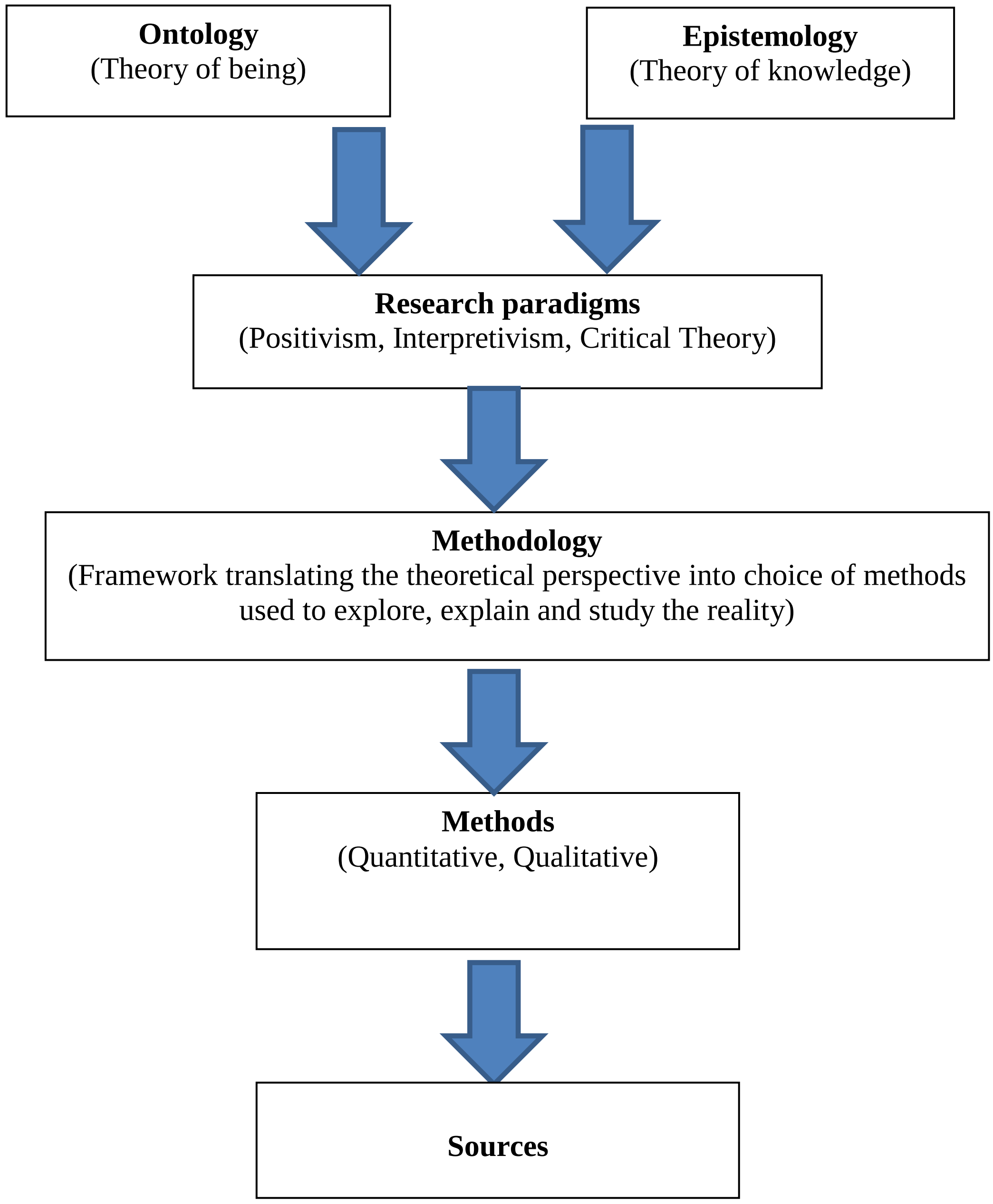

Figure 4.4: The relationship between the theoretical perspective and research practice
Adapted from: Crotty 1998, Sarantakos 2005

The methodology, in turn, translates the research paradigm into a set of principles that demonstrate how the world can be approached, explained and studied (Sarantakos 2005). A research method is a tool the researcher uses to collect and analyse the data

(Bryman, 1995, Saunders et al., 2007). Therefore, theory, while not uninformed by previous work, develops from the findings of the study.

4.5. Research methods

A research method is a particular means of approaching a research question. A method is concerned with pragmatic issues relating to particular practices and techniques which are applied in the process of research (Crotty, 1998, Ticehurst and Veal, 2000). Hence, the methods selected to conduct research should be guided by, and grounded within, a particular methodology (Easterby-Smith et al., 2002). Similarly to methodology, research methods can be classified as qualitative or quantitative (Table 4.5), although this division is not definitive (for example interviews and case studies can be designed to collect quantitative or qualitative data, etc.). The methods chosen to conduct this research are presented and justified below.

QUANTITATIVE	**RESEARCH METHODS**	**QUALITATIVE**
Statistical analysis	Case Studies	Observation • Participant • Non- participant
Modelling	Action Research	
Simulation	Interviews	Focus group
Measurement & scaling	Etc,	Life history
Etc.		Narrative

Table 4.5: Quantitative and qualitative research methods
Adapted from: Hussey and Hussey, 1997, Crotty, 1998,

In order to address these aims, the research has three sections:

- The first section considers the different factors to compute the total transport costs. These are the 'internal or out of pocket costs', the tangible costs that a transport provider faces daily and the ‘external or transport related costs not paid by the transport provider or the user.

- The second section, considers the additional variables within the generalised cost concepts that influence mode choice, that are nonetheless immeasurable in monetary terms. This part was investigated with the support of informal discussions with shippers and freight forwarders. To complete the analysis, a qualitative approach, based on previous results on values of time, followed.
- The third part takes into consideration and puts particular attention on environmental concerns, with the development of external cost internalisations.

The design is based on a three-fold analysis.

1. The first part of the work consisted of a field investigation of the elements affecting mode choice with data collected for three sets of same origin/destination corridors in Dublin, Rotterdam, Stockholm and Istanbul. The literature review had considered the two main elements: the cost/price of the service with the qualitative attributes that characterise the mode of transport.

   Further, the analysis considered the relation between transport cost and price towards identifying the differences among transport modes that could justify a different price level. There could be a direct link between costs and price, but possible variation could be identified based on their different market structures. The result offered an important tool considering that the transport user’s (shipper) choice is guided by the final price.
2. The second step is based on a qualitative analysis of the model and offered the generalised costs obtained from the three case studies. This forms the basis of a questionnaire offered to three broad sections of the freight transport industry, namely the freight users, the shippers (with the service providers) and finally the

infrastructure policy makers. A detailed description of the questionnaire is further explained in the text.

3. The final analysis resulted from the semi-structured interviews with the same three sections based on the analysis of the responses from the questionnaire.

The generalised cost approach allows the addition of other elements, particularly the role that external costs play in the case of the total costs. The exercise applied to the freight corridors was considered and the outcomes show how this measure could impact on each single mode of transport. Although the topic and the methodology are both very well known in academic research, the innovative element proposed in this thesis is the combination of the two elements and their application to freight transport in Europe. The last part of this work offers avenues and trends for further research with the possibility of implementing the generalised cost approach at the European level.

4.5.1. Case Studies

Robson (2002:178) defines **case study** as ‘a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence’. The utilisation of the case studies as a strategy is relevant when the intention is to gain a rich understanding of the context of the research and the processes being enacted (Morris and Wood 1991). The case study strategy also has considerable ability to generate answers to the question ‘why?’ as well as the ‘what?’ and ‘how?’ questions, although ‘what?’ and ‘how?’ questions tended to be more the concern of the survey strategy. For this reason, the case study strategy was considered the preferred choice in this explanatory and exploratory research.

In business strategy research, integrating qualitative and quantitative methods has become popular (Birkinshaw 1997, Ciabuschi et al., 2011, Aherne et al., 2014). The multi-method approach allows incorporating and integrating of the fieldwork and survey methods. Most of the present literatures using case study strategies reveal the triangulation process is the most common strategy.

4.5.1.1. Methodological Triangulation

Triangulation refers to the use of different data collection techniques within one study in order to ensure and confirm the proper perspective of the data with its environment (that the data is stating what it should in the fullest sense). Adaptations of data gathering of, for example qualitative data collected back or semi-structured group interviews may be a valuable way of triangulating quantitative data collected by other means such as a questionnaire (Saunders, et al 2009 p146). The challenge of research based on the critical realism paradigm is in adapting multiple methods to investigate a given research problem. Such an approach is known as triangulation. Hussey and Hussey (1997) explain triangulation as the use of multiple research approaches, methods and techniques in the same study. The main objective of triangulating research is to “overcome the potential bias and sterility of a single-method approach” (p.73), which should lead to greater validity and reliability of findings. Triangulation gets its name from the land surveying method of fixing the position of an object by measuring it from two different positions (Ticehurst and Veal, 2000).

Easterby-Smith et al. (2002) defines the four types of triangulation as follows:

- **Data triangulation**, where data is collected from different sources or over different time frames.
- **Investigator triangulation**, where different people independently collect data on the same situation.
- **Theoretical triangulation**, where models or theories from one discipline are used to explain a phenomenon in another discipline.

- **Methodological triangulation**, where both quantitative as well as qualitative research methods are employed (Merriam 2009).

Jack and Raturi (2006), describe three main reasons for using methodological triangulation:

a. **Completeness**- quantitative and qualitative methods complement each other, providing a level of investigative detail that would not be possible by using one method alone.

b. **Contingency**- this is driven by the need for insights into why and how a particular strategy is chosen. For example qualitative inquiry may be used to investigate the nature of the attributes of a phenomenon before an attempt is made to quantify or measure such attributes (Thomas 2011).

c. **Confirmation**- using both types of research methods should enhance the ability of a researcher to draw conclusions from their studies and improve the robustness and generalizability of the findings.

Maylor and Blackmon (2005) mentions the potential disadvantages of mixed- method approaches that should be considered in planning the research:

• They are more time and resource-consuming

• Possible difficulties can arise in reconciling the answers from different methods

• Different methods may not produce additional information

• Only a specific method or a narrow set of methods may be considered appropriate in a given research area

• Different methods may reflect different and incompatible research approaches

Regardless of these potential flaws, there has been considerable support and endorsement amongst logistics and supply chain experts in the concepts of triangulation. New and Payne (1995) suggests that “the mechanism of academia offers a trade-off: one can pursue artificial and abstract problems with the rigour necessary to play the research game, or one can pursue more interesting and real issues and be lost in the extraordinary complexity and ambiguity of the real world" (p.62). The authors further add that employing different investigation methods helps to cover the wide scope of the logistics discipline and improve chances of generating relevant and applicable research. Naslund (2002) and Mangan et al. (2004) argue that the use of both qualitative and quantitative methods is necessary to advance logistics research and to gain a "real-world" perspective on the subject.

4.5.2. Spreadsheet modelling

Collyer (1992) suggests that spreadsheet can be used to focus academic research and teaching on theoretical models. Two main strengths of this approach are:

(1) Spreadsheet provide a relatively user-friendly alternative to some kinds of instructional and research programming; and

(2) Linked tables and graphs of modern spreadsheet provide a powerful display medium and a fast way to examine the behaviour of models as parameters change.

Spreadsheet software has been extensively employed as a major tool supporting decision making processes, managerial planning and analysis (Coles and Rowley 1996, Seila 2006).

Most modern software packages offer spreadsheet programs in all the major desktop operating systems (Microsoft Excel) (Seila 2006). Popularity of the software has ensured its connectivity to other applications (for instance they allow to import or export data from / to other programmes). Using a spreadsheet model also permits an analysis of the value a particular variable must take if the desired output is to be achieved (Coles and Rowley, 1996). This allows the user to contemplate the implications of various scenarios (Seila 2006).

Coles and Rowley (1996) introduces spreadsheet modelling with the following stages:

i. Conceptualisation of a problem;

ii. Model design;
iii. Model construction;
iv. Validation and verification;
v. Documentation;
vi. Implementation and use.

A spreadsheet model has been constructed following the above steps and calibrated using freight-related data from official data sources and evaluating the total costs linking a series of transport-related internal and externalities. The ITCM was first designed and used to evaluate the total costs on three transport corridors.

4.6. Reliability and validity of research

Anderson (2010) comments that of because of the scale and anecdotal nature of qualitative research, it is often criticized as biased and/or lacking rigor; however, when it is carried out properly it is unbiased, in depth, valid, reliable, credible and rigorous. In qualitative research, there needs to be a way of assessing the "extent to which claims are supported by convincing evidence" (Murphy et al 1998). Although the terms *reliability* and *validity* traditionally have been associated with quantitative research, increasingly they are being seen as important concepts in qualitative research as well. Examining the data for reliability and validity assesses both the objectivity and credibility of the research. Validity relates to the honesty and genuineness of the research data, while reliability relates to the reproducibility and stability of the data.

The validity of research findings refers to the extent to which the findings are an accurate representation of the phenomena they are intended to represent. The reliability of a study refers to the reproducibility of the findings. Validity can be substantiated by a number of techniques including triangulation use of contradictory evidence, respondent validation, and constant comparison. Triangulation, as explained earlier, uses 2 or more methods to study the same phenomenon. Contradictory evidence, often known as deviant cases, must be sought out, examined, and accounted for in the analysis to ensure that researcher bias does not interfere with or alter their perception of the data and any insights offered. Respondent validation, which is allowing participants to read through the data and analyses and provide feedback on the researchers' interpretations of their responses, provides researchers with a method of checking for inconsistencies, challenges the researchers' assumptions, and provides them with an opportunity to re-analyse their data. The use of constant comparison means that one piece of data (for example, an interview) is compared with previous data and not considered on its own, enabling researchers to treat the data as a whole rather than fragmenting it. Constant comparison also enables the researcher to identify emerging/unanticipated themes within the research project.

Mentzer and Kahn (1995) emphasises the need attention to be paid to reliability and validity in logistics research as much of it “remains largely managerial in nature and lacks a rigorous orientation towards theory development, testing and application” (p.231). Reliability is concerned with the credibility of the research findings. The findings are considered reliable if they can be repeated. Reliability is very important in positivistic studies and tends to be tested by replicating a research study and comparing the results. Under an interpretive paradigm, reliability is concerned with whether similar observations and interpretations can be made on different occasions and by different observers (Hussey and Hussey, 1997).

Validity reflects the accuracy of the research findings of the investigated phenomena (Maylor and Blackmon, 2005). Mentzer and Kahn (1995) describe the four components of validity:

i. **Validity of the statistical conclusion-** refers to whether there is a statistical relationship between the two phenomena, i.e. whether the independent variable varies with the dependent variable.
ii. **Internal validity**- where there is a relationship between the two phenomena and in can be assessed to be causal, i.e. whether the independent variables cause the dependent variable.
iii. **Construct validity**- concerns whether the measures assess what they purport to assess.
iv. **External validity**- is defined as the degree to which the research findings can be generalised to the broader population.

Concluding their study on validity in logistics research, Mentzer and Flint (1997) point out that "the only way to thoroughly research any concept in logistics is through the research concept of triangulation" (p.213). Data on transport costs were accessed through the methodological forms of triangulation. In the data collection and analysis level, this research collected a very large number as the sample size and measures for the ITCM to reduce the transport corridor bias and maximise the reliability and validity results of the research.

In their review of logistics literature, Karatas-Cetin and Denktas-Sakar (2013) cites Halldorsson and Aastrup (2003) challenging the traditional way of judging logistics research. In their opinion the criteria of trustworthiness is primarily based on Interpretivism research approaches. The authors contend that trustworthiness combines the qualities of credibility, transferability, dependability and conformability. The authors' aim was to introduce alternative views on research quality and reflect on their possible role in logistics. This research is based on the critical realism philosophy, in line with Riege's (2003) main parameters of validity and reliability.

4.7. Summary

Following from the earlier chapters and based on the academic research paradigms, this chapter set out the development of the methodologies for this research. The research question required the determination of options for an improved transport system for the freight transport user. Transport costs were considered as the preferred 'tool' comparing the operating costs between the different modes was derived from different sources.

The main step of the investigation process inspected the market structure and collected relevant, reliable and realistic practises of existing transport modes. This research considered the total transport costs in their wider and fuller application, including the three factors of internal, external and time costs. This evaluation, based on generalised transport costs, formed the central element in developing a reliable tool that could be applied to assess the efficiency other transport, trade and geographical freight corridors, based on total transport costs. The rationalisation of this process allowed a robust comparator of the generalised costs for the different modes. The resulting analysis formed a part of the discussion with the transport users, suppliers and the policy makers.

Chapter 5

Freight Transport Costs: Approaches and general modelling assumptions

5.1. Introduction

New freight transport models and model systems are being developed in response to include both responses to changes in the transport system in a given environment and forecasts of future transport and traffic flows, transport costs etc. For the short run, models depict how policies influence transport and traffic demand. In long term models the impacts of factors that are largely exogenous to the transport sector (economic development, foreign trade, land use etc.) on transport demand are modelled De Jong et al 2013). A wide range of models and model systems are applied by public agencies to assess the impacts of different types of policy measures, such as changes in national regulations and taxes or infrastructure investments in specific links, nodes and corridors.

Invariably with the widening range of studies, there were some differing interpretations within transport research; however, the concept of generalized cost still remains one of the main and accepted concepts in transport economics. It is a part of transport economics theory and more precisely applies to the analysis of price and cost formation. Issues and influences from the passenger sector have redefined the initial definitions within the transport sector. Within transport logistics, Pieck (2010) explains freight transport as the method by which goods move from one location to another and it is an essential function in product supply chains as it provides the physical movement between the suppliers and customers (Emmet 2005).

Button (2010) defines the generalized cost of a trip as “a single, usually monetary, measure combining, generally in linear form, most of the important but disparate costs, which form the overall opportunity costs of a trip”. Button asserts that the shippers are concerned with the financial costs of the trip but also with the speed, the reliability and the timetabling of the service.

5.1.1. Layout of the chapter

The review of the published literature was presented in Chapter 2. Therein the basic concepts of freight transport, transport cost factors and the limiting scope of the research was defined.

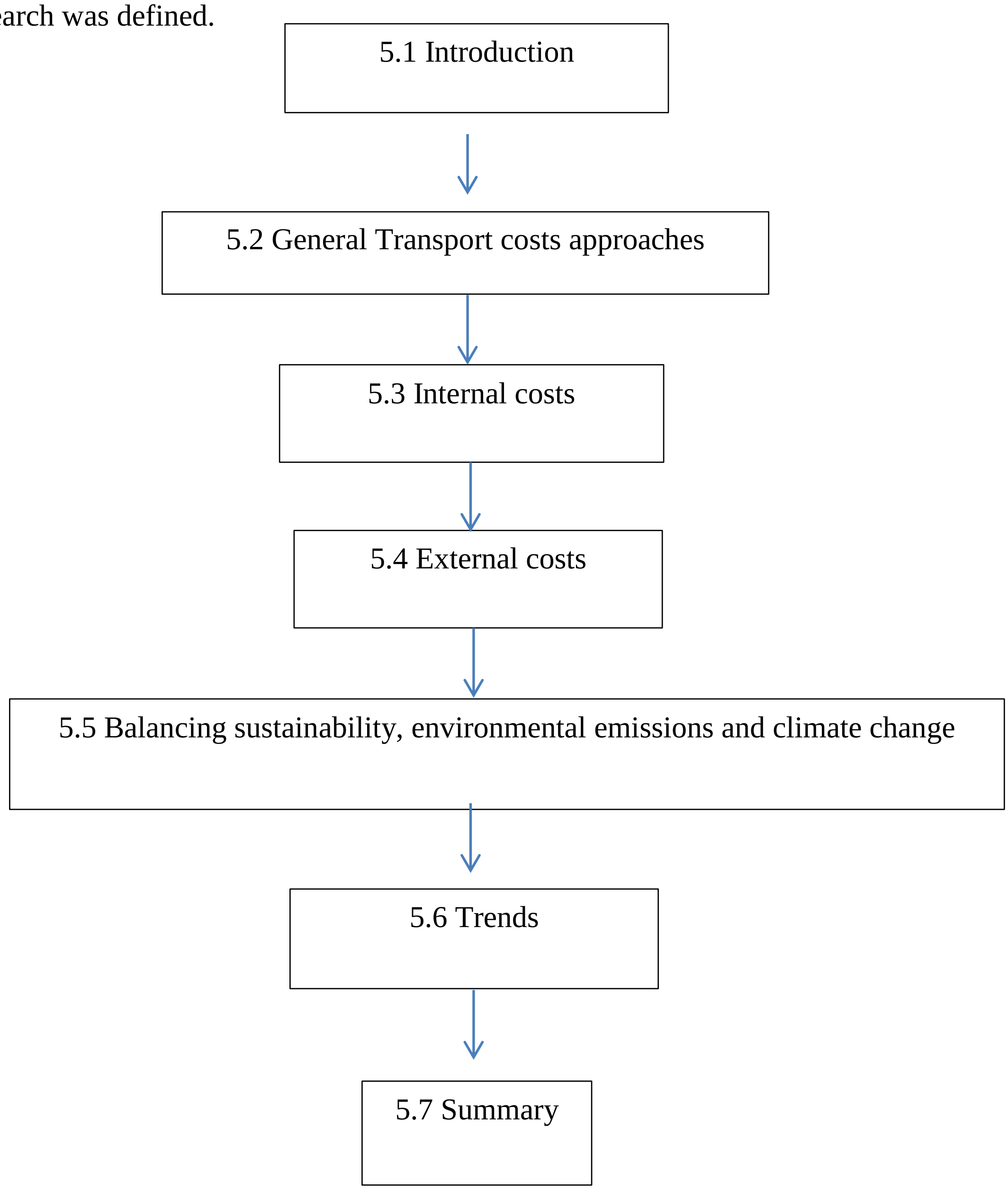

Figure 5.1: Layout of Chapter 5

The review introduced the concept of transport alternatives promoting sustainable development and presented the magnitude of environmental problems associated with freight transport sector, especially the road sector (Oberhofer and Fürst 2013).

This chapter provides an overview of the published literature related to the main research areas covered in this work. It focuses specifically on the factors determining the aggregates for the ITCM for the evaluation. This chapter will review relevant research on transport models and identify areas that require further investigation; introduces the theoretical framework underpinning the empirical research and finally examine the statistical trends in key parameters.

The available literature on the key logistics variables shaping this relationship is then reviewed. The factors likely to exert influence on transport costs arising from internal, external and time for the transport modes are identified. This leads to the development of a conceptual framework, the Intermodal Cost Model (ITCM) underpinning this research project, which concludes the chapter.

Figure 5.1 shows the layout of the chapter, set out in seven sections. Following the introduction the second section defines the main factors in this research. Sections three and four introduce the different factors and their respective aggregates used in the ITCM evaluation. Section five introduces the approaches towards balancing the issues of sustainability, transported related emissions and the resulting climate change. Section six summarises the research trends in transport research and policy. The seventh and the final section summarises this chapter.

5.2. General Transport costs approaches

Defining the concepts for ***costs***, within this research, costs will refer to the actual 'out of pocket costs incurred byte owner of the transport unit. However ***prices*** will mean out of pocket costs plus consideration, as imposed by the owner of the transport unit to the service buyer. This may include profits, bundled advantages, etc. and will not be considered within this research.

A transport cost model normally includes both transport (road, rail, inland waterway and sea) and intermodal transfer (ports, rail freight terminals, inland clearance depots) as cost components. The literature review has very few transport models incorporating internal and external costs as the total transport costs. One of the earlier models that considered both the cost items was suggested by Beresford and Dubey (1990) and subsequently improved by Beresford (1999) as cited by Komini (2015). Freight costs functions may be represented as:

1) The scope of the total cost,
2) The complexity of the freight transport units and unit costs (i.e. freight rate), and
3) Other specific issues.

Firstly, the scope of the total cost determines the form of freight cost function; it reflects the items included in the freight cost function and is normally based on:

- *Transportation costs* (often referred to as direct costs; including crew wage, maintenance costs, fuel costs, facility/equipment costs and so on),
- *Inventory costs*, *handling costs,* and *their combinations*.

There are other variations such as the EOQ (Economic Order Quantity) model (Baumol and Vinod, 1970). This model determines the optimal shipment size/frequency, clarifying the trade-off between decreased transport cost and increased inventory costs as quantity increases. Other variations, in the inland waterways, handling costs are emphasized rather than inventory costs (Kendall 1972, Jansson and Shneerson, 1982, Charles, 2008). The additional costs at the intermodal terminals are considered within the normal transit costs (Kim 2010). Further studies may include costs arising from factors as diverse as weather delays, labour related, scheduling inconstancies.

Secondly, when dealing with transport costs only, the different cost inputs are expressed in different units: distance-based costs such as fuel (e.g. €/km), time-based costs such as labour costs (e.g. €/hour) and quantity-based costs such as transhipment costs (e.g. € /TEU[48]) (De Jong and Ben-Akiva, 2007). The final expression is dependent on the sum of different cost components in different measurement units; weights carried, etc. However, costs increase in a non-linear way. With an increase of quantity shipped (in tonnes), in different parcel sizes, over the distance travelled, with the same size/type of vessels/vehicles there is an apparent increased (i.e. capacity of vehicles) performance. This is a result of 'economies of scale' (also referred to as returns of scale and often expressed as price discount). The nature of economies of scale is to save the fixed costs[49] such as labour costs (e.g. €/hour) for a certain amount of quantity and distance, since in many cases the variable costs such as fuel costs proportionally increase as quantity and distance increase. For example, regardless of the quantity (transporting 1 TEU and 2 TEU in the case of trucks), the same wage is paid to the truck driver. To sum up, the total cost (€) in a freight transport system is the total sum of the cost components with different units (e.g. €/km, €/TEU, €/ship, and €/day). In many cases, it has been expressed as one of the following:

$$T1 = f(Q) \times Q; \qquad \text{Eq 5.1}$$

$$T2 = f(D) \times D; \qquad \text{Eq 5.2}$$

$$T3 = f(Q, D) \times Q \times D \qquad \text{Eq 5.3}$$

$$T4 = F(Q, D) \qquad \text{Eq 5.4}$$

Where:

[48] 6.1m container unit referred as TEU/Twenty-Foot Equivalent

[49] The total cost consists of fixed and variable costs (Rutten, 1995, Daganzo, 1998)

T is the total cost (€);

Q is quantity shipped (tonne or TEU);

D is distance travelled;

f (Q) is unit cost function of flow (€/tonne or €/TEU);

f (D) is unit cost function of distance (€/km);

f (Q, D) is unit cost function of quantity-distance (€/tonne-km);

F (Q, D) is total cost function of quantity-distance (€)

When f (Q) is a constant, then T1 is a linear equation. Then, as Q increases, T1 increases linearly. In this case, the marginal cost is equal to the average cost.

When, f (Q) is a linear function, T1 becomes a quadratic equation which gives a non-linear relation.

In an earlier publication on less than full load for road (truck) computation of total costs (Samuelsson 1977) log and exponentials were often used for f (Q) (Higginson, 1993).

These unit costs may be declared as weight/quantity-based such as €/tonne and €/TEU, distance-based such as €/km, or could be based on a composite form such as €/tonne-km and or €/TEU-km as shown in equations T1 to T4 above (Higginson, 1993):

- T1: The unit cost in €/tonne (or €/TEU) could be a function of

  a) quantity/weight (Samuelsson, 1977, Daugherty et al., 1983, Abdelwahab and Sargious 1990, Perl and Sirisoponslip 1988, Hall 1987)

  b) Both quantity/weight and vehicle size (Kendall, 1972, Cullinane and Khanna, 2000, McCann, 2001, Kreutzberger, 2008a)

- In the case of b) above:

- T1 = f (VS, Q) * Q
  - Where VS is vehicle size (capacity of vehicle). The units of VS, such as TEU or tonne, should be same as Q.

- T2: The unit cost in €/km could be a function of distance (Perl and Daskin, 1985, Xu et al., 1994)
- T3: The unit cost in €/tonne-km (€/TEU-km) could be a function of
    - both distance and quantity (Ballou, 1990)
    - distance, quantity, and vehicle size (Rutten, 1995, Hsu and Tasi, 1999)
- T4: Total cost is a function of
    - both distance and quantity (Boyer, 1977, McFadden et al., 1986)

Transport total costs were expressed in other studies by:

- €/vehicle-km (Janic, 2007, 2008),
- €/locomotive-horsepower-mile (Bereskin, 2001).

In collecting and collating the transport data for the ITCM, the research data from Internalisation Measures and Policies for All external Cost of Transport (IMPACT) and (TREMOVE)[50] were consulted. IMPACT studied the effects on the external costs: which for sea transport, are air pollution and carbon dioxide; for rail, as some externalities are measured in relation to weight and others in relation to distance, it can be difficult to compare different systems against each other. Finally, for road based modes, all external costs are included. It is also important to bear in mind that these transport modes are not comparable in terms of volumes of transported goods. The standardised vehicles used in this report are a 40 tonne gross weight truck, a 960 tonnes gross weight train and a Short Sea vessel of 13,000 GT.

5.2.1. Analysis of costs: description of calculation tool

Generally in transport cost models, Beresford (1999) represent different unit costs of each transport mode and the total time taken for the transit; the steepness of the cost

[50] TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector. The model estimates the transport demand, modal shifts, vehicle stock renewal and scrappage decisions as well as the emissions of air pollutants and the welfare level, for policies as road pricing, public transport pricing, emission standards, subsidies for cleaner cars etc.

curves reflecting the performance values. The figures for sea transport reflect as the cheapest per tonnekm, whilst the road transport shows to be the most expensive (at least over a certain distance) and rail costs should be intermediate. In the model figure, the freight handling at ports and intermodal terminals, the freight handling charge levied is represented by a vertical ‘step’ in the cost curve therefore represents the costs incurred here, whilst there has been no advance or progress of the transit. The height of the step is proportionate to the level of the charge.

The mode choices will somewhat reflect the geography of the route; each route and mode combinations will offer a different total transport cost figure. The research is to determine the most competitive route cost wise. Bomyong and Beresford (2001) state that transport models have been used as a contributory tool in the debate over the value of time in freight transport operations. Although this approach in itself is not new (Levander, 1993; Christopher, 1998), the portrayal of the cost components as increments along the transport chain is quite novel.

Figure 5.2 shows the influence of the various cost elements, comparing the costs over distance for a unimodal and an intermodal alternative:

- The four points (A, B, C, and D) and their four projected points on the X-axis (*A′*, *B′*, *C′*, and *D′*) indicate the physical distance travelled in each mode.

Point A indicates the origin location, where the initial cost is incurred equally by both intermodal and truck only systems, (in practice, however, the initial costs for two transport systems may differ).

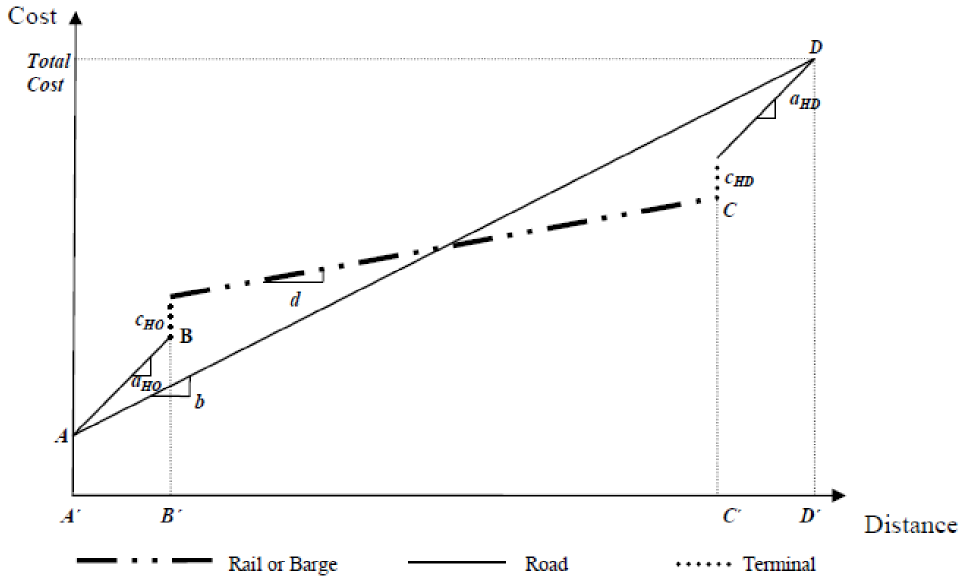

Figure 5.2 Cost structures of unimodal road mode and intermodal system

Source: (similar McGinnis 1989, United Nations 2006, Janic 2007, Kim and Wee 2011)

- Points B and C are the locations of the two intermodal terminals (i.e. hubs).
- Point D is the location of the final destination (i.e. the receiver).
- The segments A'B' and C'D' are the drayage distances; B'C' is the long-haulage distance by rail or barge;
- A'D' is the break-even distance;
- The values a, b, and d represent the rate per kilometre for each mode (different slopes/lengths)
- The pre-haulage and post-haulage drayage sections are represented by a_{HO} at origin and a_{HD} at destination. The two drayage rates are higher than the main haul road rate (b), as drayage mainly occurs on urban or regional roads while truck-only transport has a high share of relatively fast and therefore relatively cheap motorways. Since drayage at each end in the intermodal chain takes place in different areas, the rates (i.e. a_{HO} and a_{HD}) could be different.

- Intermodal terminal transhipment charges: C_{HO} represents the costs at the 'origin' terminal (drayage to main haul transfers) and C_{HD} represents those at the 'destination' terminal (main haul to destination drayage).

Following Figures 5.3 and 5.4 offers a graphic representation of the static period, when the freight unit incurs costs, as 'time costs, transhipment costs, without any advance along the transit line.

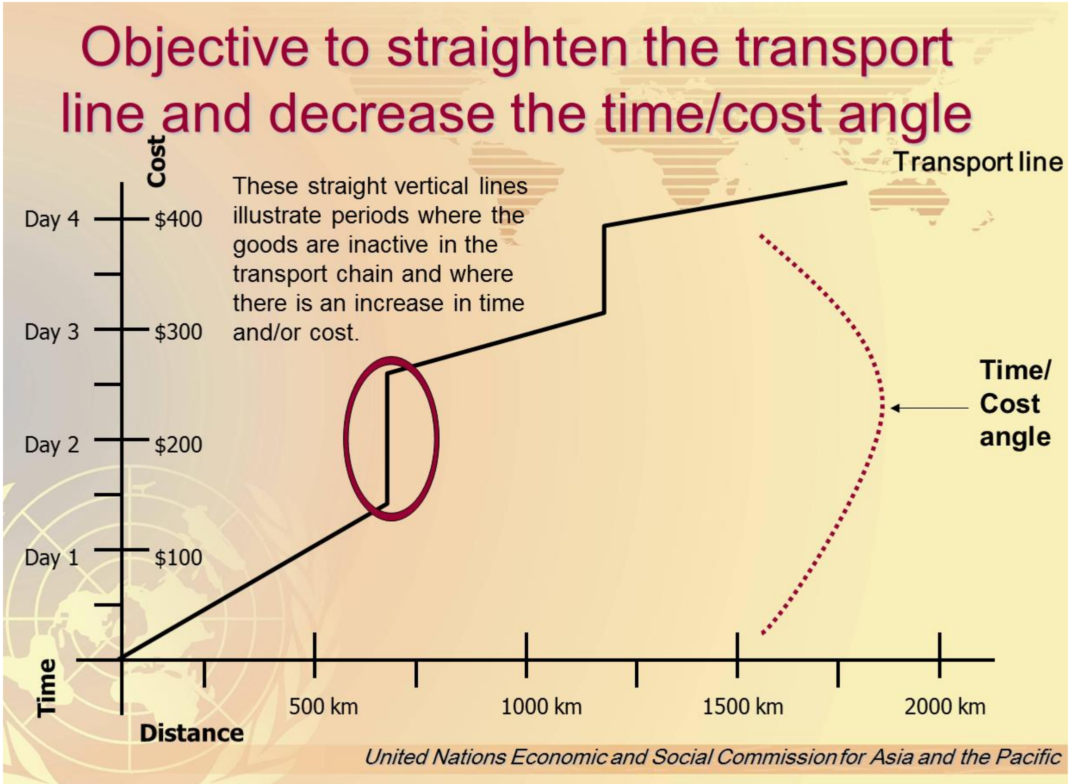

Figure 5.3: Static periods of goods along the transport chain View 1

Source: UNESCAP

The transport models show the effect of the 'time/cost angle' and the effective reduction in the angle (UNESCAP).

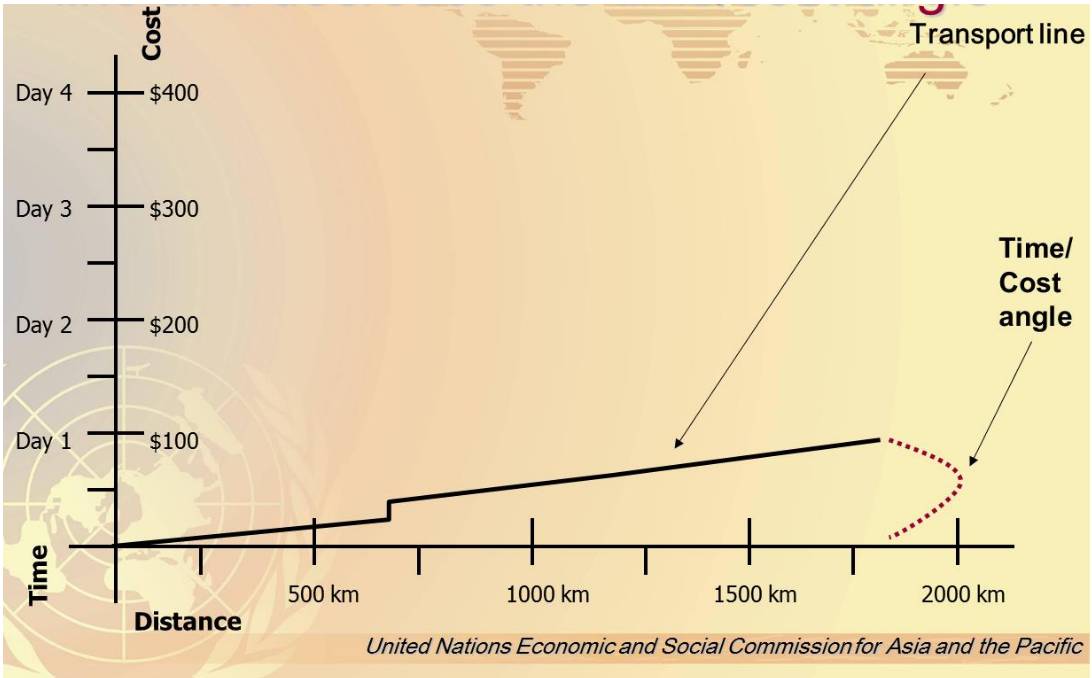

Figure 5.3: Static periods of goods along the transport chain View 2

Source: UNESCAP.

Table 5.1 shows the general performance of the 4+1 transport modes, comparing the six criteria, where 1 is the lowest and 5 is the highest).

Table 5.1: General performances of the various transport modes

Determinants	Road	Rail	Water/Sea	Air	Pipelines
Cost	4	3	2	5	1
Transit Time	2	3	4	1	----
Reliability	1	2	4	3	----
Capability	2	1	4	3	5
Accessibility	1	2	4	3	----
Security	2	3	4	1	----

Source: Management of Business Logistics (7th Ed)

The first is the distance at which the costs for the unimodal (road only) and the intermodal system are the same. The second are the negativities arising from each of the transport systems. The actual cost structure/function of an intermodal freight transport system is more complicated (i.e. non-linear) than that of a unimodal system, such as the long-haul road mode.

In general, the costs per kilometre of SSS and rail were found to be cheaper than road. Along with transport cost, there are several other factors that influence the final choice of mode, including the availability of alternative modes, scheduling reliability and transport time and commodity type. In the EU 27[51] road had a modal share of 45.6%, SSS 37.3% and rail only 10.5% (Delhaye et al 2010).

Eq 5.5 represents the General Transport Cost (GTC) for intermodal transport chain,

GTC = INTERNAL +EXTERNAL + TC + Others Eq 5.5

Where:

- INTERNAL COSTS are the sum of total haulage costs = pre/post-haulage to/from terminals + Main haulage (i.e. rail/inland/short sea operations)
- EXTERNAL COSTS are the sum of costs caused by the transport mode during transit;
- TC is total costs for transit time costs; it is commodity dependent.
- Others may include transhipment costs (at the terminals); toll charges; congestion charges; etc. These costs could be mode-specific;

Based on these assumptions, the generic structure for calculating particular cost categories (internal, external) and cost type (transport, time, handling, type of externality) for particular steps of operation of the networks is developed. Included in this structure are:

- Internal cost:

  Transport cost = Cost frequency x Cost per frequency

  = [(Demand)/ (Load factor x Vehicle capacity)] x (Cost per frequency)

  Time cost = Demand x Time x Cost per unit of time per unit of demand

[51] DG MOVE, EU-27 Modal split of freight transport in percentage

Handling cost = Demand x Cost per unit of demand

- External cost:

External cost = Frequency x External cost per frequency

= [(Demand)/ (Load factor/Vehicle capacity)] x (External cost per frequency)

Earlier published articles on transport mode choices were based on shippers seeking a transport solution that gives the lowest generalized costs (Hanssen et al 2012). A linear expression for the costs C to a company carrying X tonnes over D kilometres (Eq 5.6) can be expressed as follows:

$C = a_0 + a_1 X + a_2 XD$ Eq 5.6

Where:

- a_0 is the incremental cost, independent of the tonnage and distance;
- a_1 is the incremental cost (rate) per tonne; and
- a_2 is the incremental cost (rate) per tonne-kilometres.

First, the out of pocket or pecuniary costs, P, are related to price for the transport service. Second, time cost is the product of time cost per hour, H over the transport time, T. It is assumed that P, T and thereby also C, are positively related to transport distance D which is measured in kilometres (km). Here H is independent of the transport distance.

Extending the concept to the general costs (out of pocket or internal costs)

$C(D) = P(D) + HT(D)$ where $\partial P/\partial D, \partial T/\partial D > 0 => \partial C/\partial D > 0$ Eq. 5.7

Computing the general cost C

Where:

P is the out of pocket cost for the transport mode

D is the distance

H is the rate/cost per hour, over

T the transit time

Time costs per hour, H, is equal for a given type of goods independent of transport mode and distance. It will, however, in practice be a self-selection of which goods use a specific transport mode. The value of H for a commodity can be calculated by considering the value per tonne, the interest rate per hour and the deterioration costs per hour. Value, interest rate and deterioration rate are all positively related to time costs per hour.

This has been the accepted definition of the generalized transport cost given by equation Eq 5.7 with respect to the costs relevant for the shipper of freight. However, this research introduces and includes the mitigating costs resulting from the freight of transport. In the event, all external costs were included in the generalized transport cost function, then the model would offer the combined costs, both internal and welfare economic costs would be equal and the chosen transport solutions would be optimal for the society as a whole.

It remains a policy issue to incorporate additional measure (tolls and taxes) to extend the principle of ‘the polluter pays’[52] on environmental issues and campaigns to change attitudes could make transport companies more aware of the costs they impose on others. Based on earlier models (Janic 2007), Hanssen et al (2012) extended the concepts of total transport costs towards including whether an intermodal transport solution is preferred to unimodal transport for a transport purchaser aiming to minimize generalized transport costs.

[52] Pigouvian taxes were corrective taxes, proposed by Arthur C. Pigou (The Economics of Welfare” 1920) and levied on each unit of output an externality-generator agent produces. Pigouvian taxes are punitive and are used to mitigate the negativities of externalities, especially in highly polluting industries.

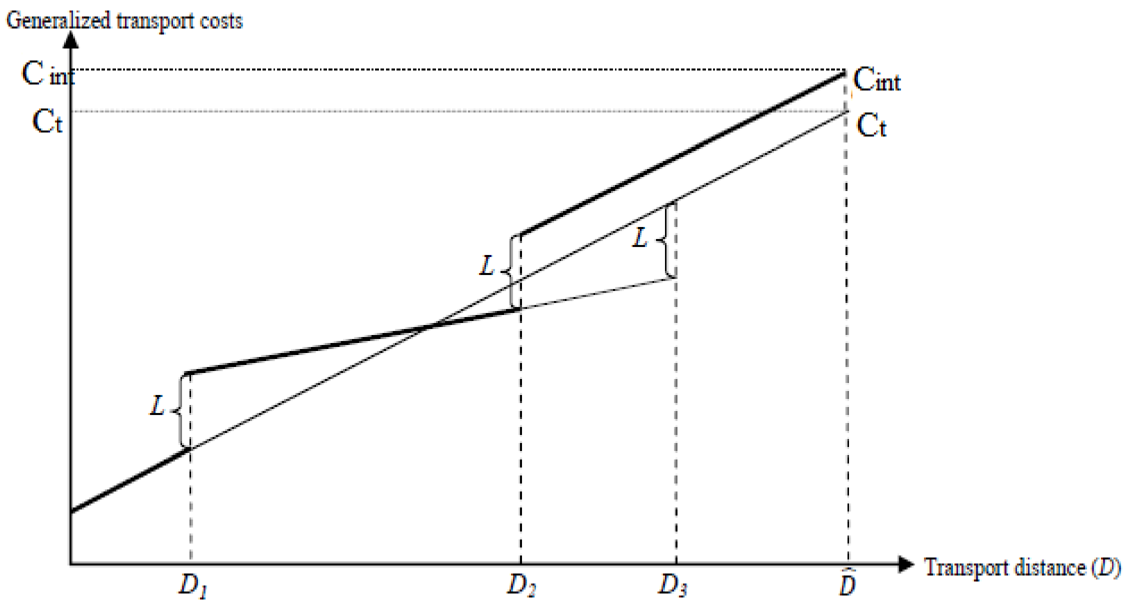

Figure 5.5 Relationship between generalized transport costs over transport distances Source: Several; Janic 2007; Hanssen et al 2012.

Figure 5.5 shows cost/time relationships for a freight unit from Origin to Destination Ď. In the figure, intermodal transit is preferred to the unimodal transport between long-haul distances (D_2 – D_1). If, when the long-haul distance is D_3, then the generalized costs for the two alternatives become equal. A unimodal alternative applies to road transport only with the corresponding generalized costs as defined in equation 5.8.

$$C_t = \rho_{0t} + \rho_{1t}\,\check{D} \qquad \text{Eq 5.8}$$

The container can be transported from origin by truck (pre-haulage) to the distance D_1; then by rail or water for the long-haul distance (D_2-D_1) and finally by truck to the final destination (post haulage) Ď (See Figure 4-4).

Costs for transferring the container (handling at terminal) from truck to rail or water and back to truck are symmetric and each defined by L. L is the sum of transhipment costs which includes handling costs and time costs. The generalized transport costs for this intermodal transport solution using truck and rail; C_{int} is defined in Eq 4-9.

In equation 5.9, the Pre/Post Haul costs are adjusted when $\varphi \geq 1$. This factor recognises that the drayage truck costs may be higher, per kilometre, than the performances of long-haul transport by road.

$$C_{int} = (\rho_{ot} + \varphi\ \rho_{1t}\ D_1) + (L + \rho_{1r}\ (D_2 - D_1)) + (L + \rho_{1t}\ (\check{D} - D_2)) \qquad \text{Eq 5-9}$$

In equation 4-9:

- $(\rho_{ot} + \varphi\ \rho_{1t}\ D_1)$ represents generalized transport costs by road from origin to the terminal at distance $D_{1.}$
- $(L + \rho_{1r}\ (D_2 - D_1)$ represents costs for loading the container on rail and the long-haul transport by rail between terminals at D_1 and D_2.
- $(L + \rho_{1t}\ (\check{D} - D_2)$ represents the final transhipment costs for loading the container back on a truck for the post main haul transport by road to the final destination.

The total transport costs over the total distance are represented by the intermodal and unimodal transport solutions for C_{int} and C_t, respectively. The pre and post generalized costs with respect to distance are equal for pre- and post-haulage distances and equal to $\varphi\ \rho_{1t}$. In the computation of the road costs, overall generalized transport costs increase more rapidly with distance for truck compared to water and rail.

As long-haul distance increases, intermodal transport offers the better alternative.

Modelling the full costs of an intermodal and equivalent road transport network involves developing the model, collection of data and applying the model. Table 5-2 shows the fixed and operating costs relevant to the three modes plus the pipelines system.

Developing the model includes identification of the relevant variables and their relationships. The variables reflect the type and format of data needed for the model application. Data collection is particularly challenging (Janic 2007).

Table 5.2 Transport mode related Fixed and operating cost factors

Mode	Fixed/capital Costs	Operating Costs
Rail or Highway	Land, Construction, Rolling Stock	Maintenance, Labour, Fuel
Pipeline	Land, Construction	Maintenance, Energy
Air	Land, Field & Terminal Construction, Aircraft	Maintenance, Fuel, Labour
Maritime	Land for Port Terminals, Cargo Handling Equipment, Ships	Maintenance, Labour, Fuel

Source: Author

External costs are estimated using a four-stage process:

1) Differentiating of transport mode
2) Quantification of emissions / burdens and estimation of their spatial concentration,
3) Estimation of the prospective damages and
4) Quantifying monetary values on short and long-term damage.

In both networks, data on the internal and external costs refer to particular parts (segments, actors) operating under different technical / technological market and environmental-spatial conditions. The results are then aggregated as stated.

Intermodal network

- Collection and distribution
    - Vehicles of the same capacity and load factor collect and/or distribute load units in a given zone.
    - Each vehicle makes a round trip of approximately the same length at a constant average speed.

- The collection step starts from the vehicle's initial position, which can be anywhere within the 'shipper' area and ends at the origin's intermodal terminal. The distribution step starts from the destination intermodal terminal where the vehicles may be stored in a pool and ends in the reception area at the last receiver.
- Headways between the arrivals and departures of the successive vehicles (and thus loads) at the origin and from the destination intermodal terminal, respectively, are approximately constant and independent of each other.

- Line-haul between two terminals
    - Headways between successive departures of the main mode's vehicles between two intermodal terminals are constant, reflecting the practice of many non-road transport operators in Europe to schedule regular weekday services.
    - Each intermodal vehicle has identical capacity irrespective of whether it is rail or road.
    - The average speed and the anticipated delays of the main mode are constant and approximately equal.

5.3. Internal (out of pocket) costs

There have been conflicting views regarding the relative importance of the different costs that make up composite internal cost structures. Studies in Spain (Polo 2000) showed in international liner shipping, that the capital cost (33%) was the most important cost, followed by the loading cost (25%). This was confirmed by a later study (Sauri 2006). However, in their study on SSS, Paixão and Marlow (2002) found that port operations charges and costs were about 70% of the total costs. The study further stated that port inefficiency was one of the main causes leading to the lack of competitiveness of SSS. Fuel costs were considered as the most important costs by

Grosso et al (2008) followed by the depreciation costs of the assets. Martinez-Lopez et al (2013) concluded that except in a very few cases, cost functions reflect the features of the fleets and of the service (Ametller, 2007; Sauri and Spunch, 2009) and cost estimations tended to be based on vessel (type) generalized cost models for the different distances (Koi and Ng 2009). Other cost models were developed based on market information or interviews (Grosso et al, 2008) based on a particular SSS service. However, results from this research limited the range of extrapolation for comparing the performance with other kinds of fleet (number of vessels, kind of ships) or SSS services (frequency). The utilization of general cost models for intermodal transport, understood as a combination of rail and road, is especially typical of the analysis of competitiveness against road haulage (Janic, 2007; Hanssen et al, 2012).

The generic structure for calculating particular cost categories (internal, external) and cost type (transport, time, handling, type of externality) for particular steps of operation of the networks is developed by consideration of the factors here:

Internal cost

Transport cost	=	Frequency x Cost per frequency
	=	[(Demand)/ (Load factor x Vehicle capacity)] x Cost per frequency
Time cost	=	Demand x Time x Cost per unit of time per unit of demand
Handling cost	=	Demand x Cost per unit of demand

Table 5.3 Cost evolution road transport (truck >32 tons) (€/tonnekm)

COST	2010	2015	2020	2025	2030
Repair	0.0098	0.0093	0.0093	0.0094	0.0095
Purchase	0.0241	0.0225	0.0224	0.0226	0.0248
Labour Tax	0.0184	0.0168	0.0168	0.0169	0.0169
Labour	0.0172	0.0157	0.0157	0.0158	0.0158
Insurance	0.0064	0.0062	0.0063	0.0064	0.0066
Fuel	0.0154	0.0119	0.0124	0.0130	0.0132
TAXES					
Registration	0.0001	0.0001	0.0001	0.0001	0.0001
Ownership	0.0017	0.0015	0.0015	0.0014	0.0014
Network	0.0016	0.0016	0.0033	0.0033	0.0032
Insurance	0.0011	0.0011	0.0011	0.0011	0.0012
Fuel	0.0090	0.0081	0.0079	0.0077	0.0076
TOTAL COSTS	0.0913	0.0825	0.0830	0.0841	0.0848
TOTAL TAXES	0.0134	0.0123	0.0138	0.0135	0.0134
TOTAL €/tonnekm	0.1046	0.0947	0.0968	0.0976	0.0982

Source: TREMOVE; Delhaye et al (2010)

Factors for road

There are several studies on road transport with a very wide array of vested interests, making it difficult to select unbiased data.

However, the results from the TREMOVE model offered relevant and detailed data for this research. In Table 5.3 the costs are separated into fixed costs, labour costs and other variable costs. The table shows that taxes represent about 13% of the road freight costs and that energy and labour costs, on average, are about one third of the total costs. For longer distances, the share of the labour costs would be higher. The energy cost is about 23% of total costs (Delhaye 2010).Total Road Transport Costs are given by:

Capital costs (Depreciation/Renting costs, Personnel, Fuel, Maintenance and Repair)

+ TAXES (Registration, Ownership, Network, Insurance, and Fuel)

+ Operations (Loading/unloading, transhipment)

+ TOLLS

Factors for rail

One of the main difficulties in obtaining valid information for research into the freight rail industry comes from the reluctance of the rail operators to make public its operating data and figures.

In general, there is very little publicly available information for rail. As the case studies are based on European operations, the data was collected for the analysis of the railway line Iron Rhine between Belgium and the Netherlands (Delhaye et al 2010). This offered detailed and valid information and it was possible for it to be verified by some of the Belgian, Dutch, German and French railway undertakings. The drawbacks of this data is that ~ firstly, it is probably more valid for central European countries than for other countries; secondly, comparison with other – albeit scarce – data, shows that these costs appear to be underestimated. For example, ECORYS (2004) gives information on total revenue from freight transport and the total amount of tonne-kilometre driven in a year. This information is based on company accounts for a selection of countries. Revenue divided by tonne-kilometre leads to prices around 0.04-0.08 €/tonne-kilometre.

There are three types of costs:

1) Fixed costs (€/h) (average) : cost of the locomotive, wagon, personnel and overheads;
2) Variable costs (€/trainkm) (average): infrastructure fee, shunting costs. Depending on the baseline scenario, this average cost could also include an externality tax for future years.

3) Energy cost (€/trainkm) (average): distinguishing diesel from electric traction. A weighted average speed of 62.5 km/h (diesel and electric traction) has been used.

Table 5.4 Rail transport commodity costs in €/tonne-kilometre in 2010

Freight commodities		Electric	Diesel
0	Agriculture products and live animals	0.0066	0.0078
1	Food stuff and animal fodder	0.0067	0.0079
2	Solid mineral fuels	0.0060	0.0068
3	Crude Oil	0.0048	0.0056
4	Ores and metal waste	0.0049	0.0056
5	Metal products	0.0067	0.0079
6	Crude and refined minerals; Building materials	0.0060	0.0068
7	Fertilisers	0.0048	0.0056
8	Chemicals	0.0061	0.0072
9	Machinery, transport equipment, manufactured items and miscellaneous articles	0.0081	0.0096
10	Petroleum products	0.0048	0.0056

Source: Delhaye et al (2010)

Total Rail Transport costs are:

Labour costs
+ Energy costs (Fuel)
+ Energy costs (Electric power)
+ Insurance costs
+ Maintenance and Repair costs
+ Depreciation/Renting costs
+ Tolls + Overhead costs
+ Other costs
+ Rail Tracks costs
+ Shunting operations costs
+ Loading/Unloading costs

Improved efficiency and costs will influence electric power generation and its source (electric power from hydrocarbon fuelled power stations, hydro-electric or nuclear) and reflects on direct and indirect costs as shown in table 5.4. (Note: taxes are not included for rail, as they are mostly exempt).

Table 5.5: EURO general costs (percentages) of the 4 types of SSS vessel

Vessels	RoPax Large		RoPax Small		Ro Ro		Lo Lo	
Size (TEUS/Trailers)	290		40		200		600	
Deadweight Tonnes	12000		3000		10000		11000	
Full Cargo Tonnes	7250		1000		2800		7200	
Speed knots	22		8		17.5		14	
Fuel Tonnes/day	53.3		7		37.9		28	
Fuel/day: €	22%	16987	10%	2231	32	12079	47%	8924
Capital repayments	19%	14945	16%	7960	21	7960	12%	2189
Interest	15%	12286	13%	2857	17	6543	9%	1799
Manning	9%	7500	15%	3300	5	1901	8%	1588
Gross Margin	10%	8199	12%	2675	9	3302	7%	1283
Port Costs	8%	6000	4%	850	8	3000	6%	1200
Repairs & Maintenance	4%	3300	5%	1000	4	1382	4%	802
Administration	3%	2700	5%	1000	2	870	3%	504
Stores & Lubes	8	6000	19%	3800	1	328	2%	351
Insurance	2	1500	1	300	1	443	2%	313
Total €/day costs	€79417		€21488		€37807		€18952	

Source: Delhaye et al (2010)

Factors for short sea

The model incorporates the impacts of the new regulations by determining their extent on emission factors costs of SSS. The model considers the price changes and computes the effect on the total volumes and emissions. As there are several countries and different factors, the main information and data are sourced from the ETIS and the

Eurostat database (transport routes and volumes), the SKEMA study (specific information on maritime transport) and the TREMOVE (road and rail transport costs and emissions) and EMMOSS (shipping emissions) models.[53] Table 5.5 provides the general percentages and costs for each of the SSS vessels.

The cost/day figures were converted for the transport model into cost/tonne-kilometre to allow a comparison across the types of vessels. The conversion involved dividing the cost per day (€/day) figures by distance per day (km/day). For the €/tonne-kilometre figure, the €/km cost was divided by the ship's carrying capacity, in tonnes, generating the final value. The SSS 'costs per tonne km' depends on the commodity, route and the type of vessel. This makes a direct comparison of the SSS figures with road and rail rather complex, especially the values for 'time costs' from intermodal transfers and scheduling issues. This quantitative assessment is complemented with a qualitative assessment to take into account any non-quantifiable factors. The baseline factors for the transport were the results from extensive collative studies of over 250 O/D main EU freight corridors (Delhaye et al 2010). The baseline conditions (including economic growth projections) reflected the environmental regulations towards reducing environmental pollution from freight transport. Five policy scenarios suggested by iTREN were:

- Scenario A: Sulphur regulation of 0.1% in the ECAs
- Scenario B: Sulphur regulation of 0.1% in the ECAs + eMaritime
- Scenario C: Sulphur regulation of 0.1% in the ECAs + eMaritime + Greenhouse Gas (GHG) policy
- Scenario D: Sulphur regulation of 0.1% in all European seas except the Atlantic Coast + eMaritime + GHG policy
- Scenario E: Sulphur regulation of 0.1% in all European seas except the Atlantic Coast + eMaritime + GHG policy + NOx regulation in ECAs.

[53] EMMOSS Emission model for inland shipping, maritime transport and rail

Overall, the first policy scenario – lowering of sulphur content within the ECAs - leads to the largest changes in transport volumes – from only 1% for RoPax Small to 9% for routes where a LoLo is used. Assuming that the ship operators' switch to low sulphur content fuels to comply with this regulation, this will directly increase the fuel costs, leading to a rather large increase in total costs (varying from an increase of 6% for RoPax Small up to 29% for LoLo). A price increase for SSS also decreases the budget for road transport as switching to road would not lead to a cost saving.

Adding the effects of the eMaritime policy somewhat mitigates the decrease in volumes, but the outcome is rather small as eMaritime is not expected to lead to high cost decreases. It is assumed that port costs will be lowered by 5%, which leads to a total cost reduction varying between 0.2% (RoPax Small) and 0.4% (RoPax Large and RoRo). The effect of internalising GHG emissions by SSS via a market based instrument at a price of 25 €/tonne CO_2 leads to an increase in costs of about 3% (RoPax Small and Large) to 10% (LoLo) and causes an additional decrease in volumes of 0.1% to 3%.

Factors for time

Globalisation and market pressures have led to a dramatic increase in travel, mainly driven by a desire for the freight to be delivered faster and over ever greater distances.

Transport geographers stress that the present rate of growth is unsustainable and the situation needs to be reassessed through substantially reducing the levels of consumption (energy and carbon) in transport. This suggests that travel activities should consider a more flexible interpretation of time constraints. Transport geographers have outlined the changing patterns of movement, before concentrating on urban areas where most daily travel takes place, by examining the trilogy of distance, speed and time (Bannister 2011).

Table 5.6 Value of time (€/ton/hour)

	Commodity	EURO/Tonne/Hr.
0	Agriculture Products and Live Animals	0.0119
1	Foodstuffs and Animal Fodder	0.0124
2	Solid Mineral Fuels	0.0011
3	Crude Oil	0.0065
4	Ores and Metal Waste	0.0062
5	Metal Products	0.0086
6	Crude and Manufactured Minerals, Building Materials	0.0009
7	Fertilisers	0.0047
8	Chemicals	0.0281
9	Machinery, Transport Equipment, Manufactured Articles and Miscellaneous Articles	0.1350
10	Petroleum Products	0.0071

Source: TREMOVE as referred by Delhaye (2010)

The recent trend in calculating of time has been based on the conventional transport paradigm that the travel time needs to be minimised and consequently speeds need to be increased. The time cost in this model is equal to the cost of the in-vehicle time, multiplied by values of time in euro per hour or per tonne hour. As speed determines the transit time, it is a parameter that can be changed in the scenarios[54]. The values of time (see Table 5.6) are based on the values used within the TRANSTOOLS model and are shown in the table below. The values of time depend on the type of goods, but not on the transport mode.

The TREMOVE model determines the value of time in cost per km is found by relating it to the speed of the relevant transport mode. Table 5.7 shows the TREMOVE model's assumed values for the speed for each of the transport modes. Reflecting

[54] In theory, a congestion function could be included. Speed would then be a function of transport volumes. The research utilises the predicted speed evolution used in the TREMOVE model, which incorporates a congestion function.

recent trends, there is a reduction in the average road speed because of increased volumes and the resulting congestion.

Table 5.7: Assumed model of speed for the various modes

		2010	2015	2020	2025
Road		59.97	59.26	58.58	57.96
Rail		62.48	64.07	65.67	65.7
SSS	LoLo	25.93	25.93	25.93	25.93
	RoRo	32.41	32.41	32.41	32.41
	RoPax Small	25.93	25.93	25.93	25.93
	RoPax Large	40.74	40.74	40.74	40.74

Source: TREMOVE & Review of published vessel speeds

The overall road average does not register the new demands for ‘rest periods’. This might give rise to an incorrect speed calculation over longer distances. This potential error occurs because there was no direct information obtained from the road hauliers in respect of relief drivers on the long haul journeys. The Irish hauliers stated the requirement for the drivers to maintain their drive times and the trip tachographs. On the assumption of a 48 hour working week, a truck may transport a distance of 2900km/week, as per the stated speeds. For the other modes, there is an assumed increase in rail speeds due to the expected improvements brought about by national policies. The SSS speeds reflect the balance between costs and emissions. However, they do not include the occasional commercial pressures brought about by shippers for ‘slow steaming’.

For the SSS transport route price per km, incorporating the combinations of road, SSS and/or rail, a composite average does include the pre- and post-haul road segments. In order to formulate a standard weighted measure, a reasonable value was assumed for all the routes. Road distances were verified against Google maps; rail distances were collected from the relevant network information statements. This facilitated the OD distances and computing of the total price for each option.

5.4. External costs

Transport contributes significantly to economic growth and enables a global market. Unfortunately, most forms of transport do not only affect society in a positive way but also give rise to side effects. Transport is a major consumer of two critical 'exhaustible' resources: fossil fuels and land. The transport industry, with its near complete dependence on fossil fuels, are the predominant-and fastest growing consumer of fossil fuels and their continued and unrestricted supply raises critical concerns. Worryingly, transport has been the only sector in which oil demand has been growing over the past twenty years (EU Energy and Transport 2010). Transport negativities contribute to congestion, ambient noise levels and air pollution. However, mitigating these side effects give rise to various resource costs that are expressed in monetary terms: time costs of delays, health costs caused by air pollution, productivity losses due to injury and deaths in traffic accidents, abatement costs due to climate impacts of transport, etc.

When the side effects[55] of a certain activity impose a cost upon society, economists define these as external costs. The marginal (social) costs represent the costs generated by an additional transport unit when using the infrastructure. The owner bears a part of these internal costs or 'out of pocket costs'. There is another set of costs that are not borne by those who cause them, but affect third parties (such as pollution and accidents) and these are termed as external marginal costs. By internalising these external costs in the marginal costs, the volume of transport activity will reach the socially optimal level. However, when these external costs are not borne by those who

[55] Congestion; Accidents; Noise; Air pollution; Climate change; Other environmental impacts (costs of up- and downstream processes); Infrastructure wear and tear for road and rail.

generate them, there is a failure in the market mechanism of allocating resources efficiently; the tax payer subsidizes the difference.

In order to define external costs properly it is important to distinguish between them. They are:

- Private (or internal costs), directly borne by the transport user, such as wear and tear and energy cost of vehicle use, own time costs, transport fares and transport taxes and charges.
- Social costs reflecting all costs occurring due to the provision and use of transport infrastructure, such as wear and tear costs of infrastructure, capital costs, congestion costs, accident costs and environmental costs.

The study focuses on short run marginal costs, assuming that capacity of the infrastructure is constant. Long-run marginal costs include also the capital costs of increasing capacity to accommodate an increase in output; they are difficult to measure. Linking charges to long-run marginal costs would lead to inefficiencies where excess transport capacity exists. Although this study focuses on the short-term marginal costs an indication will be given of what happens if investment costs are included. The short run marginal social costs generated when a transport vehicle uses a mode (road, rail, air or sea) were the main costs structured, as follows:

- Infrastructure costs; the increased costs of operating, maintenance and repair of infrastructure and technical facilities as a result of an additional vessel.
- Environmental costs; additional damage resulting from emissions to air, water and soil from an additional vessel, including noise pollution (Patsia et al 2013).
- Safety and accident costs; the economic value of the change in accident risk when a user enters the traffic flow (this risk relates to the user himself as well as to

others). These costs include repair costs, medical costs, suffering and delays imposed on others as a result of an accident.

- Congestion costs; increased operation costs and costs of extra time spent travelling as a result of an additional vessel entering the traffic flow or an accident

Internalisation of these costs means making such effects part of the total costs and adds to the decision making process of transport users. It quantifies a monetary value for the policy maker, city officials and the transport user. This may be done directly through regulation, i.e. command and control measures, or indirectly through providing the right incentives to transport users, namely with market-based instruments (e.g. taxes, charges, emission trading, etc.). Combinations of these basic types are possible: for example, existing taxes and charges may be differentiated, e.g. by the EURO emission classes of vehicles.

'Europe 2020'[56] the EU's ambitious Roadmap for moving to a competitive low carbon economy in 2050[57] and the 2011 White Paper on Transport[58] recognise the huge challenges facing the transport sector. This involves the reduction of the transport based GHG emissions by 60% by 2050 compared with 1990 levels (Van Essen et al, Final Report 2012). The policy extends to the reduction of road congestion through the objectives of TEN-T, co-modality and modal shift. In line with the transport policy and the remits of TEN-T, policy favours the internalisation of external costs for solving these challenges (Van Essen et al 2012). A possible internalization of external cost will not entirely solve the problem, but could help in creating a more sustainable environment.

In addition, the internalization follows the 'user-pays' and 'polluter-pays' principles, thus helping in informing a better awareness of each action's consequences. Pigou

[56] COM (2010) 2020
[57] COM (2011) 112
[58] COM (2011) 144

proposed these concepts (Economics of Welfare 1932) as ‘divergence between social and private product’.

> *“Here the essence of the matter is that one person A, in the course of rendering some service, for which payment is made, to a second person B, incidentally also renders services or disservices to other persons (not producers of like services), of such a sort that payment cannot be extracted from the benefited parties or compensation enforced on behalf of the injured parties.”* (1932, Page 183).

Those concepts still define the positive/negative externalities, where externalities are costs or benefits, not paid by the person who produces them.

Internalization often includes the company’s social costs included into the company’s private costs (Piecyk et al., 2010). Rationalising the costs of the externalities must be borne by the entities that generate them; this may be realized by government, market or private organizations (Van Essen et al 2011). More precisely, in transport economics, for a positive or negative transport activity consequence; the person that is benefiting or suffering the consequence of the transport activity is not paying or receiving any monetary compensation. There are no comprehensive single studies internalizing the external costs of transportation, as it is a complex issue requiring a large interlinked data. It is made difficult to incorporate the various parameters, estimates, externalities, and transportation modes into an enveloping model. Appendix Table A3.1 summarises the literature on externalities for different transport modes.

Some studies sought a generic set of cost factors that can be used for similar externalities while others focus on more specific and detailed cost with different vehicle/engine types, countries, etc. Whilst specific cost factors may enable more accurate estimations than a generic set does, they have a more detailed data availability and involve more complex calculations. Appendix Table A3.1 (page 357) tabulates the earlier literatureon the externalties.

5.4.1. Transported related emissions (Europe)

The 2009 figures for transport related emissions (including international maritime and aviation) were nearly 24% of all EU Green House Gas (GHG) emissions. Figure 5.6 shows the emissions distributions from the various modes.

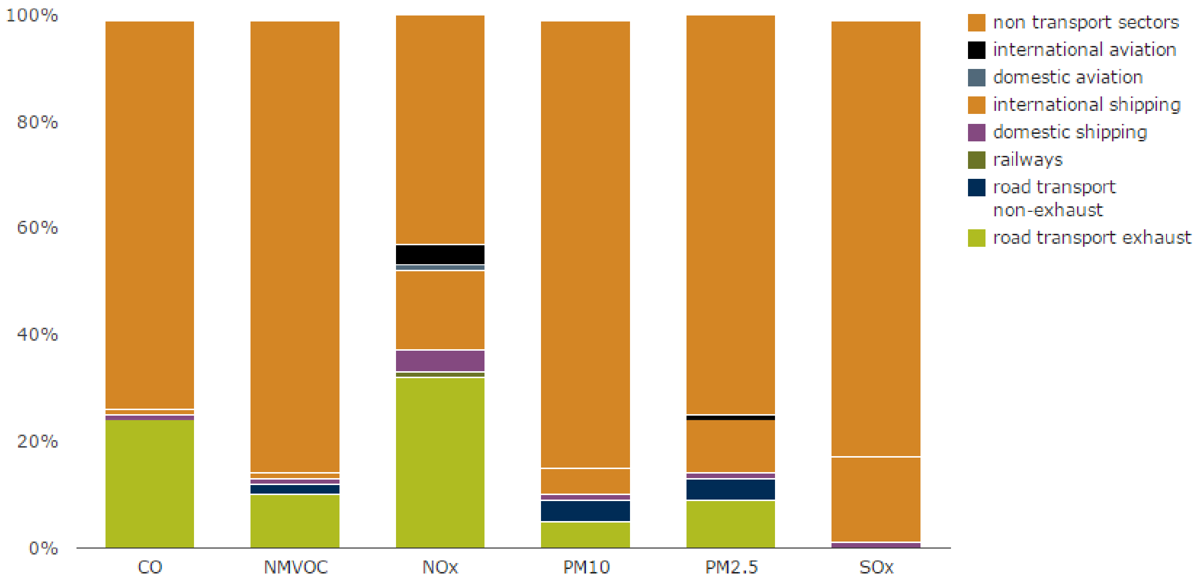

Figure: 5.6 Total emissions of the main air pollutants from transport
Source: European Environment Agency Report 7/2014

The European Environment Agency (Transport emissions of air pollutants (TERM 003 - Dec 2014) reported an on-going trend in the reduction of transport related air pollutant emissions. The transport derived pollutants, between 2011 and 2012, showed a decrease, by 6 % in the case of NO_x, 7 % for SO_x and by 6 % and 7 % for the cases of PM_{10} and $PM_{2.5}$, respectively.

Increases in aviation and shipping activity since 1990 have offset reductions elsewhere, in particular for SO_x but also for NO_x and PM. There have been significant increases of NH_3 emissions in road transport and aviation over the last two decades.

However there has been an overall reduction in road transport emissions, but aviation has not yet been able to achieve a reduction. In general terms, the transport sector achieved important reductions in the period 1990 through 2012: reductions in CO and non-methane volatile organic compounds (NMVOCs) (both 81 %), but also in NO_x (33 %), SO_x (26 %) and particulates (by 23 % in the case of $PM_{2.5}$ and by 18 % for PM_{10}) (EEA 2014). The different emissions per mode are shown below in Figure 5.5.

The reduction targets for EU member states are set out in the 2011 White Paper "Roadmap to a Single European Transport Area" to reduce GHGs from transport by 60% by 2050, compared with 1990 levels. Transport sourced GHG emissions were lower in 2008 and 2009, mainly due to the effects of the economic recession.

5.4.2. Social Costs

Government policy and decision making has been assisted by cost-benefit analysis. It is through the process of monetizing the environmental costs and benefits that a viable estimate of the social carbon costs (SCC) is found (Ackerman et al 2009). The release of GHG and CO_2, in tonnes, along with the SCC estimates, expressed in monetary value, provides the figures that allow the recovery of social costs.

The transport owners bear the private marginal costs (such as wear and tear costs of the vehicle and personal costs for the driver). Table 5.8 summarises the various external cost components and its attributes.

In this context, accident, congestion and environmental costs differ significantly with respect to the parts of society affected: while external accident costs are typically imposed on readily-identifiable individuals (victims of an accident and their families), congestion costs are imposed on the collective of transport users caught in a traffic jam or having been crowded out.

Table 5.8: Summary of external cost components and their attributes

Cost component	Private and social costs	External part in general	Differences between transport modes
Costs of scarce infrastructure (congestion and scarcity costs)	All costs for traffic users and society (time, reliability, operation, missed economic activities) caused by high traffic densities.	Extra costs imposed on all other users and society exceeding own additional costs.	Non-scheduled services (road sector), the external cost component is the difference between marginal cost and average cost based on a congestion cost function. Scheduled services (rail, air), the external cost component is the difference between the willingness to pay for scarce access slots and the existing access slot charge.
Accident costs	All direct and indirect costs of an accident (material costs, medical costs, production losses, suffering and grief caused by fatalities).	Part of social costs which is not considered in own and collective risk anticipation and not covered by (third party) insurance.	There is a debate on the level of collective risk anticipation in individual transport; are the costs of a self-induced accident a matter of (proper) individual risk anticipation or a collective matter? Besides, there are different levels of liability between private insurance schemes (private road transport) and insurance schemes for transport operators (rail, air, waterborne).
Environmental costs	All damages (health costs, material damages, biosphere damages, long	Part of social costs which is not considered (paid for).	Depending on legislation, the level of environmental taxation or liability to realise avoidance measures differs between modes.

	term risks).		

Source: Update of the Handbook on External Costs of Transport (2014).

This is relevant as the mitigating costs are imposed on society, especially the fact that accident costs, those imposed on readily-identifiable individuals, may require a more tailor-made (individual) approach of internalisation.

Within existing practice, the focus is directly on the external elements of these costs and is considered here.

- Parts of the congestion costs are 'paid' in the waiting and delay costs of the users, but the 'costs' imposed on other users, are not.
- Parts of the accident costs are paid by third-party insurance; other parts are 'paid' by the victim having themselves caused the accident (either through their own insurance or through suffering uncompensated damage, etc.). Existing cost estimation practises focus is on translating the external part into internalisation measures, where the national liability systems have to be considered.
- Parts of environmental costs could be seen as already 'paid' for, such as through energy taxes or environmental charges (e.g. noise-related charges on airports).

5.5. Balancing sustainability, environmental emissions and climate change

Transport activities give rise to environmental impacts, accidents, congestion, and infrastructure wear and tear. In contrast to the benefits, the costs of these effects of transport are not fully borne by transport users. Without policy intervention, the so called external costs are not taken into account by transport users when they make travel decisions. Transport users are thus faced with incorrect incentives, leading to welfare losses. The internalisation of external costs means making such effects part of the decision making process of transport users. The welfare theory explains that internalising the external costs through the market-based instruments may lead to a more efficient use of infrastructure, reduce the negative side effects of transport activity and improve the fairness between transport users.

The 2008 Handbook proved to be an important source of input data and unit cost values for policy analysis, research projects and academic papers in Europe. In order to maintain this strong standing, this revised Handbook aims to update the 2008 Handbook with new developments in research and policy. This updated Handbook continues to present the state of the art and best practice on external cost estimation. Accordingly, the most recent information for the following impact categories has been gathered:

1. Congestion;
2. Accidents;
3. Noise;
4. Air pollution;
5. Climate change;
6. Other environmental impacts (costs of up- and downstream processes);
7. Infrastructure wear and tear for road and rail.

Most important in this context is the road transport sector, due to the fact that road transport is responsible for the majority of external costs.

The Intergovernmental Panel on Climate Change (IPCC 1996) methodology for estimating of the emissions and greenhouse gases from energy activities are based on two main tenets, fuel combustion and fugitive emissions.

Table 5.9 tabulates the IPCC methodologies of estimating SO_2 and GHG from energy activities or sources. These are divided into fuel combustion and fugitive emissions. The estimation of emissions for the activity/source categories used in the methodologies is as per the IPCC definitions. These definitions were rigorously drafted to conform to other international reporting systems and to minimise the risks of double counting.

Table 5.9 IPCC methodologies of estimating SO_2/GHG from energy activities

<table>
<tr><td colspan="4">Fuel Combustion</td><td></td></tr>
<tr><td rowspan="7"></td><td rowspan="6">Tier 1</td><td rowspan="2">CO_2 Emissions</td><td>Reference Approach</td><td></td></tr>
<tr><td>By Main Source categories</td><td></td></tr>
<tr><td rowspan="4">Non CO_2 from fuel combustion</td><td>Coal</td><td></td></tr>
<tr><td>Natural Gas</td><td></td></tr>
<tr><td>Oil</td><td>Gasoline/diesel oil for transport and other oil products</td></tr>
<tr><td>Biomass</td><td>wood /wood waste/ charcoal /other biomass and wastes</td></tr>
<tr><td>Tier 2</td><td>Emissions from aircraft</td><td></td><td></td></tr>
<tr><td colspan="5">Fugitive</td></tr>
<tr><td rowspan="3"></td><td colspan="3">Methane Emissions from Coal Mining and Handling</td><td></td></tr>
<tr><td colspan="3">Methane Emissions from Oil and Natural Gas Activities</td><td></td></tr>
<tr><td colspan="3">Ozone Precursors and SO_2 from Oil Refining</td><td></td></tr>
</table>

Source IPCC 1996.

In Tier 1, the estimating of the emissions is based on the carbon content of fuels supplied to the country as a whole (the Reference Approach) or to the main fuel combustion activities (source categories). This last method has been recently developed in parallel with its counterpart for estimating non-CO_2 emissions from fuel combustion and responds to the need for emissions figures by sector for monitoring and abatement policy formulation.

The methods involved in the estimation of emissions for the activity/source is incorporated to provide the maximum conformity with other international reporting systems and to minimise the risks of double counting.

The national annual consumption of fuels is expressed in energy units or mass units. The fuel consumption is converted to energy units using the net calorific value (or lower heating value). Gaseous fuels may be expressed in volume units. In order to obtain a realistic value for emissions, the fuel consumption is split by main activities, as emissions of non-CO_2 GHGs (CH_4, N_2O, NO_x, CO and NMVOC) which vary greatly depending on combustion technology, operating conditions and industry, as tabulated in Table 5.10.

Sustainability

The 'Bruntland Report' (1987) had popularised the term 'sustainability' bringing about 'sustainable development', where this was the "*development that met the needs of the present without compromising the ability of future generations to meet their own needs*" (World Commission for the Environment and Development 1987, pp. 43).

Later, the Organisation for Economic Co-operation and Development (OECD 2006a) defined environmentally sustainable transport as "*Transport that does not endanger public health or ecosystem and meets mobility needs consistent with (a) use of renewable resources at below their rates of regeneration and (b) use of non–renewable resources at below the rates of development of renewable substitutes"* (CEI 1999, 20).

Reviewing literature on transport generated polluting emissions confirms the increasing share and the amounts of transport related environmental and social pollution (Bollen et al 2010; Nam et al 2010). New transport related studies have redefined the subject seen through the concept of sustainability, encompassing logistics systems and their impacts (Yim and Barrett 2012, Drexhage & Murphy 2010). These papers based on sustainability as a guide formed the basis of future logistics planning. This allowed the industry to respond and adapt to the demands of sustainability (McKinnon & Piecyk 2012).

Table 5.10: List of manufacturing and construction industries

Manufacturing and construction Industries	
Transport	Aviation
	Road
	Rail
	Sea
Other sectors	Commercial/Institutional
	Residential
	Agricultural/Forestry/Fishing
	Stationary
	Mobile

Source: Black (1996) and others

Environmental emissions

Using vehicle-km or tonnekm from the model, the effect on emissions can be calculated. This is achieved by using emission factors. The emission factors only include the direct emissions. The emissions from well-to-tank[59] are not included. Table 5.11 tabulates the various types of externalities covered by each of the transport modes. However, in some cases, such as sulphur requirements (SECA) these emission factors will be directly impacted. Other policies will only have an indirect impact on emissions, for example, by lowering total demand.

The following pollutants are considered: VOC, CO_2, NOx, SO_2 and PM. The various externalities considered for the different modes are shown in Table 5-11.

[59] TREMOVE incorporates the well-to-tank emissions for road and rail, but as there is no information on the well-to-tank emissions for SSS, the research has excluded them for all modes for a balanced comparison.

Table 5.11: Externality types covered per transport mode

	Externalities	Road	Rail	SSS
1	Air pollution	x	x	x
2	Noise pollution	x	x	
3	Climate change	x	x	x
4	Accident	x	x	
5	Congestion	x	x	
6	Socio-economic	x	x	

Source: Author

Air pollution

For air pollution, marginal costs are assumed to be equal to average external costs, so a top-down approach is adopted. The marginal external costs of air pollution for a specific (sub) mode are calculated as in Eq 4.10, where '*i*' denotes the different pollutants (Brons and Christidis 2013).

$MEC_{air} = \Sigma_i$ (emission per vkm of pollutant i) x (unit cost of pollutant i)   Eq **4.**10

The basis for the calculations for different modes is described here:

Table 5.12 sets out ITCM transport modes and their characteristics.

Table 5.12: Overview vessel types and power generation categories

Mode	Sub categorisation criterion	Categories
Road	Truck size	(<7.5t; 7.5-16t; 16-32t; >32t)
	Fuel emission category	EURO-0 to EURO-5
	Network type	metropolitan; other urban; motorway; other interurban
Rail	Traction type	Diesel; Electricity
	Network type	metropolitan; other urban; motorway; other interurban
SSS	Freight type	(<250t; 651-1000t; 1001-1500t; 1501-3000t; >3000t

Source: Brons and Christidis (2013)

Road, rail and IWW: For road, rail and IWW the calculations are based on IMPACT (2008). Average emission factors per pollutant per sub-mode[60] are derived from the TREMOVE (2008) model. The valuation of $PM_{2.5}$ and PM_{10} emissions are based on results from the HEATCO (2006) study; the emissions values of other pollutants are based on results of the CAFE (2005) project.

Road: The model for road emissions was based on the COPERT IV [Samaras, 2007] which is employed in the TREMOVE model [De Ceuster, 2005]. In COPERT methodology, the vehicle emissions factors are a function of speed. COPERT distinguishes several classes of lorries, engine technologies, vehicle load effects (empty, half full, full) and road slope effects (0%, 2%, 4%, 6%). In the present case, only road vehicles in the 16- to 32-tonne class are concerned. The load factor and the degree of gradient are “full” and “0%” respectively. The latter assumption is in fact a simplification, as certain route segments (possibly) partly follow a sloping road. However, this has a very marginal influence on the total emission figure.

As far as the technology is concerned, due consideration is given to the EURO standard, which isn’t the same on all trucks, but does yield different emissions.

Table 5.13: Sample of road traffic conditions for Sweden (weather dependent)

Road type	Traffic situation	Distance (km)	Time (h)	Speed (km/h)
Secondary road	Smooth	20	0.3	67
Motorway	Smooth	300	4	75
Secondary road	Smooth	28	0.8	35
Motorway	Smooth	123	1.7	72
Average		471	6.8	69.26

Source: Van Herle 2008; Delhaye et al 2010, TREMOVE.

[60] Cost calculations are based on the cost of wheel-to-tank emissions. For electric rail, in order to render the coefficients comparable to the other (sub) modes, calculations are based on the cost of energy production (well-to tank) minus the cost of energy production for diesel trains.

The speed-dependent emission functions are then applied to route segments. The participants in the routes by road were asked to make a record of the various road types (motorway, secondary road or city road); traffic situations (congestion or smooth traffic), distances covered and times elapsed. The tabulated speed for each of the transit segments are shown in Table 5.13 for Gothenburg to Stockholm route (Case study 2).

Table 5.14: Truck Emission factors >32 tons for 2010, 2015, 2020 and 2025

g/tonnekm	2010	2015	2020	2025
VOS	0.013	0.008	0.002	0.001
CO_2	62.792	57.812	52.833	50.725
NO_X	0.547	0.408	0.269	0.154
SO_2	0.000	0.000	0.000	0.000
VOC	20.013	18.426	16.839	16.167
PM	0.013	0.009	0.005	0.005

Source: TREMOVE version 3.3

The emission factors for road vehicles, based on a 2010 baseline, with predicted values are shown in Table 5.14.

The speeds observed, as derived from the participants' data, have been checked against the speeds used in the TREMOVE model, which accommodates widely diverging data (e.g. lower speeds on secondary roads as opposed to motorways) within the scope of the data.

Rail: Again the model is based on TREMOVE as an input for the emission factors. As there are two basic energy sources, the emission factors are averaged for the energy mix for weighted emissions of both diesel and electric traction. The average emission factors and the possible trends for rail are shown below in Table 5.15:

Table 5.15: Freight rail emission factors for year 2010, 2015, 2020 and 2025 (g/tonnekm)

g/tonnekm	2010	2015	2020	2025
VOS	0.011	0.011	0.011	0.011
CO_2	8.148	8.091	7.932	7.984
NO_X	0.003	0.003	0.003	0.003
SO_2	0.001	0.001	0.001	0.001
VOC	2.597	2.597	2.528	2.544
PM	0.005	0.005	0.005	0.005

Source: TREMOVE version 3.3

The TREMOVE model is based on the TRENDS database and the MEET and EX-TREMIS projects and takes into account the train types and the train age distribution. For the sea transport vessels, the external marginal cost data are obtained for three ship types (RoRo/RoPax; general cargo & bulk; containership).

The model considers three types of ship:

- MV 'BG Ireland' LoLo with a capacity of 600 TEU and 11000 DWT
- MV Peter Pan RoRo with a capacity of 200 Trailers and 10000 DWT
- Small RoPax 40 Trailers and 3000 DWT
- MV Stena Adventurer Large RoPax 290 Trailers and 12000 DWT

Table 5.16 shows the cost coefficients at the EU27 level for the road and rail modes at € per 1000 kilometres.

Table 5.16: EU 27 marginal cost coefficients for road and rail €/1000 km

Coefficient	Road	Rail	
Externality	Motorways	Diesel	Electric
Air Pollution	8.58	10.25	1.00
Climate Change	3.92	1.90	1.46
Noise	1.93	1.88	1.49

Accidents	0.64	0.54	0.33
Congestion	3.43	0.20	0.20
Environmental	14.43	14.04	3.95
Socio-Economic	4.07	0.74	0.53
Total	18.50	14.77	4.48

Source: Brons and Christidis 2013

The trends indicate the decreasing of the emission factors resulting from sustainable policy measures and improvements in technology. Table 5.17 provide overviews of the estimated cost coefficients at the EU27 level SSS € per 1000 kilometres. When the emissions in kg/tonnekm between the different modes are compared, it is clear that SSS is more polluting than road and rail. However, it should be taken into account that these emission factors assume a loading factor of 70% for SSS. In reality, this may be lower and possibly the emissions per tonnekm will be higher than the estimates. The LoLo containership MV 'BG Ireland' is the reference vessel having the basic characteristics from the EMMOSS study.

Noise

The calculation of marginal external costs of noise for road and rail are based on IMPACT 2008 (refer to equation (5.11).

$$MEC_{noise} = \frac{\delta dB(vkm)}{\partial vkm}\ x\ unit\ costs\ per\ person\ dBxP \qquad \text{Eq 5.11}$$

Table 5.17: EU27 SSS cost coefficients in €/1000 tonne kilometre

FUEL Technology	Externality	Ship Type					
		General	LoLo Container	RoRo <17kn	RoRo 17/20Kn	RoRo 20/23Kn	RoRo >23kn
Low Sulphur	Air Pollution	4.48	3.09	1.56	1.98	3.00	5.20
	Climate Change	0.21	0.40	2.94	5.65	8.47	11.29

	Total	4.70	3.49	4.50	7.63	11.47	16.50
High Sulphur	Air Pollution	6.98	4.81	2.43	3.08	4.67	8.10
	Climate Change	0.22	0.41	3.00	5.76	8.64	11.53
	Total	7.20	5.22	5.43	8.85	13.32	19.63
Fresh water scrubbing	Air Pollution	4.00	2.76	1.39	1.77	2.68	4.65
	Climate Change	0.22	0.41	3.00	5.76	8.64	11.53
	Total	4.22	3.17	4.39	7.53	11.32	16.17
Sea Water scrubbing	Air Pollution	4.05	2.79	1.14	1.79	2.71	4.70
	Climate Change	0.22	0.41	3.00	5.76	8.64	11.53
	Total	4.27	3.20	4.41	7.55	11.35	16.22
LNG/ Methanol	Air Pollution	0.38	0.26	0.13	0.17	0.25	0.44
	Climate Change	0.17	0.33	2.14	4.61	6.92	9.22
	Total	0.55	0.59	2.53	4.78	7.17	9.66

Source: Brons and Christidis 2013

Where the first term represents the increase in decibel level following an increase in traffic by one vehicle kilometre; P is the population affected (Brons and Christidis 2013).

Road: The average coefficients from the EU study (INFRAS/IWW 2004) were used in the road model. The coefficient values derived from values for external costs per person per dB (A) and population density. Costs are available for two truck sizes (<7.5t; >7.5 t).

Rail: For the estimated coefficients for the rail mode, the data from INFRAS/IWW (2003) and data on distribution among urban and interurban networks from INFRAS/IWW (2004) provide the base figures. Coefficients at the member state level were derived based on differences in values for external costs per person per dB (A) and population density.

Climate Change

The irreversible changes to the climate induced by worldwide greenhouse gas (GHG) emissions are currently one of the key topics of global research output. There are two main questions arising from the several studies. First of these is the realistic evaluation of the carbon price and secondly the mitigating costs involved as to who and how they may be met. The main issues of any future global climate policy will be in finding proactive solutions to:

1) Quantifying carbon footprint values: The methodology for estimating the unit cost of the carbon footprint from various transport modes is similar to the process for air pollution and noise costs, namely the Impact Pathway Approach. It encompasses the following steps:
    a) Quantification of GHG emission factors for different vehicles, expressed in tonnes CO_2 equivalent per vehicle kilometre (vkm).
    b) Valuation of climate change costs per tonne of CO_2 equivalent.
    c) Calculation of marginal climate change costs for different vehicle (and fuel) types.
2) Having a wide consensus on the major methodological issues in the estimation of external costs, even though there are several uncertainties to consider. There are two main methodologies in evaluating the cost of the effects of GHG and other emissions. Table 5-18 gives the two approaches.

Table 5.18: Methodologies in evaluating emission gases

1.	Damage cost approach	Evaluating total costs, assuming that nothing is done to reduce the pace of climate change, or the 'Do Nothing' option. It includes infrastructural modifications to allows for the various effects connected to changes in sea level, landscape, fresh water availability, vegetation, etc.
2	Abatement cost approach	Evaluates the cost of achieving a given amount of emissions reduction

Source: EEA 2014 (pp. 55), Korzhenevych et al 2014

3) Marginal external costs of climate change for a specific (sub) mode are calculated using Eq. 4.12 (Brons and Christidis 2013):
4) $MEC_{cc} = \frac{emissions\ of\ CO_2}{vkm}\ x\ unit\ cost\ of\ CO_2$ Eq 5.12
5) In assessing climate change costs, the marginal costs are assumed to be equal, allowing a top-down approach to be adopted as delineated here.
6) *Road, rail and IWW:* For road, rail and IWW the calculations are based on the approach of IMPACT (2008). Average emission factors of CO_2 per pollutant per sub-mode are derived from the TREMOVE model. These are combined with the external costs per tonne of CO_2 for the year 2014 as recommended by IMPACT (2008).

Short Sea Shipping: CO_2 emission factors from the EXTREMIS database are used combined with the data from the EU Handbook Updated to 2014[61] for the external costs per tonne of CO_2. External marginal cost data are obtained for three ship types (RoRo/RoPax; general cargo & bulk; containership)[62].

[61] The Inter-Service Group agreed upon using the cost per tonne CO_2 for the year 2014 because of the desirability for the values used to represent the damage costs when projects are likely to be implemented. The value for 2014 is calculated based on a linear interpolation of the central values for 2010 and 2020 given in Table 132 of Impact (2008) and is €31 in 2000 prices

[62] These coefficients are used as base values to derive cost coefficients for various additional subcategories based on different fuel qualities, fuel technologies and speed categories

The best methodologies for the estimation of congestion costs are based on speed-flow relations, value of time and demand elasticities. For air pollution and noise costs, the impact pathway (or damage cost) approach is broadly acknowledged as the preferred methodology. The valuation of the respective health effects is based on the willingness to pay concept. Marginal accident cost can be estimated by the risk elasticity approach, using values of statistical life. In view of the long-term reduction targets for GHG emissions, the abatement cost approach (in contrast to the damage cost approach used for other environmental impacts) offers the better practice for estimating climate cost. Other external costs exist, e.g. costs related to energy dependency, but there is for the time being no scientific consensus on the methods to value them. In those cases where there is no real scientific consensus on methodology, the different approaches are presented (Korzhenevych et al 2014 Introduction pp. xiii).

Accidents

The calculation for the marginal costs of accidents for road and rail are based on IMPACT 2008 (see equation 5-13).

$$MEC_{acc} = \frac{\delta ACC(vkm)}{\partial vkm}\ x\ unit\ costs\ per\ accident\ x\ external\ part\ of\ costs \quad \text{Eq. 5.13}$$

The model is built up on the unit costs of the mode over a distance loaded with freight tonne. The first term, $\delta ACC(vkm)$ represents the increase in accidents following an increase in traffic by one vehicle kilometre. The last term serves as a correction so as to exclude the part of the costs that is internalized through insurance schemes (Brons and Christidis 2013).

Road: For road, a bottom-up approach[63] is used, based on marginal cost function and estimates from a case study on Switzerland (see UNITE, 2002b and 2002c). Results

[63] A bottom-up approach uses marginal cost estimates and functions from case studies as input and employs value transfer and/or aggregation techniques to obtain representative values for typical transport clusters or national averages. A top-down approach uses data on mobility and external cost

are transferred to other countries by using different input values for *inter alia* unit costs per accident, risk elasticities and insurance systems. These are marginal cost coefficients at the member state level for three different networks, i.e. (urban; motorways; other non-urban).

Rail: For rail, following INFRAS/IWW (2004), a top-down approach is used based on accident statistics from the International Union of Railways (UIC) 12. Traffic demand data from the TREMOVE model are used. Marginal cost coefficients are calculated at the member state level for two networks (urban and non-urban).

Congestion

The approach followed uses the average costs of congestion for road and rail, calculated at country level in TRANSTOOLS model using Eq. 5.14 (Brons and Christidis 2013):

$$MEC_{cong} = VOT \times \frac{\Sigma L_i Q_i / V_i - L_i Q_i / V^*}{\Sigma L_i Q_i / V_i} \qquad \text{Eq 5.14}$$

Where *VOT* is the value of time for vehicles and L is the length, Q is the traffic flow (vehicles per hour), V is the actual speed and V* is the free flow speed for each interurban road segment i. The right-hand term incorporates the time lost per vehicle-kilometre for each interurban road segment, resulting from the difference between the free flow speed and the actual speed. This is aggregated at the country level and then multiplied by the value of time in order to compute the average costs of congestion.

5.6. Trends

The European Union's Common Transport Policy bases intermodality as an important component in attaining sustainable mobility. It provides the policy instruments to bring about the integration of transport infrastructure (modes, ILUs, administration,

from the national data as input and estimates external unit costs for typical transport clusters or national averages.

legal documents, etc.) into a single coherent European transport industry. The improvements in the road-rail combinations have grown considerably (above 5 per cent), in stark contrast to the 2012 figures.[64] The key initiatives of the European Transport (EC White Paper 2011) were to build a competitive transport system that will increase mobility, remove major barriers in key areas and fuel growth and employment. At the same time, the proposals will dramatically reduce Europe's dependence on imported oil and cut carbon emissions in transport by 60% by 2050.

The goals for 2050 are (EU White Paper 2011):

- End to fossil fuelled cars in cities by 2050.
- 40% use of sustainable low carbon fuels in aviation; at least 40% cut in shipping emissions.
- A 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport.

Efficient modern freight transport is one of the components of the supply chain and logistics delivery system to ensure timely delivery between the origin and destination of raw materials and finished products (Crainic, 2003). The 2008 economic crisis brought about efficient measures to reduce transportation costs and improve performance. The industry, shippers, carriers, and Logistics Service Providers (LSP) offered competitive cost options while still maintaining high quality through improved consolidation and of resources by introducing sustainable options. New regulations and taxes were introduced to encourage stakeholders towards more sustainable transport solutions acknowledging that externalities were borne by the users within the supply chain system (Ghiani et al 2013).

[64] www.unece.org/trans/wp24/wp24-trends/2014-02-05.html

5.7. Summary

The quantitative relationship between the different factors making up the total transport costs has been gaining in importance in the logistics field due to influence of external costs and its influences on global warming. This study clearly shows the influences of external costs and its importance in the developing of a decision-support tool.

For the purposes of the research, this chapter redefines the concept of total transport costs with the inclusion of external costs and along with ‘time costs’. In addition, this study has evaluated the ITCM onto 2nd level intermodal systems by introducing drayage performed by other than road (rail) and be considered as a different option.

Chapter 6

A Novel Model for Costing Intermodal Transport

6.1. Introduction

This chapter sets out the intermodal cost model's (ITCM) parameters and the methodologies as explained earlier. The model is applied to nine European case studies, spread across three freight transport corridors for evaluating the total transport costs. The cost attributes of the various transport modes were collated from public domains (EUROSTAT[65], ETIS[66]). The collated data was applied to the initial research question, testing the options for a transport system with lower costs. The total transport costs evaluations are compared within each corridor towards identifying the preferable mode combinations. The options are offered by identifying if there is a willingness to accept shipping at a lower-priced alternative to the prevailing road transport routes.

6.1.1. Layout of the chapter

Following on from the previous chapter which examined the different parts of the ITCM, this chapter lays out the model constructs in the sections that follow. Sections 6.2 and 6.3 presented the modelling methodologies and the model concepts. These were rationalised in Section 6.2 as the research's intermodal cost model (ITCM). The next two sections 6.3 and 6.4 outlines the general transport costs and attributes of the model. Section 6.5 explains the main tenets defining the external costs leading on to Sections 6.6 and 6.7 which explain the aggregates of internal and external costs. Section 6.8 formulates the generic model. Finally, section 6.9 summarises the chapter prior to the evaluation of the three case studies in the next chapter.

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[65] http://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics

[66] http://www.etisplus.eu/packages/default.aspx

6.2. Research model (ITCM)

The ITCM design satisfied the following issues raised by the research question:

The ITCM design is to satisfy the two issues arising from the research question. The first was that the ITCM reflected the full impact of the three main factors in the cost structure of the freight transport market. Analysis from the literature review showed (statistics and transport databases) that transport costs were one of the main issues amongst the freight users and suppliers.

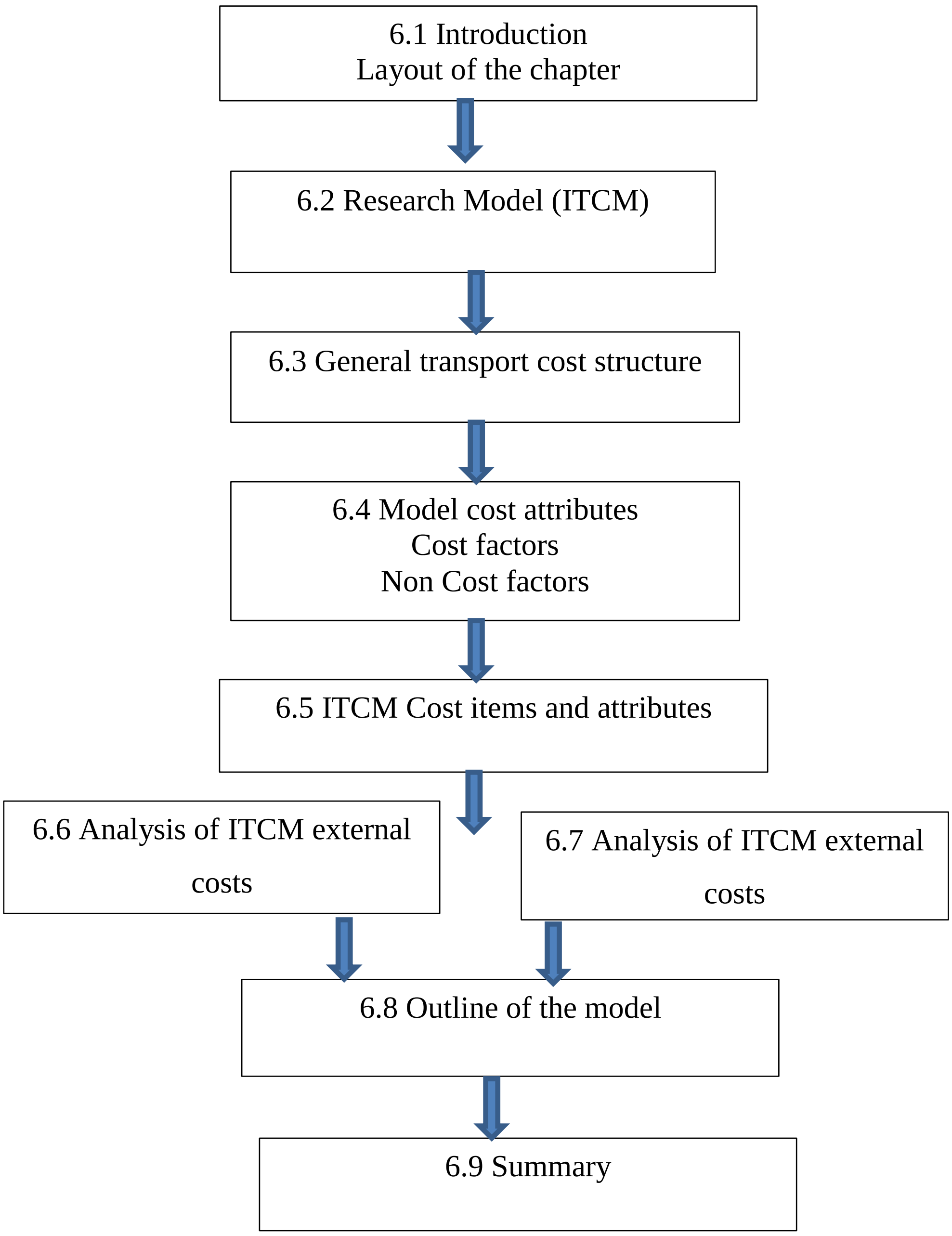


Figure 6.1: Layout of Chapter 6

The second goal was to test the ITCM. The initial issue was in the selection of the three transport corridors. Review of literature on European transport corridors showed the nine main TEN-T corridors across Europe.

- To evaluate the total transport costs along main European transport corridors (TEN-T). The freight transportation combination of case studies included one option with a major transit section by either the sea mode or the ‘rail mode’; ideally both.
- To include the influences of short seas shipping, the model had to be applied within the SECA (Sulphur Emission Control Area) zone, where the sulphur content of the ships’ fuel must be less than 1.5% (v/V) content to satisfy the emission regulation in the protected North Sea (by the IMO and European Commission legislation in all waters up to 6° West Longitude). This regulation directly affects the emissions of SO_2 and, to a lesser extent, emissions of particulate matter.
- To collect and collate total costs (internal and external transport costs) for the carriage of one unit of freight over a defined distance, utilising unimodal transport and a combination of transport modes over the transit.
- To evaluate the relevant influence of the two main haul modes, rail and the SSS operation, within the intermodal concept and their characteristics, including the following variables:
    - For the rail mode: Environmental Air Pollution, Climate Change, Noise, Socio-economic factors: Accidents, Congestion
    - For the sea mode: Type of vessel, the GT, utilisation rate, the number of available vessels for one route, frequency of the SSS line, the vessel’s speed and the distances for the transit segments. Fuel types (high sulphur,

low sulphur LNG). Scrubbing – cleaning of the exhaust gases by fresh water or sea water scrubbing

- To collect data on other factors, after costs that influence the perceptions of the stakeholders: time, reliability, distance and frequency. In order to evaluate the intermodal system and the three unimodal types, this study had three sections with data collection, geographical routes and the analysis.

Recent legislative and regulatory to transport networks, within European Transport, have demanded that the transport users are involved in the 'clean-up' of the transport related pollution. The European transport corridors, TEN-T network, shows nine transport corridors See Fig 6.2 (Annex 7)

The research model was designed to evaluate the total costs of the three case studies within three TEN-T corridors; this allowed fair comparison of costs between routes, the mode choices and the testing of the model across the TEN-T.

The model design was to:

1. ITCM evaluated the total costs on three selected corridors investigating their overall performance and determine the magnitude of transport costs from :

a. Transport Modes

b. Transport distances

c. Emissions

2. Estimate the importance of non-cost drivers on the modal choice of shippers, and how they may change the results of calculations for the first objective.

3. Investigate potential effects these policies may have on trade flows across Europe. Data was collected from European Commission research projects and Irish transport sources.

   The main sources:

   a. ETIS (with 252 routes and data)

b. Eurostat database (transport routes and volumes),

c. SKEMA study (specific information on maritime transport),

d. TREMOVE (road and rail transport costs and emissions)

e. EMMOSS (shipping emissions) models

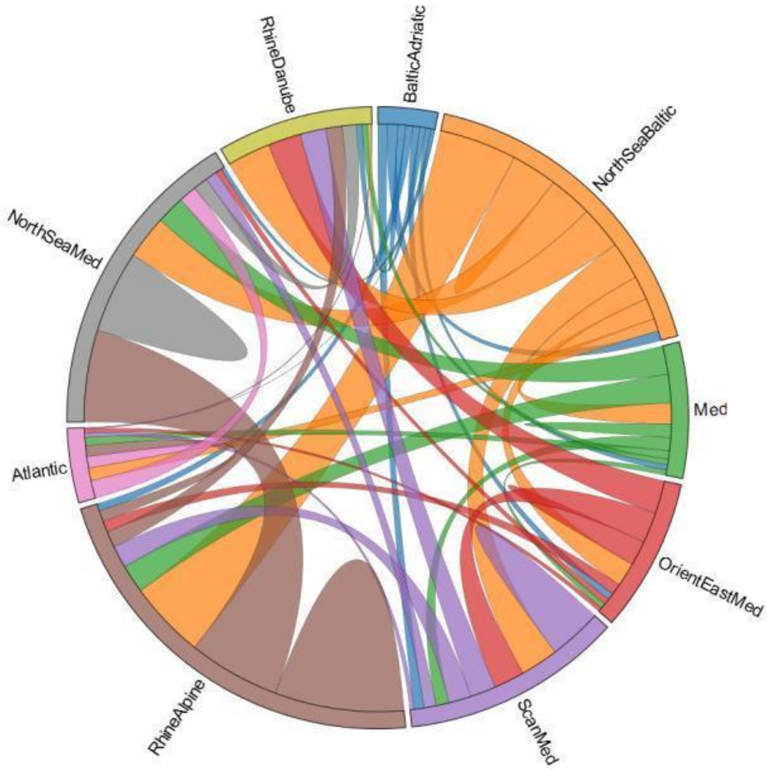


Figure 6.2: Schematics of the TEN-T corridors
Source: Intermodal Links

Figure 6.2 shows the freight transport densities of the nine TEN-T corridors. The three heavy corridors are the North Sea area (Rhine-Alpine, North Sea-Mediterranean and North Sea-Baltic). These corridors include major sea ports with extensive intermodal networks, such as Rotterdam, Antwerp and Hamburg. The second issue was in selecting other routes, offering intermodal alternatives to 'road only transits'.

The three transport corridors were selected as follows:

The first ITCM route was selected in the North Sea-Mediterranean Corridor, connecting Ireland and the north of UK through to North West Europe (the

Netherlands, Belgium and Luxembourg) to the Mediterranean Sea in the south of France. This multimodal corridor, offers better multimodal services between the North Sea ports, the Maas, Rhine, Scheldt and also better interconnecting the British Isles with continental Europe. Three routes were selected, with the Origin port was Rotterdam (The Netherlands) and the Destination was at Ballina, Ireland.

The second case studies were situated within the Scandinavian-Mediterranean Corridor, one of the heaviest freight and a crucial north-south corridor in the European economy. This corridor connects Finland, Sweden and passing through major urban centres to the Italian ports and Valletta. The three case studies were between Rotterdam and Stockholm.

The third corridor evaluated was along the East-West axis connecting Rotterdam to Istanbul (Turkey). This route included opportunities to examine the long transits by rail, road and short sea modes. This allowed the opportunity to consider the effects on road hauliers by Eurovignette[67], European 'Driving time and rest periods'[68] and the limitations imposed to marine vessels by SECA[69]. The key indicators for each origin/destination routes were collated; the attributes standardised across the varied transport segments routes within the transport corridors.

6.3. General transport cost structure

This sub-section set out the relevance of transport costs for three modes catered for in the model: SSS, rail and road[70]. Defining the concepts for ***costs***, within this research, costs will refer to the actual 'out of pocket costs incurred by the owner of the transport

[67] Eurovignette is a system to charge road users in Denmark, Luxemburg, the Netherlands and Sweden. The vignette applies to HGVs with loads greater than 12 tonnes on motorways and selected A roads.
[68] Regulation (EC) No 561/2006 provides a common set of EU rules for maximum daily and fortnightly driving times, as well as rest periods for all drivers of road haulage and passenger transport vehicles.The aim of this set of rules is to avoid distortion of competition, improve road safety and ensure drivers' good working conditions within the European Union.
[69] Sulphur Emission Control Areas (SECAs) or Emission Control Areas (ECAs) are sea areas in which stricter controls were established to minimize airborne emissions (SOx, NOx, ODS, VOC) from ships as defined by Annex VI of the 1997 MARPOL Protocol which came into effect in May 2005.
[70] Inland Waterways were not included in this analysis

unit. However, ***prices*** will mean out of pocket costs plus consideration, as imposed by the owner of the transport unit to the service buyer. This may include profits, bundled advantages, etc. and will not be considered within this research.

Analysing the literature review indicated that transport costs were one of the top priorities for selecting mode choice in the freight industry. Identifying the different transport cost items allowed for a proper evaluation on mode choice assessments at a later stage (Delhaye, et al. COMPASS 2010). In view of the focus on monetary costs, standard European average values have been used throughout for rail and road. Theoretically, separate country based costs could have been used, but given that costs are not that different between the North West European countries it would have made little difference to the overall analysis (Delhaye et al COMPASS 2010)

The ITCM highlighted the transport options on three selected transport corridors. The model's assumptions are that the three routes were within the same geographical region, with similar network sizes, intensity of operations, technology in use and internal and external costs of individual components of the system and are equivalent size in terms of the spatial coverage, number of nodes and the volumes of demand they serve. The ITCM considered intermodality three main attributes: transport links, transport nodes and the provision of efficient services. However, a fuller exploitation of intermodal systems would require additional intermodal infrastructure. These would have required improved infrastructure including enhanced and efficient transport services (Hanaoka and Regmi 2011) between the intermodal nodes (e.g. ports, airports, river ports and inland dry ports) and terminals (Flodén, 2007). The intermodal freight network, shown in Figure 6.3 shows the various nodes, as origins and destinations, representing industries, manufacturing sites, warehouses, logistics centres and/or freight terminals located in shipper and receiver areas. The infrastructure concepts would require available locations, with growth potentials located near industrial hubs with shippers'/recipients concentrations, to allow improved performance in freight handling and transhipment thus optimising the terminals loading utilization along the route (Kordnejad 2014). A freight transport network facilitates the movement of freight units. The accompanying administrative infrastructure allows for improvements, investments and accurate financial assessments. Figure 6.3 shows a generic description of an intermodal network.

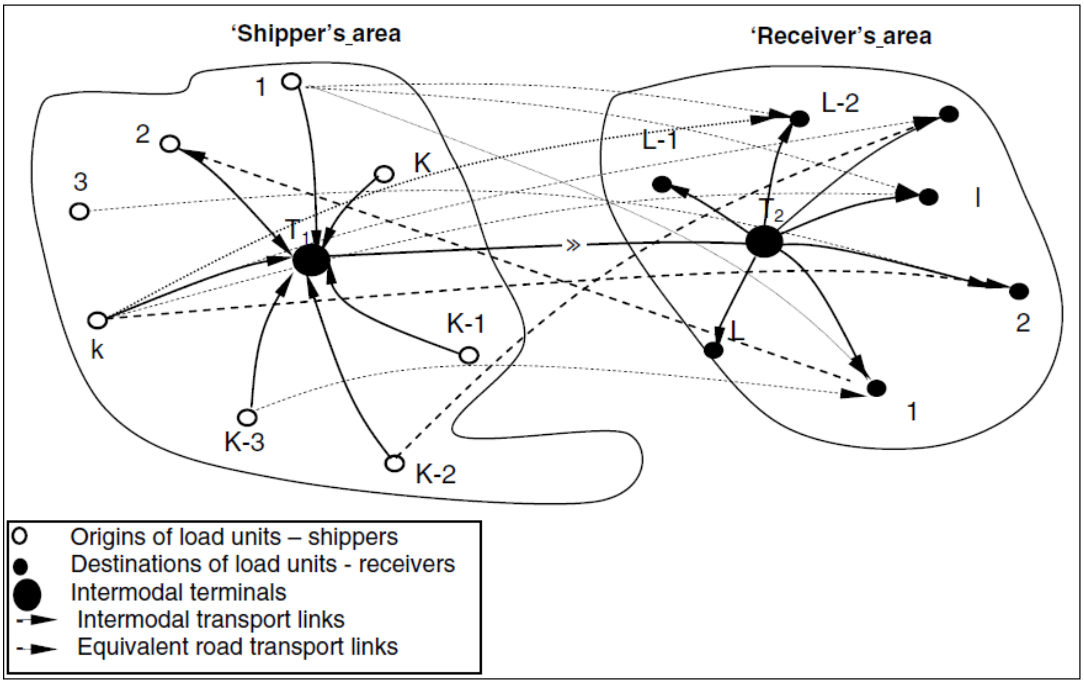


Figure 6.3 Simplified scheme of an intermodal and road freight transport network Source Janic 2007 (pp. 34)

Traditionally, evaluating the competitiveness of freight transport systems had been by comparing unimodal costs on a single O/D transport corridor, predominantly unimodal (e.g. rail vs. truck) rather than an intermodal system. Generally, the freight costs functions were determined on (1) the scope of the total cost, (2) the complexity of the freight transport units and unit costs (i.e. freight rate) and (3) other specific issues (Kim 2010).

Intermodal transport includes the following stages:

1 Collection in the originating zone and transportation by truck to the origin intermodal terminal located in the shipper area, referred to as 'pre –haul';
2 Transhipment at the origin intermodal terminal from truck to the trunk-haul, non-road transport mode (rail, inland waterways, air);
3 Main-haul transportation between the origin and destination intermodal terminals by the trunk-haul mode;
4 Transhipment at the destination intermodal terminal in the receiver area from the trunk-haul mode to trucks; and finally
5 Distribution from the destination intermodal terminal to the destination zone by truck (European Commission, 2000) referred to as 'post-haul'.

The efficiency of the logistic network is dependent on the transhipment process at the terminals, which influences the overall total productivity factor (OECD 2002). However, often, there is a difficulty in collecting these values as private carriers are reluctant to provide intermodal operating out of pocket costs. Janic (2007) applies this concept to a simplified European unimodal, road freight, along with an equivalent intermodal network using European Union data. The basic model computed an array of single trip costs for the delivery of one unit of freight per mode. The final figure was calculated to allow for the comparison of total generalised costs in the different freight corridors used by the different combinations of transport modes, with the full external costs.

6.4. Model cost attributes: Scope and conceptual model

The costs of delivering the freight, from its origin to the destination, form the main bulk of the internal (out of pocket) cost that include the cost of ownership, insurance, repair and maintenance, labour, energy, taxes and tolls/fees paid for using the network (Janic 2007). There are two additional components that add to these; the facility costs and the time costs (Oskarsson et al 2006) as displayed in Eq 6.1.

TOTAL LOGISTICS COST = IC+FC+TC Eq. 6.1

Where:

IC = Inventory Costs (consignor + consignee)
FC = Facility Cost (consignor + consignee)
TC = Time Costs

In commercial reality, all the increases to the service supplier's logistics costs are invariably added to the 'price' offered to the buyer (van Weele, 2005). This has been referred to as the 'French fries' principle'; from the fact that potato costs tend to be transferred down the supply chain.

The ITCM evaluated the total route costs, with several delivery options, for each of the route segment' transport combinations between the same O/D. The design of the ITCM was based on the methodology (Section 5.7) to assess general transport costs and offer clear results allowing transport stakeholders to make informed choices on mode and route choices.

Within each freight corridor, an origin and a destination were selected. Between the OD, three routes were selected, each with differing road transit distances. The routes reflected the present road-heavy practises and allowed for the practical selection of alternative transport networks on the three routes. Whereas the sea route offered little difficulties, assuming that vessels sailed on a direct route from point A to point B, for rail and road traffic other factors such as the available road or track connections, had to considered where some were not necessarily direct.

- The ITCM was based on a 'many to many' concept where the ports were identified as hubs and nodes as the extreme points of the lines (in line with a population criterion).

- The ITCM factors were revaluated by testing on the two parallel routes to Rotterdam/Ballina. This allowed testing the mode options on the routes.
- These factors were applied to the routes in the other two corridors from Rotterdam to Stockholm and the Rotterdam to Istanbul route.

The attributes of the modes (road, rail and SSS) is summarised as follows:

- For the road mode:
  - Fixed: independent of type/size of cargo; vehicle depreciation; vehicle maintenance, road tax and mandatory insurance, driver's salary, handling fees (loading and unloading), and overhead costs of the carrier (management, central services, dispatching, etc.).
  - Variable: Cargo dependent (type/size) on transport distance; vehicle fuel (diesel); wear/tear/replacement of tyres; tolls, on road use or engine capacity; driver's mandatory safety breaks or second driver regulations.
- For the sea mode
  - Type of vessel, the GT, utilisation rate, the number of available vessels for one route, the frequency of the SSS line, vessel speed; distance of different transit stages (port/manoeuvre/cruising) during transits.
  - Fuel types (high sulphur, low sulphur LNG[71])
  - Scrubbing – cleaning of the exhaust gases by fresh water or sea water scrubbing
- For the rail mode:
  - Fixed: Capital costs of rail locomotive and wagons; depreciation; maintenance; personnel salaries of a train's crew, handling fees (loading and unloading), and

[71] SECA (Sulphur Emission Control Area) regulations state that the ship's fuel sulphur content must be less than 1.5% (v/V) content in the protected North Sea (by the IMO and European Commission legislation) in all waters up to 6° West Longitude. This regulation also affects SO_2 emissions and, to a lesser extent, emissions of particulate matter.

overhead costs of the carrier (management, other rail employees' salaries, forming of trains, central services, etc.).

- Variable: dependent, costs of rail transport include traction energy (electricity) and fees for the use of rail transport routes (access fees, fees for train's mileage).

The ITCM made two major contributions. The first of these offered by the ITCM was empirical: the new model highlighted the need for intermodal transport choices within Ireland. Secondly, it added the effects of social costs to existing concepts of freight costs' resulting in a freight transport model. The model added new knowledge to the work devoted to Irish transport studies by introducing intermodal transport concepts intended to mitigate transport negativities.

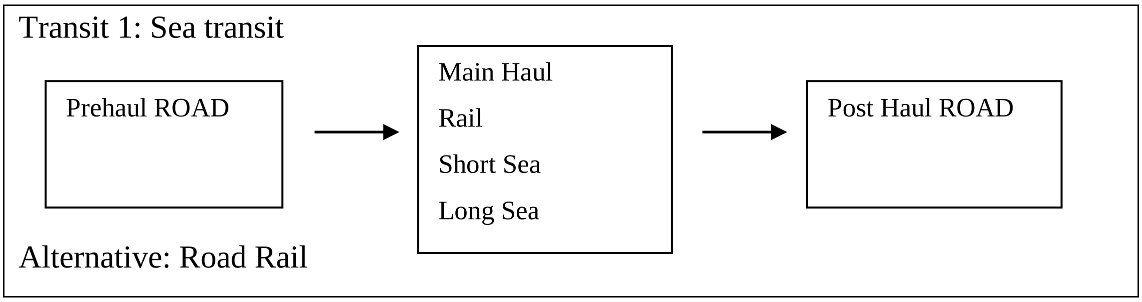


Figure 6.4 Block diagram of modal solutions: Intermodal (SSS) main haul against road/rail alternative.

The ITCM design was based on the actual services at present for the nine routes. Some mode options were either not feasible or available for each route. ITCM focuses on the transport costs on the three corridors and analyses the data in identifying the optimum mode selection to facilitate the intermodal option within the freight corridors. Different outline examples are show in the figures below (6.4 to 6.6).

The advantages in making this assumption were that the alternative/substitution was realistic for moderate changes in demand levels relative to the baseline. The main disadvantage in this model concept was that the simple mathematical structure implied a constant elasticity of demand with respect to income. This made the model less suited for forecasting travel demand.

The Transit 1 figure shows a transit system with the Short Sea Service (SSS) option compared with the road/rail alternative. ‘Sea Transit’ reflects a combination of road and SSS. This option offers the choice of whether to go for a long SSS part and a short road part or vice versa. Alternative ‘Road/Rail’ means that a truck is used on a part of the main haul transit between origin to destination. For some links the journey is in combination with rail, for example: Dublin/Ballina; Channel Tunnel.

In Transit 2, the first choice made is whether to go intermodal or not. Once this choice is made, on certain routes, rail becomes an option (Fig 6.4). This schematic is most relevant for transport of bulk.

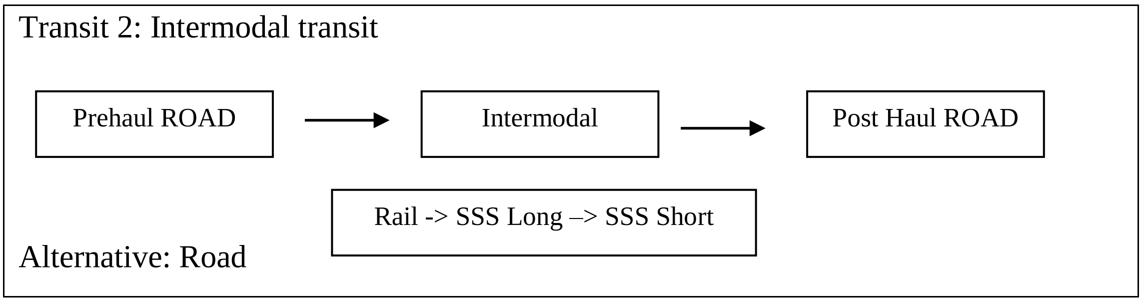


Figure 6.5 Transit 2 with intermodal for main haul

For the ‘road option’ the major section of the journey is by road; it may have short spans of rail and SSS. The SSS option includes a combination of road and SSS transport where the SSS is the most important mode.

Transit 3 offers two options for each OD: a road option and a Rail option (Figure 6.5).

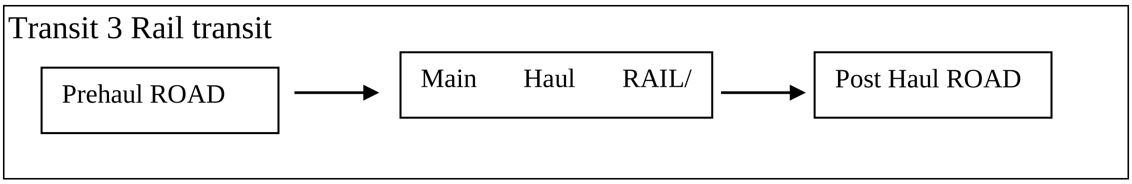


Figure 6.6 Transit 3 where rail is the main haul with SSS as alternative

This option is chosen for the Irish case study with a rail link from Dublin to Ballina.

Operating time of the networks

Within a transport paradigm, the value of the operating time is one of the main factors. However, for the scope of the ITCM routes in computing the network transit time, the elasticities are considered as 1. An earlier study computed transport costs as the total sum of out of pocket costs (internal costs) and time costs (Blauwens et al 2008) and was presented in Euro per hour (€/hr.) and Euro per kilometre (€/km) were also covered.

Grosso (2010) refers to earlier studies of 'time travel costs' based on similar calculations, applied to different case studies, covering urban and rural passenger transport (Kumar, 2004), urban road pricing scheme in Milan (Rotaris, 2010) and CO_2 pricing on container transport, (Zhang, 2011). The European Project into developing of Harmonised European Approaches for Transport Costing and Project Assessment (HEATCO) defined the value of travel time saving (VTTS) for the harmonised guidelines for project assessment for trans-national projects in Europe as *"The VTTS for commercial goods traffic is the marginal benefit arising from a unit reduction in travel time"*. De Jong (2004a, 2009, 2010) applied these criteria to studies, based in the Netherlands, to mode choice situations (e.g. with definite monetary values for tonne hour, offered for each of the modes. The Dutch studies were the most relevant data available for the North Europe area and were in monetary values. Subsequent transport cost figures for €/tonne hour formed the base for the Central European Bank's (2011) inflation index and referred to in Grosso (2011) for internal and time costs in Table 6.1 (Grosso 2011). The Dutch freight figures are within the EU 15 figures; however, they differ from the Irish averages. As there are no similar Irish data, it was possible to extrapolate the EU 15 (and EU 27) figures with the very few Irish data figures solely for academic purposes. The lack of values for the Irish freight industry for inland navigation, rail maritime and air transport is explained by the shortage of studies and research by each European country on these transport modes.

Table 6.1: Monetary values for transit time and tonnages per tonne hour

Mode	Euro/tonne hour
Road	6.23
Rail	1.13
Inland waterways	0.54

Source: Grosso 2011, based on de Jong 2004

The average figure for the ITCM was designed for the transport of one freight unit over a unit kilometre and the price component forms a part within the generalised cost function. However, in the final price's ranking it differs little from the ranking of the modes obtained by their cost analysis.

6.4.1. Cost factors

In determining the ITCM's different factors, the distinctions between logistics costs, transport prices, transport costs and vehicle operating costs are explained here. The distinction is relevant, as in some cases, the prices may or may not be transport costs[72]:

- Transport prices are the rates charged by a freight forwarder to the shipper or importer. Transport prices are usually negotiated rates between the shipper and the transport service provider. Transport prices normally cover transport costs; the operator's out of pocket costs and profit margins.
- Vehicle operating costs (VOC) include the direct costs the transport provider must pay to operate a given vehicle, notably labour, capital, fuel, tyres, maintenance and the depreciation cost of a vehicle.

[72] Logistics costs can be added; however, there is no agreement for precise definition of logistics costs. Logistics is the process of planning, implementing, and controlling the efficient, cost effective flow and storage of raw materials, in-process inventory, finished goods and related information from origin to consumption for the purpose of meeting customer requirements. Then, logistics costs may reflect a wider definition than transport costs; including transaction costs (those related to transport and trade-processing of permits, customs, standards), financial costs (inventory, storage, security), and non-financial costs (insurance)

- Transport costs are the costs the transport operator incurs when transporting a cargo. These are in addition to VOC including indirect costs, such as license fee, roadblocks, etc.

In reviewing the freight transport market, the overall price offered to deliver a unit of freight is connected to the factors that influence ‘demand’; a complex subject in itself. This is especially so for freight and more than the factors influencing passenger demand because[1]:

- Shippers, carriers and receivers decide on the carriage of a shipment to be made and also its mode and route;
- The freight market covers a wide range and types of commodities making freight traffic dependent on a very complex range of prices or values associated with its transportation;
- Freight movements are measured ‘market units’; various units such as dollar value; quantity; weight; volume; container; carload; truckload; etc.; and
- The actual cost of moving freight is much more complex than the task of estimating the passenger costs, say over the same distance/geography/remits. This is because freight requires additional services as in handling, loading, unloading, classifying, storing, packaging, warehousing, inventorying, etc.).

Transport costs have a major influence on the industry’s (shippers, users etc.) selection of route, mode, etc. Based on earlier studies prioritising the mode choices in Ireland (Matear and Gray 1993), firms naturally opted for the most economical option for reducing both monetary and time costs. Other variables that are crucial for determining costs of shipping items include: fuel costs; labour costs and maintenance and operation costs. Fuel costs reflect a complex set of criteria, based on the current price of oil, international business environs relations, influencing the local economy. Labour costs vary according to mode choice factors that are specific to the vehicle, service type and local regulations. Operation and maintenance costs, collectively, may include: vehicle and driver insurance; vehicle maintenance and servicing (e.g. lubricating oil replacement) and parts replacement (e.g. tyre replacement costs).

Generally, transport costs are dependent on being:

- Proportional to distance
    - Each additional unit of distance adds an equal increment of cost
- A function of time
- Subject to other factors that influence the paradigm that makes transport costs lower than proportional to distance
    - Fixed costs of transport facilities incurred regardless of length of journey
    - Fixed or terminal costs (interest on capital, costs of maintaining plant and equipment, depreciation) dilute the unit cost as distance increases
    - Costs per mile tend to decline with increasing distance

Summarising the various attribute values in terms of transit time, frequency, reliability and cost of existing freight demand, models allowed for results to identify and evaluate freight demand factors to predict mode choices.

Econometric studies suggest that freight costs have an important impact on the volume of trade and the modal choice. For the shipper, the modal choice is primarily a trade-off between higher monetary transport costs and faster journey time. Reliability and a reduction in delivery uncertainty are particularly important for trade in intermediates or in products where demand may be transient. Transport studies in the United States have reported on the value of time saving and price of air freight relative to ocean shipping as well as time delays associated with ocean shipping (Behar and Venables 2010).

A summary of the main factors that affect the costs of multimodal transportation, with relevance to the ITCM are shown in Appendix 10. There were a number of issues, like door-to-door distances, energy prices, train speed etc. that were not included. The local economic considerations on the costs are influenced by external and local economic pressures and other local contingencies for routes and transport modes. There are several influences on the local transport industry, which in turn are tempered, to a large degree, by national interactions and long and short term goals (Button 2010). There is a growing trend of firms' being willing to pay more for expensive air freight, in view of shorter transit-time (number of days) and a perceived saving with airplanes having a lesser premium for transporting by air (Harrigan & Venables, 2006).

There have been other quality attributes, with money-values, proposed in other studies (Feo-valero et al 2011), where the transport cost, measured in Euros, represented the shipment costs for the O/D service; transit time was the total time of the O/D carriage; punctuality, expressed as the percentage of shipments that met the deadline criteria as originally planned and finally, the service frequency, expressed as number(s) of departures per unit time (day/week) (Arencibia et al 2015).

Relationship between transportation costs and externalities

Transport offers substantial socioeconomic benefits to society but with huge costs in mitigating its external negativities. The negative effects or externalities "consist of the costs and benefits felt beyond or 'external to' those causing the effect" (Anderson, 2006). The negative externalities (costs) from transport are air pollution and accidents. Since external effects do not have a market price, they are a form of market failure.

The transportation activities promote and provide increased mobility options for passengers and freight with growing levels of environmental externalities affecting the atmosphere, the hydrosphere, the lithosphere and the ecosphere. A point has been reached where the transport industry is the dominant source of emissions of most pollutants and their multiple impacts on the environment (Rodrigue, Comtois and Slack 2013).

The resulting impacts may be divided into three categories:

- Direct impacts. The immediate consequence of transport activities on the environment where the cause and effect relationship is generally clear and well understood.
- Indirect impacts. The secondary effects of transport activities on environmental systems. They are often of higher consequence than direct impacts, but the relationships involved are often misunderstood and difficult to establish.
- Cumulative impacts. The additive, multiplicative or synergistic consequences of transport activities. They take into account the varied effects of direct and indirect impacts on an ecosystem, which are often unpredicted.

Externalities: The ITCM incorporates the externalities resulting from the transport of a unit of freight into the general transport costs. This sets up the relationship between logistics costs, externalities and CO_2 emissions towards evaluating the total costs or seeks to answer the question: *What is the total of the negative externalities in transport costs?*

Two different approaches of handling this issue were recognised. These were the traditional external cost concept and the proposed shifting cost concept. Each concept is described here.

1) General external costs include air pollution, noise and traffic accidents (EC, 2002b). When CO_2 only is taken into account as the external cost, the main task to estimate it is to identify the global warming effects and express them in monetary

terms (EC (1999a), Mayeres et al. (2001), Int Panis et al. (2000)). Some of the factors taken into account are for example the impact on mortality, morbidity, public health, agriculture, energy demand, water supply, rise in sea level, extreme weather events (EC, 1999a, 2003). However, there is no consensus for a single external cost or even a range of costs (EC, 1999a, Mayeres et al., 2001). Tol (2005) clearly showed how wide the range is. Despite the uncertainty of the CO_2 cost, several studies internalise such externalities because there seems to be no feasible alternative which can appropriately consider them (EC, 2000, 2002a, Janic, 2007, Maibach et al., 2008).

2) Shifting the costs per tonne of CO_2 from a predominantly road only system to another system with a greater intermodal content such as a rail/SSS based intermodal system. When the CO_2 cost is based on environmental economics (i.e. first approach) it can be used as a weighting factor. In other words, CO_2 emissions are converted into money.

The outcome of the second approach provided an evaluation of a multi-objective optimisation problem (i.e. Pareto optimal). The ITCM evaluated the total costs, by internalisation, on three European freight corridors: between Ballina (Ireland) and Rotterdam (Netherlands); Rotterdam (Netherlands) to Stockholm (Sweden) and finally Rotterdam (Netherlands) to Istanbul (Turkey). The analysis considered the total costs of three routes, operating from the same origin and destination (O/D) within each of the three corridors.

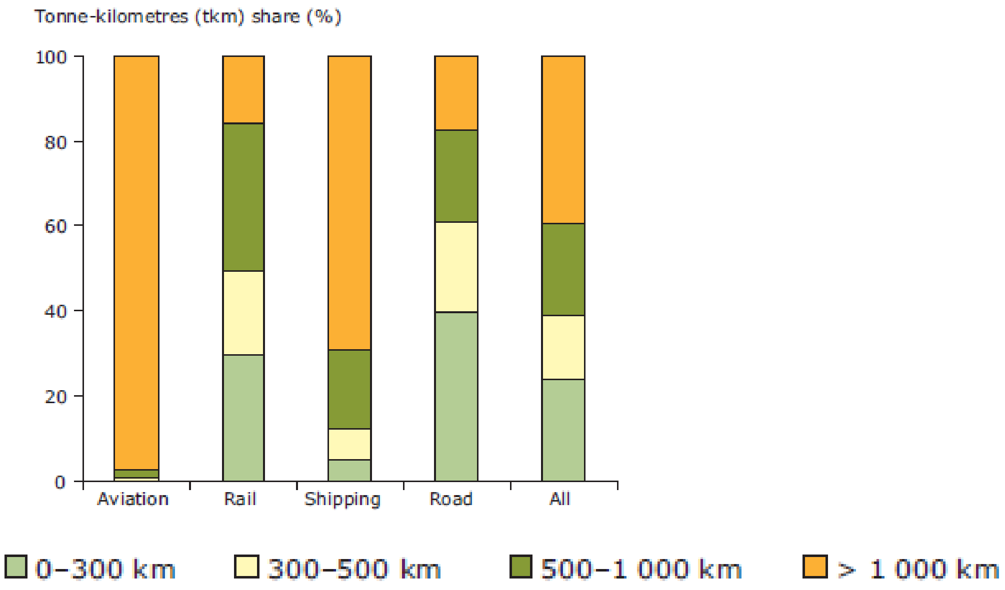


Figure 6.7: Freight transport shares in distance bands in the EU-28, 2010
Source: EEA Report 7/2014

Long distance freight

Figure 6.7 displays 2010 total freight transport volumes across the different distance bands for the transport modes. It shows that over 75 % of the total volumes were carried over long distances (above 300 km) of which half (37 %) were above 1000 km. The shares are mainly constant in time but varied significantly across modes. Over 95% of the volumes in aviation and shipping (both IWW and short sea shipping) were long-distance transport, while for road and rail the shares were lower. The figure confirms that shipping dominates long-distance freight transport, with approximately 53 % of total tonne-kilometres.

Literature refers to a geographical scope (differentiating between urban and non-urban transport, or between domestic and international transport) or to transport activity over a certain distance. There are no clearly defined concepts for ‘long-distance transport’ offered by statisticians, policymakers or researchers (EEA 2014 pp. 35). However, in the recording of data and statistics there are some typical thresholds with EUROSTAT data for road freight, differentiating the haul distances 0–50 km, 50–150 km, 150–300 km, 300–500 km, 500–1000 km, 1000–2000 km and beyond 2000 km. Distances in between seaports and air transport are tabulated between the ports of origin and destination.

The 2011 Transport White Paper (COM [2011] 144)[73] sets a 300 km limit for a distance towards shifting 30 % of road freight transport to other modes (rail or inland canals) by 2030 and to more than 50 % likewise by 2050. For passenger transport, the goal set for medium-distance trips is 50 % over 300 km to be by rail by 2050 and 75 % for freight volumes over distances of 300 km. EUROSTAT figures indicate that the load factors for long-distance road transport are higher than for short distance transport and have remained stable over time (EEA Report 2014).

Transport volumes

For a shipper offering shipping services for transporting freight volumes from a network of depots with a spread of commodities, the final modal choice is a result of the compromises by minimisation of generalised transport cost, i.e. the sum of the monetary and time cost of transport (Tavasszy and van Meijeren, 2011). For an origin–destination pair, the monetary cost and the transit cost of time vary and this explains why different modes may be chosen. The factors influencing the demand for freight given here are more complex and interdependent:

- Decisions by shippers, carriers and receivers affect whether or not a particular shipment is made and, if so, by what mode and route;
- There are many different types of commodities that make up freight traffic, and these commodities have a wide range of prices or values associated with them (also some are perishable while others are not);

[73] Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. COM(2011) 144 final

- Freight movements are measured in various units such as dollar value, quantity, weight, volume, container, carload, truckload etc.; and
- The cost of moving freight is much harder to determine than the cost to move passengers because more specialised services are required for freight (i.e. handling, loading, unloading, classifying, storing, packaging, warehousing, inventorying, etc.).

In freight transport, the mode choice model is often based on the trade-off between the out-of-pocket costs of transport (the tariff paid by the shipper) and the transport time[74]. Transport time is weighted by the value of time (measured in euro/hr., per shipment or tonne) and the weighted sum of tariffs and time is called the generalised costs of transport and determines the attractiveness of transport modes. In assessing the break-even point between the fastest and the cheapest mode, the recent socio-economic trends (with increased consumption of high valued products and rapidly changing consumer tastes) indicate a preference for the faster modes as they are likely to further increase competitive advantage (EEA 2014 pp. 57).

The present literature on EU freight forecasts indicate the most likely continuation of existing trends with business as usual (BAU) scenarios (application of the TRANS-TOOLS model to 2030[75]) and the projections to 2050, assuming "other things being equal." The future trends do not consider extreme scenarios concerning economic development, world trade pace, population growth and other social/political background scenarios e.g. insurgency, terrorism, lack of security, natural disasters etc. (Tavasszy et al 2011 pp. 8).

[74] The model can be extended by including additional attributes of modes such as reliability. Also, extension is possible by adding combinations of different modes (multimodal routes).
[75] The TRANS-TOOLS transport forecasts to 2030 have been analysed in the TEN CONNECT study (2009) and elaborated and projected to 2050 in the TRANSvision study (2009). The TRANS-TOOLS forecasts have also been used in the FREIGHTVISION project (2009)

Total long-distance freight transport volumes decreased significantly between 2008 and 2009, after a sustained constantly increasing trend. Volumes increased again in 2010, but have not yet reached the 2007 peak (EEA 2014). However, with integration of the world economy, European international trade should continue to grow at higher rates compared to intra European transport trade.

Economic models indicate that global economic activities have a direct influence on the growth in freight movement which approximately increases proportionally when compared with global economic growth. Over 90% of world trade by volume is carried by sea and this offers the most cost-effective way to move large volumes and tonnages around the world. International aviation moves about 40% of world trade, by value, although far less in physical terms (EEA 2014 pp. 53).

Two underlying facts emerge (EEA 2014):

- Several socio-economic trends (such as the increased share of high-value products, rapidly changing consumer tastes and just-in-time logistics) give a positive competitive advantage to fast modes such as air transport. However, policy could also affect modal choice and efficiency.
- EU projections predict an increase in freight transport in line with GDP until 2030 (EC, 2013b). This estimated growth was subject to the GDP in subsequent years; changes to service economy as well as sourcing of products and resources.

The long term transport projections by transport mode are shown in table 6.2 which gives the predicted growth in rail freight and maritime volumes compared with road transport, due to the high growth of goods imported and exported overseas and among the European Inter regions.

Table 6.2: Annual freight transport growth projections of by modes 2005 to 2050

	2005	2020	2030	2050
p.a % of Freight traffic	-	2.0%	1.9%	1.4%
p.a % of Road Freight traffic Intra NUT S2	-	0.2%	0.6%	0.4%
p.a % of Road Freight traffic Inter NUT S2	-	1.5%	1.7%	1.3%
p.a % of Rail Freight traffic Inter NUT S2	-	2.5%	2.3%	2.3%
p.a % of Maritime Freight traffic EU 27	-	2.5%	2.2%	1.5%
p.a % of Maritime Freight traffic overseas	-	2.5%	2.2%	2.0%
Freight rail share long distance	25.3%	28%	28.6%	34.2%

Source: Sessa and Enei (2009 page 65); TRANSvisions 2009a; Enei 2010

Economic forecasts indicate that with an overall increase in external trade, there is a good chance of an increase in rail traffic to gain share by connecting these freight terminals. With the expected shift over to rail the congested freight corridors linking industrial centres to hub ports may be eased (Enei 2010).

6.4.2. Non cost factors

A review of transport options in Slovenia (Erjavec et al 2014) confirms that the influences of non-cost items include other criteria such as service reliability and connectivity. Literature shows the route options are often a compromise between several factors (Cook, Das, Aeppli & Martland, 1999).

In some cases, shipment size determined the mode choice and type (Holguin-Veras, Xu, de Jong & Maurer, 2011).

Prioritising from a list of shippers' preferences of cost and non-cost items confirms the influence of non-cost factors on freight transportation demand and transport costs Delhaye et al 2010). They range from geography, technology; infrastructure, fuel costs and policy towards trade facilitation.

Freight related factors include the transit time and commodity types also impact the decision, as shown in Figure 6.8.

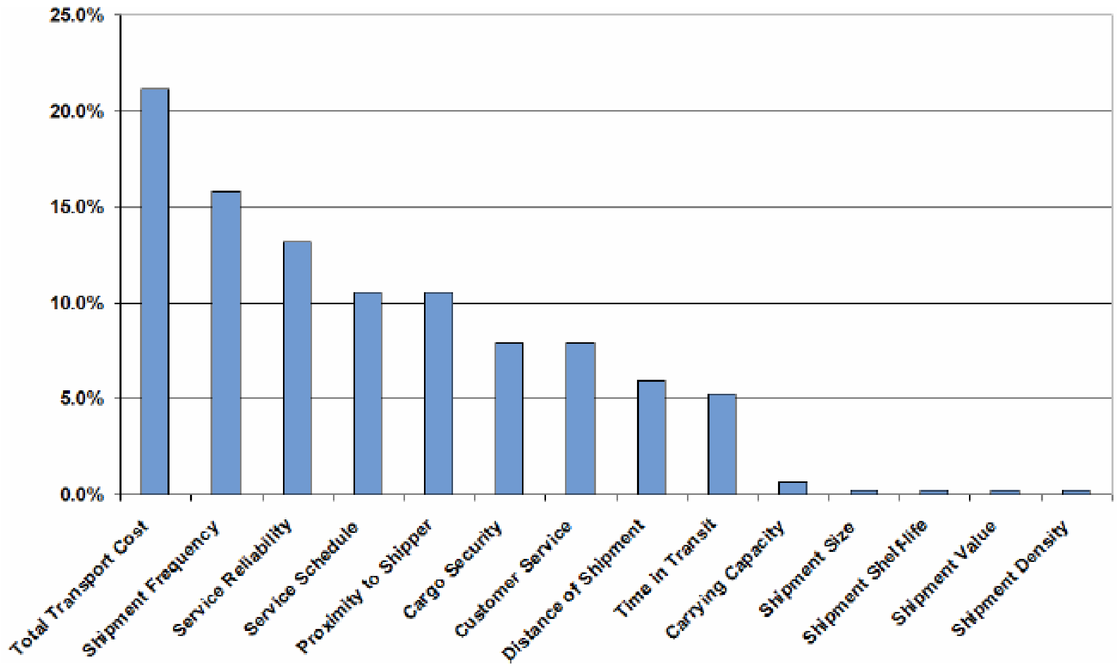


Figure 6.8: Influence of cost and non-cost drivers on transport
Source: Delhaye et al (2010)

6.5. ITCM cost items and attributes [76]

The ITCM's cost attributes items were collated from data records in ETIS, EUROSTAT (See Ch. 4 section 12). The unit cost figures were evaluated for the consumptions, distances covered and commodities carried from the nominated ports over a known number of voyages/trips. These figures were evaluated to obtain the unitary cost factors in Euro per kilometre (€/km) from other units of measurements (those based on time €/h; Blauwens, et al., 2008). In the computation of the internal costs, the annual cost data was evaluated down to a level of per unit or vehicle. For other cost figures, such as tolls, the cost figure was obtained by the actual expenses based on the specific route covered (ETIS, Delhaye 2010, Grosso 2010). As stated, the ITCM presented a simplified transport methodology to evaluate the total freight costs within nine routes in three European freight corridors. The model primarily compared transport delivery systems on each of the routes with two alternative systems.

[76] See Appendix 10 for factors influencing transport costs

This allowed the costs per unit to be interpolated within the ITCM, for each of the transport modes, in spite of their different technical nature. The unit costs for each mode of transport, road, rail, inland navigation and intermodal transport evaluated (total cost (€), cost per tonne (€/ton), cost per kilometre (€/km), the cost per hour (€/h) and finally the cost per tonne per kilometre (€/tkm)). The base data for the modes were collected and collated from public sources (Eurostat, Central Statistical Office, Ireland, TREMOVE COMPASS, etc.).

Research on transport analysis and modelling has always involved direct and indirect costs. Cost implications of time and service quality elements in metropolitan passenger travel were well understood and documented, however, the understanding of freight transport costs are a lot less satisfactory (Ernst and Young 1996). In conventional modelling only the main haul and transhipment costs were included and only in some instances were terminal handling and value of goods in transit considered. Until recently, the interlinking connections of the transport to warehouse distribution and production/supply management were largely ignored in strategic modelling. At a more detailed level, there is a considerable body of literature and documentation for the direct and indirect costs of freight transport and the task appears to be one of making use of them in modelling.

The costs involved in freight transport could be summarised as:

- Direct costs incurred in the course of transport, including transit and loading/unloading at terminals and transhipment sites
- Costs associated with transport service quality, which include time-related inventory costs, operation-related inventory costs and product quality related costs

Generally, it is the shipper that decides the freight transport process: this reflects the volume, frequency and mode-choice and that directs the total energy consumption, pollution, accident rate, etc. Over the years, some of these negativities have been internalised as monetary costs to some extent and thus promoted the lower polluting transport systems.

There are two types of cost categories: transport costs and transhipment costs. A table in Appendix 11 tabulates the costs and their attributes. Costs for alternative transport modes are discussed here.

Road

Road operating costs were based on data sources (TREMOVE[77] v.3.3.2), which were aggregated emission factors; differentiated by country, type of region, type of vehicle, vehicle technology. TREMOVE provided the European data for road, rail, air, and inland waterway transport with the emission factors from COPERT v4. ITCM costs and emissions figures are for road vehicle EURO V, i.e. 2-axle truck with 3-axle chassis and a payload of 24 tonnes.

Collating the costs and taxes for European countries presented a very complex and difficult proposition. The sources allowed a relatively broad-spectrum of the road cost figures. There were several meetings (initial and follow-ups) with road transport operators, which allowed a clearer insight and a better understanding of the internal cost spread. To compute tax burdens for Ireland based transport operators, with forwarding companies in the UK and delivering freight to Europe was a very complex and complicated issue, as it was difficult to obtain the actual costs. Further, to evaluate the labour costs for road sections on distances over 500 km, would include additional

[77] TREMOVE: DG ENV directed policy assessment model to study the effects of transport on transport related emissions. The model estimated transport demands and environmental pollution and the welfare level road and rail for policies in road pricing, public transport pricing, emission standards, subsidies for cleaner cars etc. The model covers passenger and freight transport in 31 countries over the 1995-2030(TREMOVE 2007) http://www.tmleuven.be/methode/tremove/home.htm

costs; either as time costs linked to compulsory rest periods[78] or the use of two drivers to allow for non-stop road haulage services (Delhaye *et al* 2010 COMPASS, TREMOVE 2007). The latter costs are not included in the costs – leading to an underestimation of (especially labour) costs for longer distances.

Table 6.3: Summary of costs and taxes for the road (based on 2010 costs)

COSTS	€/TONKM
Fuel cost	€ 0.0154
Insurance costs	€ 0.0064
Personnel costs	€ 0.0172
Purchase costs	€ 0.0241
Repair costs	€ 0.0098
TAXES €/TONKM	
Fuel tax	€ 0.0090
Insurance tax	€ 0.0011
Personnel tax	€ 0.0184
Network tax	€ 0.0016
Ownership tax	€ 0.0017
Registration tax	€ 0.0001
TOTAL	€ 0.1046 /tonnekm

Source: TREMOVE (COMPASS 2010)

In most of the trips, the pre/post main haul journeys are done by road to the intermediate intermodal terminal. At the intermodal terminal, freight is transhipped onto the main haul for carriage to the next/final terminal. At the final terminal, the freight is transferred onto the post haul mode for delivery to the destination. In most

[78] Regulation (EC) No 561/2006 on the harmonisation of certain social legislation relating to road transport.

places this is also by road. TREMOVE separates internal costs for trucks over 32 tonnes) shown in Table 6.3.

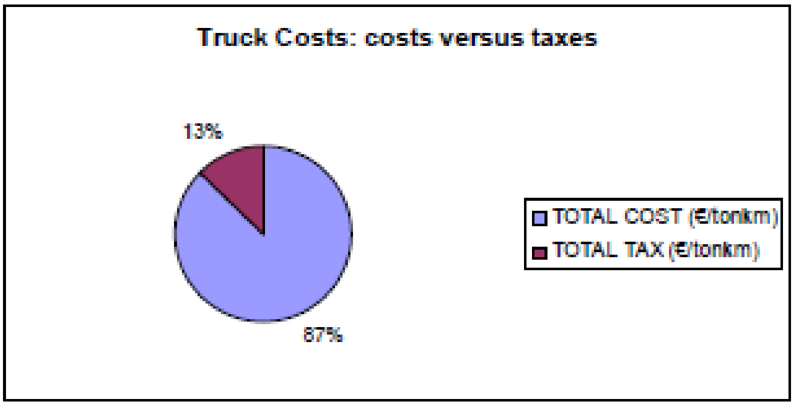
The total cost factors for a truck are:

= [Personnel costs + Energy costs (Fuel) + Insurance costs + Maintenance & Repair costs + Depreciation/Renting costs + Taxes/Charges costs + Tolls + Overhead costs + Tyres costs + Other costs + Loading/Unloading costs]

+ [Air Pollution; Climate Change; Noise; Environmental; Accidents; Congestion];

or as represented by Eq 6.2:

$$C_T = [P_t + E_t + I_t + M\&R_T + D/L_t + T_t + OVt + TY_t + O_t + L/UL_t] + [AP_t + CC_t + N_t + E_t + A_t + C_t]. \qquad \text{Eq 6.2}$$



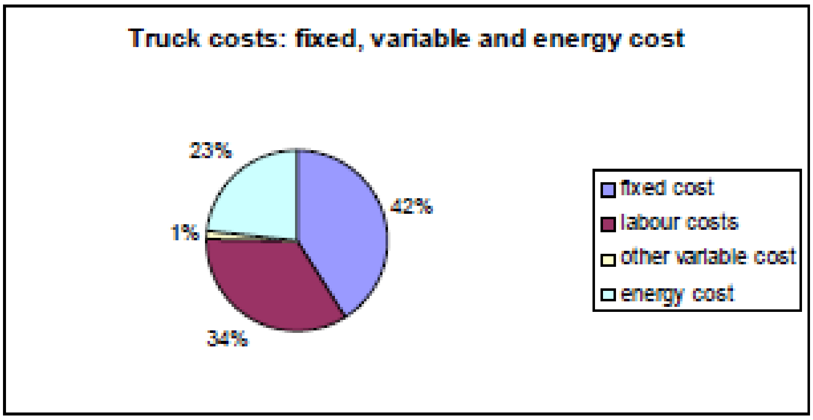


Figure 6.9: Cost breakdown road transport (taxes; fixed/variable/energy)
Source: TREMOVE (COMPASS 2010)

In the total out of pocket costs for the road vehicle, taxes represent about 13% of the total Figure 6.9. Further, when the costs are broken down between fixed costs, labour costs, fuel and other variable costs, labour costs accounts for about 34% of the total costs. On longer distances, the share of the labour costs would be higher, representing either rest costs or costs of a second driver. The energy cost is about 23% of total costs.

Waterborne (Inland waterways and Short Sea)

The ITCM data for short sea shipping (SSS) with its cost structures for four types of ship were collected from Drewry research and NECL (Nautical Enterprise Centre Ltd. Ireland) ship cost databases. For additional comparison and relevance, data on the Irish trade from two shipping companies (Eucon Shipping & Transport Ltd. and B.G. Freight Line B.V) were obtained. These data were of central importance during the consultation with industry representatives via the survey and meetings.

The two main short sea shipping services considered were:

- Lo-Lo, (Lift on-Lift off) transport service loaded containers on short sea service or a feeder service from gateway ports to the neighbouring smaller ports. Container vessel ships can be employed, for the transhipment from the mother vessel in the hub port.
- Ro-Ro, (Roll on-Roll off) the transport is developed through an accompanied service, in which the freight is loaded/unloaded horizontally. Ro-Ro units are transported on dedicated Ro-Ro ships or with mixed Ro-Pax ships.

The summary of the operating costs for the vessels were collated from Drewry's and other studies (Delhaye 2010). The European data were compared with the vessel data from ships calling in at Dublin port and from consultation with industry representatives via the survey and meetings.

Table 6.4: Summary of daily costs for SSS

COST STRUCTURE (€/DAY)				
Ship type	LoLo	RoRo	RoPax Small	RoPax Large
Capacity	600 TEUs	200 trailers	40 trailers	290 trailers
Deadweight	11,000	10,000	3000	12000
Manning	1588	1901	3300	7500
Insurance	313	443	300	1500
Repairs & Maintenance	802	1382	1000	3300
Stores & Lubes	351	328	3800	6000
Administration	504	870	1000	2700
Capital repayments	2189	7960	3476	14945
Interest	1799	6543	2857	12286
Gross Margin	1283	3302	2675	8199
Port charges	1200	3000	850	6000
Fuel (tonnes/day)	28	37.9	7.0	53.3
Fuel (€/day)	8924	12079	2231	16987
Speed (knots)	14	17.5	8.0	22.0
Full Cargo	7200	2800	1000	7250
Total €/day	18952	37807	21488	79417

Source Delhaye et al 2011

Table 6.4 shows the generic values for each of the type of vessels on the Irish/NW Europe freight corridor.

Sea transport handles over 80 per cent of the volume of global trade and accounts for over 70 per cent of its value. Since 1970, global seaborne trade has expanded on average by 3.1 per cent every year, reaching an estimated 18.9 billion tons in 2013 (UN 2013). When a cargo is carried by more than one mode, the transport is termed intermodal or co-modal.

Within EU waters, short sea services extend from the Mediterranean Sea to the North Sea and the Baltic Sea. The traffic flows reflect commercial reasons and geographic morphology of the countries in these areas and may be either direct shipping or transhipment on either international or local routes.

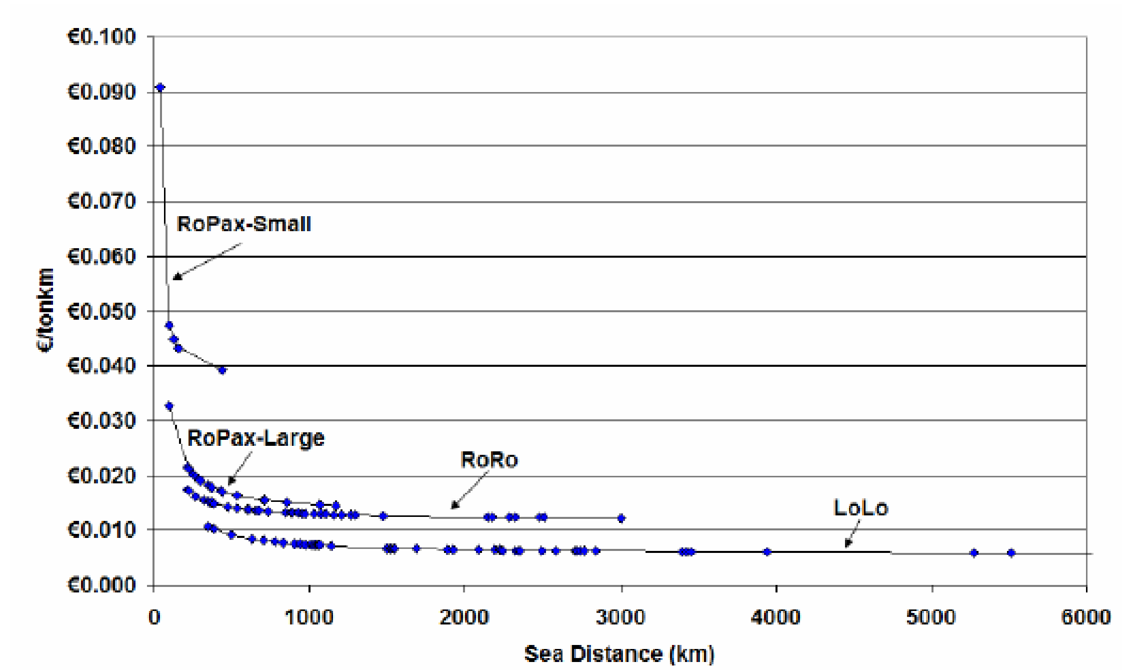


Figure 6.10: Costs in €/tonnekm for the different ships according to sea distance
Source: Delhaye et al (2010)

For the ITCM, it was necessary to convert the €/day figures into €/tonnekm. This was achieved by dividing the cost per day (€/day) by the number of kilometres covered per day (km/day). The resultant €/km cost is then divided by the carrying capacity of the ship in tonnes, generating the €/tonnekm figure. Figure 6.10 summarises the costs per tonnekm for the four types of SSS and coastal vessels.

Costs per tonne km vary by route and ship type, making the comparison with road and rail rather complex (Kim 2010).

Rail

There has been a radical change in the ownership of rail services in Europe, over the past twenty years, with the traditional state-owned railway corporation controlling both track and trains becoming a rarity (Tessa Journal March 2012). Changes brought about in the governance are based upon strong devolved government to local bodies.

EU based reform packages have liberalised both the international passenger and freight services (Salveson 2014). This complex ownership mix has exacerbated the very complex infrastructural issues in: technical standards of locomotives and wagons; rail track widths; electric power specifications; etc. The lack of a standard regulatory, legislative and technical specification has added to the uncertainty in the network operations and charges. These differences have delayed the required level of improvements in rail performance and delayed its wider exploitation as alternatives to road routes (Delhaye et al 2010). The base data for the ITCM collected and collated from the EU research database, as referred earlier (Delhaye COMPASS 2010; Grosso 2010; Vlaams Vracht Model-Cost Model, Mint and K+P consulting group 2009; RECORDIT European Project 2000). Additional railway sector costs were collated from Baumgartner and Litep (2001) and updated with data from ECORYS (2006). Distances and hardware details were from ETIS, with the operational data collated from the 'Iron Rhine' research (a rail study involving Belgium, the Netherlands, France, Germany and onto central Europe). The operational data for the Irish sector was collected from Irish Rail (Iarnród Éireann). Collating data from these sources offered three advantages; first, there was detailed information available; secondly, in an industry where there are very few available sources, this information offered very good reliable data for a selection of countries and was based on total revenue from freight transport and the total amount of tonnekm driven; finally, the data was recorded from EUROSTAT and ECORYS (2006), which was reliable and in the public sphere. There were nominal differences in the rail figures for the Netherlands, UK and Ireland, as can be seen in the EUROSTAT figures.

Literature review shows (See Chapter 2) three types of internal costs for the rail sector:

1) <u>Average fixed costs</u> (€/h): costs for locomotive, wagon, personnel and overheads

2) Average variable costs (€/trainkm): infrastructure fee, shunting costs. Depending on the baseline scenario this average cost could also include an externality tax for future years.

3) Average energy cost (€/trainkm): distinguishing diesel from electric traction. For the model it was decided not to distinguish diesel from electric traction, but instead use a weighted average. In the near future, this average will include the expected evolution in electrification and cleaner energy sources.

1. Average fixed costs: are the cost factors collated for the locomotive and the wagon

- Locomotives: The following parameters were considered - Purchase price per piece (including safety system); number of locomotives; depreciation (number of years); Maintenance costs (%); insurance costs (%); rest value (%); number of working days; number of working hours/day
- Wagons: The following parameters were considered - Number per train; Loading capacity per wagon (TEU); Rental price per day; Number of working hours per day

Personnel costs for the driver were allocated as 50 €/hour (Delhaye et al 2010). Rates for other operations were included in the shunting costs. In rail operation and capital costs (locomotive, wagons and personnel) a further cost of 20% was allocated to cover overheads. Summing these four items, presents the average fixed operator cost. These vary considerably between different European countries and it is not possible to make a close comparison. Even within one country, the infrastructure fee [79] varies on different routes and also for different commodities.

The tax system for rail varies across EU states (Delhaye et al 2011).

[79] Belgian study average infrastructure fee was €2.32 per trainkm (Billieu 2010)

2. Average variable costs: include the costs that apply for 'if/when used' items. These include the infrastructure costs and the shunting costs. In the shunting costs are included the additional personnel costs.

The infrastructural costs are dependent on the country and also further variations within the same country. The European studies (TREMOVE) have considered the fee at a multiple (3.3) of the €/trainkm. The records of the total shunting costs offers €/train at € 411.65 (Delhaye et al 2011).

3. Average Energy Costs: Collating the energy costs for the model, methodologies were based on the European model Transcar. The Transcar cost model formulates the prices for diesel and electricity power, for freight rail traction, based on the price of crude oil per barrel. The oil prices are based on USD 72[80] per barrel (November 2014). Other major assumptions used in this model are

- Electricity power generated in power stations running on natural gas (not hydroelectricity);
- A stable spread between diesel and crude oil prices;
- Natural gas prices stand in fixed proportion to crude oil prices.
- CO_2 permits are needed for natural gas and for diesel

This allows the extrapolation of energy costs, used within the iTREN baseline, for the expected energy cost for future years.

For the model to run, all the transport mode costs are expressed in Euro per vehicle kilometre or per tonne; the hourly fixed costs have been divided by the mode speed. The average speed for rail on European routes was 62.48 kmph (ETIS).

[80] http://www.oil-price.net/

Table 6.5: General cost items for rail

Cost Items	Description
Personnel and social security	The European legislation defines that a driver should be present for each train
Rail Track	The price rail operator pays to the infrastructure manager in order to be able to use the rail tracks/path
Capital costs: locomotives/wagons	
Repair and Maintenance	For locomotive and wagons- stock Main rail track will incur higher costs than secondary track.
Depreciation and interest, leasing/rent,	
Shunting operations	Costs in positioning of the locomotives and wagons in order to place the train in the right direction for loading/unloading. These operations are origin/destination occurrences but may also occur at intermediate or intermodal terminals.
Loading/unloading activities	Costs for loading and unloading the train, are expressed as Euro per hour for each movement.
Fuel and other consumption material	Fuels: Hydrocarbons, nuclear and hydroelectric to power the locomotives.

Source: Grosso 2010, Irish rail (2013)

The measurement of the energy consumption is thus expressed in €/Km and can be either:

Energy costs (Fuel) = [(Energy price per litre * average consumption per km)] + Transport distance in kilometres

or

Energy costs (Electric power) (E) = (Energy price per kilometre) * Transport distance in kilometres. Additional cost items are very similar to the road mode for items like vehicle insurance and overhead costs, as shown in what follows. The general cost items for rail are tabulated in Table 6.5. For the Irish case study, the operational internal costs for the rail section were obtained from Iarnród Éireann Freight. These compared closely with the EUROSTAT figures (EU 27)

Rail costs were segmented as:

- {Pre-haul costs} = [Personnel costs road + Energy costs (Fuel) road + Insurance costs road + Maintenance and Repair costs road + Depreciation/Renting costs road + Taxes/ Charges costs road + Tolls + Overhead costs road + Tyres costs road + Other costs road + Loading/Unloading costs]
- Main haul: = {Personnel costs + Energy costs (Fuel) + Energy costs (Electric power) + Insurance costs + Maintenance and Repair costs + Depreciation/Renting costs + Tolls + Overhead costs + other costs + Rail Tracks costs + shunting operations costs + Loading/Unloading costs}

  Where, Rail Tracks costs = (Average cost for rail track) * Number of kilometres for the specific journey

- {Post-haul costs} = [Personnel costs road + Energy costs (Fuel) road + Insurance costs road + Maintenance and Repair costs road + Depreciation/Renting costs road + Taxes/ Charges costs road + Tolls + Overhead costs road + Tyres costs road + Other costs road + Loading/Unloading costs]

Except for the distance, the generic costs are very similar to the pre-haul items. The costs are summarised in Table 6.6 where the assumptions for the costs of the locomotive and the wagon used for the calculation of the average fixed cost are given below.

Computing comparative energy costs, for diesel traction and electric traction, a European model (TransCar) computes the costs from ‘well to wheel’ for exogenous crude price, the expected diesel price and electricity price for freight rail traction.

Table 6.6: Locomotive internal cost items (assumptions)

Description	Costs (Delhaye 2010)	Costs CIE (2013)
Diesel locomotive	2500000	2700000
Depreciation (years)	20	20
Maintenance %	6.25	10
Insurance %	1.5	No figures
Rest value %	10	No figures
Number of working days	300	52 weeks
Working hours	6.5 hrs per day	48 hrs per week
Wagons per train	29	18

Delhaye 2010; Irish Rail (2013)

This model allowed a formalised position for iTREN baseline energy prices to evaluate future expected energy costs. The standardised cost units are reported as €/tonnekm. The costs per tonne kilometre for each mode were obtained by dividing the fixed costs, by the speed (for rail average was 62.28 kmph 2010 TREMOVE) as delineated here. The generic relationships between the different factors for rail mode are represented in Eq 6.3.

Total Internal Cost Rail Transport = Personnel costs + Energy costs (Fuel) + Energy costs (Electric power) + Insurance costs + Maintenance and Repair costs + Depreciation & Renting costs + Tolls + Overhead costs + Other costs + Rail Tracks costs + Shunting operations costs + Loading/Unloading costs.

$$Cr = [P_r + E_r + I_r + M\&R_r + D/L_r + OV_r + RT_r + O_r + SH_r + L/UNL_r] \qquad \text{Eq 6.3}$$

In Ireland the freight rail services are all powered by diesel locomotives (CIE), whereas, approximately 90% of tonne-kms of the rail network in the UK was hauled by diesel locomotives, with the balance being hauled by electrified locomotives (McKinnon 2007). Studies at a European level gave an estimate that diesel-hauled rail freight operations had doubled the CO_2-intensity of electric-hauled operations INFRAS (2004). Other European studies showed that it was the types and combination of fuels in the power generation system, along with the average thermal efficiency of power plants that made electric traction competitive (IFEU 2005).

Intermodal

The general cost structure for the intermodal system is a combination of the three separate modes, as previously described.

<u>{Pre-haul costs}:</u> [Personnel costs road + Energy costs (Fuel) road + Insurance costs road + Maintenance and Repair costs road + Depreciation/Renting costs road + Taxes/ Charges costs road + Tolls + Overhead costs road + Tyres costs road + Other costs road + Transhipment - loading/unloading costs]

<u>{Main haul rail costs}</u>: [Transhipment costs + Personnel costs rail + Energy costs (Fuel/Electric) rail + Insurance] + cost rail + Maintenance and Repair costs rail + Depreciation/Renting costs rail + Overhead + costs rail + Other costs rail + Rail Tracks costs + Shunting operations costs + Loading/Unloading costs

<u>{Post-haul road costs}:</u> Cost during the Post-haul road section is very similar to the pre-haul, differing only in the distance from the intermodal hub to the destination.

In summary, collating the internal costs items and its attributes was a very complex operation. The costs of the numerous items were collected and collated with reference to the ITCM freight corridors. The data were derived from different sources; different industries and very different operating standards (within the SSS, costs vary largely between vessel types and distance covered). Transport data were collated costs per day and were further evaluated to convert the €/day figures into €/tonnekm. This was achieved by dividing the cost per day (€/day) by the number of kilometres covered per day (km/day). The resultant €/km cost was then divided by the carrying capacity of the ship in tonnes, generating the €/tonnekm figure.

6.6. Analysis of ITCM internal (out of pocket) costs[81]

The evaluation of the internal or 'out of pocket costs' is influenced by the commodities related criteria of mode and route selection. This is relevant in the evaluation of the total transport costs for truck/rail, truck/barge and rail/barge (Boardman et al 1999). The authors proposed that the total out of pocket costs were the sum of four operations: transport, drayage, transfer and carrying costs. The authors found that mode choice was strongly influenced by the costs in distance covered, road transport being the best for short distances.

Table 6.7 lists the main cost factors for the four modes (fixed costs and operating items). Internal costs items arising from cargo related issues or those associated with the particulars of a consignment, such as depreciation, maintenance, repair and insurance costs, are not included because they are assumed to be borne by shippers or recipients (European Commission, 2001a, b; Levison et al., 1996).

There were **two distinct factors that influenced the sum of internal costs.** The first costs were <u>fixed and capital costs were independent of distance</u>. The second set of costs were <u>those dependent on the distance transported</u> (Tavasszy and Meijeren 2011).

[81] See Appendix 11 for different internal costs

Table 6.7: Fixed and operating cost factors in transport

Mode	Fixed/Capital Costs	Operating Costs
Maritime	Land for Port Terminals, Cargo Handling Equipment, Ships	Maintenance, Labour, Fuel
Road and rail	Land, Construction, Cargo Handling, Locomotive shunting	Maintenance, Labour, Fuel
Pipeline	Land, Construction	Maintenance, Energy
Air	Land, Field & Terminal Construction, Aircraft	Maintenance, Fuel, Labour

Source: Rodrigue 2013

The following points were considered.

- The main haul road costs are lower than the overall route (average of pre-main-post haul plus terminal charges). This is due to very low terminal charges (fixed costs are only 10 % of total costs)
- Rail and Sea have relatively high terminal charges but lower line haul costs
- Rail and Sea networks are coarser than highway networks – fewer terminal facilities but larger in scale
- Containerisation has reduced costs (Behar and Venerables 2010);
    - Lower port costs as they have become more efficient.

In most of the studies on mode choice made by the shippers or the decision makers, the total cost amount has been one of the top issues. (Delhaye 2010, Tavasszy et al 2011), Table 6.8 summarises the various attributes of the factors in transport.

Table 6.8: Summary of the various attributes of the different transport factors

Factors	Attributes	Example
Geography	Distance and accessibility	Long distance rates

Type of product	Packaging, weight, perishable	Seafood; time sensitive goods
Economies of scale	Shipment size	Containers less than full
Trade imbalance	Empty travel - "back haul rates"	Wine shipment, bulk carriages
Infrastructure	Quality of Surface	Natural disasters
Mode	Capacity, limitations, operational conditions	Air cargo; rail bulk; distance limits?

Source: Source: Rodrigue 2013

6.7. Analysis of ITCM external costs

The Inter-Governmental Panel on Climate Change (IPCC), along with the national governments, initiated procedures for monitoring environmental emissions. The increasing concerns arising from the industry related negativities have made the pursuit of CO_2 reductions a major priority for many governments and companies (Harris et al 2011). Borken et al (1999) documented the wide range of industrial related negativities and their environmental impacts as:

- Acidification
- Depletion of the ozone layer
- Eco-toxicity (toxic effects on ecosystems)
- Eutrophication
- Greenhouse effect
- Human toxicity (toxic effects on humans)
- Land use
- Noise
- Resource consumption
- Summer smog

Based on these recognised transport related negativities, the factors for the ITCM allowed measures evaluation and the ability to compare the individual transport modes on costs. The ITCM performance factors were selected on the following criteria:

- Particular relevance on transport of the impact
- Proportional significance to freight cargo transports compared to overall impacts
- Data availability
- Methodological suitability for a quantitative comparison of individual transports.

Updates on the earlier studies on the external coefficients for the Marco Polo programme (2000, 2004), were requested by the European Commission's Directorate General for Energy and Transport (now Directorate General for Mobility and Transport) and were carried out by the Commission's Joint Research Centre Institute for Prospective Technological Studies (JRC-IPTS). The (JRC-IPTS 2011) project covered road, rail, inland waterways and short sea shipping (Brons and Christidis 2013). External cost coefficients covered environmental impacts (air quality, noise, climate change) and socio-economic impacts (accidents, congestion)[82]. There were subsequent updates (Korzhenevych et al. 2014), incorporating modifications and the improvements in the levels of detail and thus accuracy of the cost coefficients for the inland waterways mode. The increased demands towards internalising the costs arising from transport related environmental pollution and socioeconomic negativities have been through regulatory measures (implementing tolls and taxes, etc.) Within the EU, the internalisation ratio varies considerably for different modes, countries and routes (Meillin et al 2013).

[82] The European Commission strategy for internalising external costs of transport does not foresee the inclusion of external cost charges for infrastructure use. Hence, the present analysis does not cover external costs of infrastructure use. Certain other externalities for which no reliable estimates are readily available, such as scarcity costs of rail and inland waterways and costs of energy security and dependency on fossil fuel, are not covered either.

The ITCM's transport based negativities were evaluated on existing technology and regulations and the EU charges. The degree of internalisation was found to be highest for road and rail transport and lowest for sea transport. In the EU states, direct taxation and added tolls have been the preferred option for collecting monies[83]. EU Directives integrated elements reflecting the 'polluter pays' principle. However, Vega and Evers (2015) mention that no EU member states have started internalising external costs, though an increasing number of Member States use a form of HGV road user charging (Sweden, Denmark, the Netherlands, Belgium and Luxemburg (shared 'Eurovignette')). In the UK, an excise duty, called the HGV road user levy[84], is a time-based charge of up to £1,000 a year or ten Pounds Sterling (£10) a day applied to all vehicles weighing 12 tonnes or more, using the UK road network. The Belgian system, based on distance, will be introduced in April 2016.

6.7.1. Calculating environmental factors in transport

Early environmental emissions methodology was introduced by TREMOVE [85] to evaluate the impact of technological and legislative measures for road transport. Subsequent models widened their application and brought in COPERT[86] (COmputer Programme to calculate Emissions from Road Transport). COPERT methodology was designed to analyse Belgian road transport emissions (Samaras 2007) from vehicle based attributes, like speed, truck class, engine technologies, load factor (empty, half-full, full) and road gradient (0%, 2%, 4%, 6%).

[83] Eurovignette Directive (1999/62/EC as amended by 2006/38/EC and 2011/76) sets out the common regulatory framework setting up HGV distance-based road charges and HGV time-based road charges (vignettes) for the use of certain infrastructure.

[84] HGV Road User Levy Act 2013

[85] TREMOVE is a transport and emissions simulation model developed for the European Commission. The model estimates the transport demand, the modal split, the
vehicle stock turnover, the emissions of air pollutants and the welfare level under different policy scenarios for passenger and freight transport in 31 countries between 1995-2030

[86] COPERTIII (2000) was designed to calculate road transport emissions. The regulated emissions include (CO, NOx, VOC, PM) and unregulated pollutants (N_2 O, NH_3, SO_2, NMVOC speciation); fuel consumption was also computed.

The analysis of the early model, which was primarily based on road systems, short-listed seven factors (Kim 2010 p 45).

The road vehicles for the model (EURO V type) are within the 16-32 tonne class, with full loads and assumed to operate on flat roads (0%), though some sections of the road may be hilly. However, the impact on emissions is small. Examples include measures to reduce CO_2 emissions from passenger cars, the introduction of EURO VI standards for heavy duty vehicles, effects of the internalisation of external costs and others (De Ceuster 2005).

Figure 6.11 shows the schematics overview of the methodological approach for the calculation of external cost coefficients. Some of these factors are also relevant to calculate emissions of individual transport modes, but become of particular relevance when comparing intermodal transport with single mode transport.

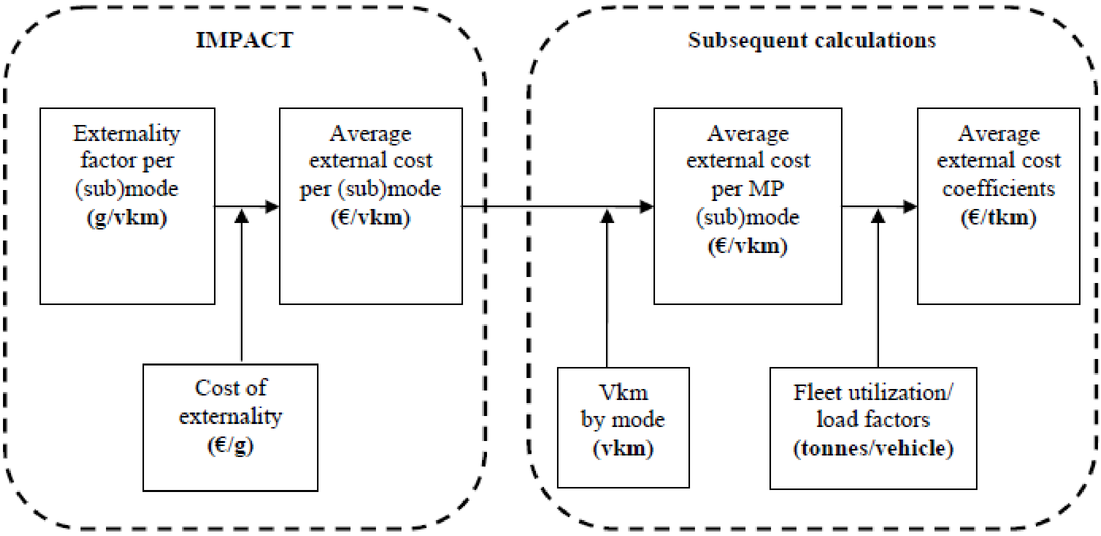


Figure 6.11: General Approaches for the calculation of external cost coefficients

Source: Brons, et al. 2011, 2013.

1) Unimodal and intermodal systems emissions were evaluated from terminal-to-terminal, on long-haul. Total journey emissions (O/D) were the sum of the pre/post and the mail haul segments. The geographical distinction becomes relevant for

truck-only and intermodal systems, or would allow an inbuilt error, especially when comparing total emissions from other transport systems.

2) Terminal based emissions (e.g., from the electricity consumption of electric cranes and lighting, from forklifts and from reach stackers) have not been included.
3) The emissions during component production from fossilised fuels, which can affect the global environment in the medium-term, have often been ignored.
4) Supply sources of electricity related to electric-powered trains and terminal operations. Local electricity supply had often been overlooked.
5) The unaccounted loss of electricity due to transmission from the power plant to locations of use (i.e., railway and terminal).
6) When comparing the loading operations, measurements of the standard 'loading unit' were ignored in view of the huge array of different weights and sizes. This was relevant as intermodal systems were limited to standardised transporting units.
7) Utilisation factors based on the capacity of vehicles/vessels. Needless to say, two 500-TEU vessels are more efficient than five 200-TEU vessels, for example.

For the ITCM, the external costs included two components; first was the environmental pollution[87] (GHG, CO_2 and particulate matter); the second was from cumulative effects from transport, noise, accidents and the wear and tear on infrastructure. With the increase of vehicles, far exceeding the designed capacity frequent road congestion has ensued. Congested roads have led to situations resulting in costs from delays and waste of energy. However, the amount of congestion costs seems to be systematically overestimated, especially when compared to other external effects, like air pollution costs or accident costs (Hansen 2001). The external costs based on land use and the loss of landscape and soil and water pollution are not considered here.

[87] Pollutants CE Delft (2008 and updates 2011), the relevant pollutants include particulate matter (PM), nitrogen oxides (NO_x) and sulphur dioxides (SO_2).

The ITC model evaluated the carriage of one container of 24 tonnes over a distance in kilometres and expressed in Euro cost per kilometre and the charges were basically the charge per (extra) kilometre. The marginal costs were based on data presented in the handbook on estimation of external costs in the transport sector (CE Delft, 2008, 2011), commissioned by the EU, which was referred to as IMPACT[88]. The IMPACT Handbook was the result of a request by the European Parliament of the so-called Eurovignette Directive for the Commission to present an analysis of external costs. IMPACT calculated the external per vehicle kilometre (e.g. CO_2 emissions per extra kilometre for a truck) and this was multiplied by the unit costs per externality (e.g. costs of a tonne CO_2 emitted). This approach extended to road, rail and inland shipping, for all externality types except congestion costs. The calculation of external costs of short sea shipping was based on input data from the EX-TREMIS (2008) project. The road congestion calculation for road and rail were based on estimations of the TRANS-TOOLS transport model (TRANS-TOOLS 2008).

The ITCM's methodology allowed the computation of total external costs, on the three corridors, incorporating the EU 27 based values (JRC-IPTS 2011). This allowed the ITCM to calculate the total costs from each route based on mode-specific factors with estimates of the distances travelled by each mode. Whenever possible, the same or similar vehicle types as used by the OECD/International Transport Forum (ITF) in its study on fees and taxes for road and rail (ITF, 2008a and 2008b) were used for the ITCM. The general assumption was that the unimodal (truck-only) system, per unit cargo (TEU) had greater environmental and socio-economic negativities than the intermodal system. In seeking to quantify all the transport related external costs the ITCM offered a qualified solution.

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6.8. Outline of the model

The ITCM design allows the comparison of total costs of transporting a container of 24 tonnes on three routes, within one transport corridor, between same origin/destination. This setup allows a fuller comparison of costs with the mode selections at different segments. There are several underlying factors in the model:

- The influence of load consolidation on the overall operating costs and the transport related pollution. Freight transport efficiency of goods transportation is the continuous product of time, distance, speed and load consolidation (Samuelsson and Tilanus 1997). The study included various permutations (up to 18), starting from a theoretical and ideal point where goods are transported continuously, non-stop, along the shortest route, at maximum speed and at maximum capacity from an origin to the destination and back. The theoretical efficiency suggested by the research was not credible [89] and resulted from the introduction of too many approximate variables resulting in highly questionable outcomes. The ITCM load data was collated from the ETIS database, which is based on a large number of journeys, between the same O/D. The ITCM data represented the average values of time, distance, and speed and load density. These figures were compared with the recorded Irish figures for road, rail and waterborne modes.
- Fuel consumption is directly proportional to the freight load on the vehicle; the freight weight influences the energy expended per unit freight weight, per kilometre and per hour of the transit into the amount of environmental pollution. However, there is no marked influence on the social factors (accidents, noise, and congestion) dependent on the load of a vehicle.
- Regulatory measures influence the service providers promoting particular transport modes as being more ‘green’ and sometimes base CO_2 calculations for their mode

[89] The study stated a figure of 0.00043 as the final theoretical efficiency.

on high levels of utilisation while using average load factor data for competing modes (McKinnon 2007). Service providers respond to the market forces and their response is dependent on the available transport modes and the levels of infrastructure logistics, which influences the overall costs.

Increasing concerns on the negativities arising from the transport industry have influenced the need for ‘desirable’ environmentally friendly networks leading to academic research to consider both the economic and environmental impact of network design (Harris et al 2011). The ITCM combines internal, external and time costs on three transport corridors Here, internal costs are the ‘out of pocket’ costs paid by the service provider; the external costs include the costs of the impacts on the environment and society due to local and global air pollution, congestion and noise pollution and traffic accidents.

The ITCM offers a comparative tool to the freight buyer and the service provider to offer competitive ‘green’ options to the market.

Following on from the concepts of operating costs (internal), socio-economic costs (internal) introduced in Eq 6.1 results in Eq 6.4.

Total Cost_{MODE} = Internal Costs + External Costs + Time Costs + Others. Eq 6.4

Formulating a generic relationship for total costs for intermodal transit:

$C_{IMT} = C_{internal} + C_{external} + C_{time}$ Eq 6.5

Where:

C_{IMT} = Costs for Intermodal Transport
C_i = [Freight tonnage x coefficients for mode inter costs items]
C_e = [Freight tonnage x co-efficient for (environmental pollution + socio-economic)]

(Environmental pollution = air pollution, climate change, and socio-economic = noise, accidents and congestion)

C_t = Transport period x Commodity Co-efficient

Shown below are the generic total costs for road mode and Intermode concepts:

C_{Road} = [Personnel costs truck + Energy costs (Fuel) truck + Insurance costs truck + Maintenance and Repair costs truck + Depreciation/Renting costs truck + Taxes/Charges costs truck + Tolls + Overhead costs truck + Tyres costs truck + Other costs truck + Loading/Unloading costs] + [Personnel costs inland navigation + Energy costs (Fuel) inland navigation + Insurance costs inland navigation + Maintenance and Repair costs inland navigation + Depreciation/Renting costs inland navigation + Charges costs inland navigation + Tolls + Overhead costs inland navigation + Other costs inland navigation Loading/Unloading costs]

C_{IMT} = [Personnel costs truck + Energy costs (Fuel) truck + Insurance costs truck + Maintenance and Repair costs truck + Depreciation/Renting costs truck + Taxes/ Charges costs truck + Tolls + Overhead costs truck + Tyres costs truck + Other costs truck + Loading/Unloading costs] + [Personnel costs rail + Energy costs (Fuel) rail + Energy costs (Electric power) rail + Insurance cost rails + Maintenance and Repair costs rail + Depreciation/Renting costs rail + Overhead costs rail + Other costs rail + Rail Tracks costs + Shunting operations costs + Loading/Unloading costs]

For the IMTC, for transporting a 24 tonnes container with road pre/post haul and the main haul is by Short Sea shipping is shown below:

$TC_{IMT\ (Truck+RoPax)}$ = 24 tonnes * {Distance *Internal costs} + {Distance* External costs} + Time Costs + Terminal charges, toll charges and fees and Taxes

= 24* {[Distance $_{(Pre+Post)\ road}$ * GTC $_{road}$] + [Distance $_{(Pre+Post)\ road}$ * Emissions$_{road}$] + [Distance$_{sea}$ * GTC$_{sea}$] + [Distance$_{sea}$ * Emissions$_{sea}$] + (Total transit time* Commodity factor)} + Charges (Transhipment; tolls; etc.).

6.9. Summary

Following on from the methodology set out in Chapter 4, this chapter delineates the model design which allows the comparison of total costs in nine routes, with the same O/D, spread between three distinct transport corridors. The ITCM allowed the application of factors to each of the separate freight transport infrastructure networks in terms of cost methods and algorithms. The ITCM included both the economic factors and the externalities, including social impacts (congestion noise and traffic incidents/accidents and environments items (CO_2 and other greenhouse gasses (GHG) such as SO_x, NO_x) that allow for the new and comprehensive comparison tool. Trends in recent literature suggest that '*When creating an environmentally friendly network it is important to consider economic and environmental trade-offs of logistics redesign. For this reason, it is prudent to model environmental issues as part of the design objectives rather than as constraints'* (Harris, *et al*. 2011).

The ITCM design offered a new freight transport network concept, beyond the existing models, by incorporating multimodal, multi-actor and service networks. The ITCM combined the freight transport infrastructure networks with the total pricing policies, internalising the externalities, thereby enabling an efficient integrated infrastructure based on sustainable factors. Design problems were resolved with a two-fold approach; the first proposed an alternative multimodal transport system compatible with existing and upgraded infrastructure, improving the logistic flow over a large-scale multimodal network and the second allowed opportunities for combinations of policy measures towards implementing the alternative transport systems.

The ITCM model was applied on three freight transport networks designs in terms of architecture, attributes and algorithms. It included the environmental emissions and the other factors influencing climate changes (greenhouse gas (GHG) such as SO_x, NO_x, and social impacts such as noise and traffic incidents/accidents. The model allows users to evaluate the mode choices for each freight transit for the lowest total transport costs. The model evaluated the total costs per route/network at each level: link, terminal, regional and/or network level, per mode, per commodity type, and/or a combination of these. The model's flexibility allowed additional variable to assist in the selection of mode choice options best suited for the transport route. The model's design allowed the investigation of impacts of the traditional total costs on overall logistics costs and external factors (environmental and socio-economic pollutions) by taking into account the road transport delivery process with an intermodal alternative. The model was calibrated and validated for a case study of container transport using real-life transport logistics. The results offer new solutions for total transport costs based mode-choice options. The model allows new research directions that could incorporate dynamics of both service demand and supply.

Chapter 7 presents the results of the total costs on the nine case studies in the three European transport corridors. The result of the nine case studies clearly demonstrates the cost differences in costs between the routes with the same O/D by following different mode combinations.

Chapter 7
Intermodal Transport Case Studies and Analysis

7.1 Introduction

This chapter presents the ITCM's results of the three case studies, with the nine routes, based on the research methodology as in Chapter 4 using the model concepts set out in Chapter 6. This chapter is presented in seven sections. The second section explains the testing of the ITCM. The third, fourth and the fifth sections present the three case studies. The results are examined in the sixth section. Finally, the seventh section concludes the chapter.

7.2 Testing of the ITCM

The ITCM was tested on three transport corridors, where each journey has three routes, starting with the same origin and ending at the same destination. This will allow for a fairer comparison of the total transport costs between the three routes.

The following chapter sections deal with the three case studies, each with three routes with the same Origin and Destination. The ITCM was designed to evaluate the total costs in the transport of a container with a combination of road, rail and short sea modes. The chosen routes allowed the fullest testing of the model, based on the same O/D, with three different combinations of the transport modes. Of the three case studies, one of the studies was 'road heavy', reflecting present practises where the road/truck was a major part of the main haul. The other two case studies include alternatives to road with the use of a second mode to reduce the road transit length, as an example of intermodal concept. The third case study evaluates a dedicated intermodal transit; this includes more than one transport mode during the main haul, as an alternative to road, subsequently having a lower costs and environmental footprint.

The ITCM's evaluated the sum of internal, external and time costs in each of the routes within three freight transport corridors.

The following steps were designed for the ITCM simulation:

1) Setting of the transport corridors and analysing the effect on;
   a) Determining generalised price of each mode;
   b) Determining the emission factors for each pollutant and each mode;
2) Evaluating the generalised costs for the ITCM between the same O/D sets;
3) Applying the relevant emission factors and calculation of the emissions using the change in demand found from the previous step.

This allowed cost drivers to be fully analysed, (for example the fuel cost, purchase cost, time costs…) and/or which had an impact on the emissions directly (for example emission standards). Based on the discussions with the services buyers and providers, it appeared that the firms frequently opted for the lowest financial option, minimising both monetary and time costs, under certain constraints.

In all case studies, the general assumptions were that there were no extraordinary delays arising from:

- Sailing schedules brought about by weather, labour or other disputes;
- Road related delays arising from urban congestion, weather (snow, flooding, etc.) and labour issues.
- Rail shunting and turnarounds[90];
- Time and infrastructure changes during intermodal transhipments.

[90] The extent of the European rail network is in Appendix 12.

Based on the literature review and collated from TRANS-TOOL and TREMOVE, research indicated that the values of time depended on the types of goods and not on the transport mode. The freight factor chosen for the ITCM was for machinery, transport equipment, manufactured articles and miscellaneous articles. This allowed the interpolation to reflect the true time related costs in the subsequent evaluations.

7.3 Case Study 1: Rotterdam to Ballina

The routes in this corridor connect the main land of Europe to Ireland with the potential for alternatives to the primarily road-only services offered at present. This route offered the ideal alternative to road through a combination of short sea and rail connecting Rotterdam to Ballina. The lack of rail infrastructure connecting the ports and the hinterlands through modern intermodal terminals area hinders the fuller implementation of intermodal solutions in Ireland.

There are three Ro/Ro corridors connecting Ireland and the UK; northern, central and southern to Great Britain and the fourth corridor to France and the Benelux countries. On an all-island basis, 7% of Ro/Ro traffic is shipped direct to mainland Europe from Ireland (Great Britain[91] IMDO 2012). The Department of Transport, Tourism and Sport (DTTAS) ports policy document (2013), designated the five ‘core ports’ of Dublin, Rosslare, Waterford, Cork and Shannon/Foynes. The report stated that it was the Department’s priority to move freight efficiently to connect the ports, roads and rail access along the ‘core’ network to the emerging European TEN-T network. Ballina has rail connections to Dublin Port intermodal terminal operated for International Warehousing and Transport (IWT). Figure 7.1 shows the three case studies of route 1, connecting Rotterdam to Ballina.

[91] Some of the Irish exports are ferried by Ro/Ro and connect with international flights out of London

Figure 7.1 Case Study 1 with three routes from Rotterdam to Ballina

The road transports on all the routes were the EURO V type, to maintain compatibility in the evaluation of costs, internal and related externalities.

7.3.1 Route 1.1: Rotterdam/Felixstowe/Holyhead/Dublin/Ballina

This has been the preferred route from Rotterdam, across the UK land bridge between Felixstowe to Holyhead and by ferry to Dublin and transport by road to Ballina.

Table 7.1: Route 1.1: Rotterdam /Felixstowe/Holyhead/Dublin/Ballina (ferry/road/ferry/road)

Route 1		Case Study 1	Rotterdam to Ballina	
Leg	Origin	Destination	Distance km	Mode
A	Origin	Rotterdam Port	5	EURO V
B	Rotterdam Port	Harwich	185	Ro-Pax
C	Harwich	Holyhead	547	EURO V
D	Holyhead	Dublin	111	Ro-Pax
E	Dublin	Ballina	240	EURO V

Table 7.1 shows the transits, combining ferry, road, ferry and final segment by road.

It was assumed that the container was delivered to the shippers' container berth at Rotterdam and prior to being loaded on a RoRo ferry bound for the port of Felixstowe, United Kingdom. In Felixstowe, the trailer unit was discharged and was driven across to the port of Holyhead, in the west of the UK on the Isle of Anglesey, North Wales.

The port of Holyhead has good connections to all three modes, especially with rail links to the UK hinterland.

7.3.2 Route 1-2: Rotterdam /Kingston upon Hull/ Holyhead/ Dublin/ Ballina.

(ferry/road/ferry/road)

This route has been that preferred by shippers with their chosen links to the North East of UK. This route consisted of the transit on RoPax ferry from Rotterdam to Kingston upon Hull. On discharge the freight unit was transported by road, transiting across the UK land bridge to Holyhead and loaded onto the second RoPax ferry to Dublin. The final leg of the transit was completed, by road from Dublin to Ballina.

Table 7.2 Route 1.2: Rotterdam /Kingston upon Hull//Holyhead/Dublin/Ballina (ferry/road/ferry/road)

Route 1		Case Study 2	Rotterdam to Ballina	
Leg	Origin	Destination	Distance km	Mode
A	Origin	Rotterdam Port	5	EURO V
B	Rotterdam Port	Kingston upon Hull	370	Ro-Pax
C	Kingston upon Hull	Holyhead	353	EURO V
D	Holyhead	Dublin	111	Ro-Pax
E	Dublin	Ballina	240	EURO V

Table 7.2 shows the connecting transport segments in case study 1, combining ferry, road ferry and final segment by road.

The container was delivered to the shippers' preferred container berth at Rotterdam and loaded onto a RoRo ferry bound for north east coast port of Kingston upon Hull, United Kingdom. The trailer unit was discharged in Hull, a shorter road transit across to the ferry port of Holyhead, in the west of the UK on the Isle of Anglesey, North Wales. The port of Holyhead was chosen as it was well connected to all three modes, especially with rail links to the UK hinterland.

7.3.3 Route 1.3: Rotterdam /Dublin/ Ballina (Short sea shipping/rail/road)

This route has been that preferred by shippers with their chosen links to the intermodal infrastructure in Dublin. This route consisted of the transit on a feeder container ship directly from Rotterdam to the port of Dublin. On discharge at Dublin port, the freight container was transhipped to the rail link, in Dublin port, for the transport to Ballina rail freight station. The final post haul was completed by road, from the station to the destination. Table 7.3 shows the different segments of this SSS/rail route from Rotterdam to Ballina.

Table 7.3 Route 1.3: Rotterdam /Dublin/ Ballina. (short sea/rail/road)

Route 1		Case Study 3	Rotterdam to Ballina	
Leg	Origin	Destination	Distance km	Mode
A	Origin	Rotterdam Port	5	EURO V
B	Rotterdam Port	Dublin Port	1243	SSS – LoLo
C	Dublin Port	Irish Rail	5	EURO V
D	Irish Rail	Ballina Station	276	Rail Diesel Locomotive
E	Ballina Station	Destination	10	EURO V

This route offers the ideal intermodal alternative to the above two over the land bridge routes. This route's main haul is carried out by short sea shipping and rail, with its pre and post haul carried out by road transport. The main assumptions on this route were that there was no operational delay(s) in the transfer and the transhipment operations of the freight unit from Dublin Port onto the freight train for Ballina.

7.4 Case Study 2: Rotterdam – Stockholm, Sweden

This case study with its three routes offers the main haul transits with combinations of short sea shipping, rail and with ferry/road combinations for the transit from Rotterdam to Stockholm. Figure 7-2 shows the three routes in case study 2, between Rotterdam and Stockholm.

7.4.1 Route 2.1 Rotterdam to Stockholm (Road/Rail/Road)

This route has been that preferred by shippers with their chosen links to the intermodal infrastructure between Rotterdam/Duisburg/Gothenburg and Stockholm. This route consisted of the freight unit being transported by road from the origin, in Rotterdam, to the intermodal terminal at Duisburg, Germany. The freight unit was transhipped onto a rail networks for the second part of the main haul directly to Stockholm, Sweden.

Figure 7.2 Case Study 2 with three routes from Rotterdam to Stockholm

Table 7.4 shows the different segments of this SSS/rail route from Rotterdam to Stockholm. The ITCM on this route combined the two modes in the main haul, short sea shipping and rail transport, from Rotterdam to Stockholm, (See Fig 7.2 route 2.1). This route has been that preferred by shippers with their chosen links to the intermodal infrastructure between Rotterdam/Gothenburg and Stockholm. This route consisted of the freight unit pre-haul transit by road from the origin to the port of Rotterdam. The container vessel transited the first section of the main haul, from the intermodal terminal at Rotterdam to the intermodal terminal at Gothenburg. It was assumed that, the unit was transhipped onto rail freight, powered by an electric locomotive to the intermodal terminal at Stockholm. The final post haul section was completed by road to its destination.

Table 7.4: Route 2.1: Rotterdam to Stockholm (road/rail)

Case Study 2		Route 1	Rotterdam to Stockholm	
Leg	Origin	Destination	Distance km	Mode
A	Origin	Rotterdam IMT	5	EURO V
B	Rotterdam	Duisburg	250	EURO V
C	Duisburg		5	EURO V
D	Duisburg	Stockholm	1470	Rail (Electric)
E	Stockholm	Destination	10	EURO V

7.4.2 Route 2.2: Rotterdam/Gothenburg/Stockholm (short sea/rail)

The ITCM on this route combined the two modes in the main haul, short sea shipping and rail transport, from Rotterdam to Stockholm, (See Fig 7-2 route 2.2).

Table 7.5 shows the different segments of this SSS/rail route from Rotterdam to Stockholm. This route has been that preferred by shippers with their chosen links to the intermodal infrastructure between Rotterdam/Gothenburg and Stockholm.

Table 7.5: Route 2.2: Rotterdam/Gothenburg/Stockholm (short sea/rail)

Case Study 2		Route 2	Rotterdam to Stockholm	
Leg	Origin	Destination	Distance km	Mode
A	Origin	Rotterdam Port	5	EURO V
B	Rotterdam Port	Gothenburg	937	SSS/ LoLo
C	Gothenburg Port	Rail Terminal	5	EURO V
D	Gothenburg terminal	Stockholm Terminal	430	Rail Electric Locomotive
E	Stockholm terminal	Destination	10	EURO V

This route consisted of the freight unit pre-haul transit by road from the origin to the port of Rotterdam. The first part of the main haul was from the intermodal terminal at Rotterdam to the intermodal terminal at Gothenburg. The container was transhipped onto a freight rail, powered by an electric locomotive to the intermodal terminal at Stockholm. The final post haul section was completed by road to its destination.

7.4.3 Route 2.3: Rotterdam /Travemunde/Trelleborg/Stockholm (Road/RoPax/Road)

In the third route for Rotterdam/Stockholm, route 2.3 in Figure 7.2, the ITCM evaluated the transport combination of road and freight ferry. The freight was delivered at the road terminal for the main haul from Rotterdam to Travemunde, Germany. At the RoRo stage, truck and trailer was transhipped on to a RoPax ferry bound for Trelleborg, Sweden. On arrival at Trelleborg, the RoRo trailer was discharged and transported directly, by road, to the destination. The model assumed that there were no delays (scheduling, weather or labour, along the route) and that there would be two drivers in the event of the transit time required the EU regulatory 'rest periods'. Table 7.6 shows the route 2.3 modes and distances.

Table 7.6: Route 2.3: Rotterdam/Travemunde/Trelleborg/Stockholm (road/ropax/road)

Case Study 2		Route 3	Rotterdam to Stockholm	
Leg	Origin	Destination	Distance km	Mode
A	Origin	Rotterdam	6	EURO V
B	Rotterdam	Travemunde	570	EURO V
C	Travemunde	Trelleborg	220	RoPax
D	Trelleborg	Stockholm	601	EURO V

The freight was delivered at the road terminal for the main haul from Rotterdam to Travemunde, Germany. At the RoRo stage, truck and trailer was transhipped on to a RoPax ferry bound for Trelleborg, Sweden. On arrival at Trelleborg, the RoRo trailer was discharged and transported directly, by road, to the destination.

7.5 Case Study 3: Rotterdam to Istanbul (Turkey)

This transport corridor was selected for the ITCM as it offered real alternatives, ranging from total unimodal (road or short sea shipping) to combinations of road/rail, road/IWW, etc). This case study allows the ITCM along the West to East axis of the European transport zone. The three case studies will allow the fullest exploitation of each of the main modes and also introduce the new legislations. For the road sector it introduces the EUROVIGENETTE, with the introduction of tolls and the enforcing a 'level playing field' with regards to the labour market. This section also allows the opportunity to evaluate the effects of cleaner fuels, under SECA regulations for short sea marine modes (See page 160). Route 3 case studies are shown in Figure 7.3.

7.5.1 Route 3.1: Rotterdam/Duisburg/Wels/Istanbul (Road/Rail/Road)

This case study evaluated the transport of the freight container by rail, from its origin at Rotterdam to its destination at Istanbul, Turkey. The unit was delivered to the intermodal rail terminal at ECT Delta terminal on the Maasvlakte, Rotterdam.

Figure 7.3 Case Study 3 with three routes from Rotterdam to Istanbul

This terminal allows a 24 hours' access to the transhipment operations. This model incorporated the rail links of RNE corridor 03, from Rotterdam to Hannover, Germany. The freight transfer was at Hannover, connecting to the RNE corridor 04 to Munich.

At the intermodal rail terminal in Munich the freight unit was transported to RNE corridor 11 till Svilengrad, Bulgaria. At Svilengrad the freight container was transferred on a connecting Turkish rail provider with its delivery at Istanbul rail terminal. The final post haul was completed by road. Table 7.7 shows the different modes and distances transited for case study 3-1.

Table 7.7: Route 3.1: Rotterdam/Duisburg/Wels/Istanbul (road/rail/road)

Case Study 3		Route 1	Rotterdam to Istanbul	
Leg	Origin	Destination	Distance km	Mode
A	Origin	Rotterdam terminal	5	EURO V
B	Rotterdam Terminal	Duisburg (Germany)	240	Rail Diesel locomotive
C	Duisburg	Wels (Austria)	700	Rail Diesel locomotive
D	Wels (Austria)	Istanbul Station	1580	Rail Diesel locomotive
E	Istanbul Station	Destination	5	EURO V

7.5.2 Route 3.2: Rotterdam – Istanbul (road/sss/road)

The ITCM for this case study evaluated the transport, where the mail-haul was by short sea shipping. The transit is shown in Figure 6-4. The pre-haul transit was done by road, from the origin to the container terminal. The container was loaded on to a container vessel for transit to Istanbul, Turkey. This case study included the effects of sea going vessels having to comply with the new Sulphur Emission Controlled Areas (SECA) in view of the management of SO_x and particulate matter emission controls arising from the combustion of all fuel oils. These apply to the combustion equipment and devices on-board and therefore include both main and all auxiliary engines together with items such as boilers and inert gas generators. These controls divide between those applicable inside Emission Control Areas (ECA) (see Appendix 6) established to limit the emission of SO_x and particulate matter and those applicable outside such areas and are primarily achieved by limiting the maximum sulphur content of the fuel oils as loaded, bunkered and subsequently used on-board. These fuel oil sulphur limits (expressed in terms of % m/m – by weight) for areas within the zones must be less than 0.10% m/m (on/after 1 January 2015). This applies to the transit segment from Rotterdam to a point at longitude 5 degree west at the west end of the English Channel. Table 7.8 shows Route 3.2 below.

Table 7.8: Route 3.2: Rotterdam – Istanbul (road/sss/road)

Case Study 3		Route 2	Rotterdam to Istanbul	
Leg	Origin	Destination	Distance km	Mode
A	Origin	Rotterdam port	5	EURO V
B	Rotterdam port	SECA 5 W	1043	SSS LoLo
C	SECA 5 W	Istanbul port	5962	SSS LoLo
D	Istanbul Port	Destination	5	EURO V

On arrival at Istanbul the container was discharged and loaded onto road transport for the final post haul to the destination.

7.5.3 Route 3.3: Rotterdam/Istanbul (Road)

The ITCM evaluated the third case study with the whole transit by road transport. The transit is shown in Figure 6-4. The pre-haul, from the origin to the road terminal was carried out by a local truck unit. At the road terminal, the container was transhipped onto main haul EURO V technology road transport. This transport delivered the container directly to the destination at Istanbul. Table 7.9 shows the case study details and distances.

Table 7.9 Route 3.3: Rotterdam/Istanbul (road)

Case Study 3		Route 3	Rotterdam to Istanbul	
Leg	Origin	Destination	Distance km	Mode
A	Origin	Terminal	5	EURO V
B	Rotterdam Terminal	Budapest	1400	EURO V
C	Budapest	Istanbul	1360	EURO V

7.6 Results

The ITCM evaluated the total costs (internal, external and time) for the nine case studies. As pointed out previously, here, internal costs are the 'out of pocket' operational costs paid by the shippers; the external costs include the costs of the impacts on the environment and society due to local and global air pollution, congestion and noise pollution and traffic accidents.

The factors of the freight transport costs were collated and extrapolated from two European Commission researches: RECORDIT and MEET, respectively (EC, 2000, EC, 1999). Although there are many factors affecting CO_2 emissions, the most crucial one in the long-distance trips in this case study is the average cruising speed rather than the acceleration rate, cold start emissions, ambient temperature and so on. For the model, the CO_2 emissions are collated (over a period on short sea vessels over several voyages with its berthed, manoeuvring and sea cruising speed and distance travelled with the average values for other factors such as cold start emissions and ambient temperature).

The factors include the modes of choice, freight system (unimodal or intermodal), available scheduling and the complexity to generalize the freight costs for each freight system. In other words, one mode dominates one route (region), while it is not even comparative in another route (region). In addition, one mode is economically superior to the others in one route, while it can be significantly worse in another route.

The ITCM is based on the evaluation that the average cruising speeds of trucks, railway, and shipping (ferry and short sea) to be 66.67 km/h, 64.07km/h, and 25.93km/h respectively. These values were crucial to the performance values for external (environmental emissions and socio-economic issues) used in the model's linear programming and were interpolated by the recorded distances based on different modal networks (i.e. road, rail, and short sea waterway) as stated in ETIS.

Table 7.10: Summary of total transport costs on the three case studies

Route Case studies		Origin	Destination	Mode	Hours	Kms	COSTS			
							Int	Ext	Time	Total
1	**1**	Rotterdam	Felixstowe	Ferry	28.42	1088	2286.60	385.61	3.84	2676.05
		Felixstowe	Holyhead	Road						
		Holyhead	Dublin	Ferry						
		Dublin	Ballina	Road						
	2	Rotterdam	Hull	Ferry	30.54	1079	1986.07	320.69	4.12	2310.88
		Hull	Holyhead	Road						
		Holyhead	Dublin	Ferry						
		Dublin	Ballina	Road						
	3	Rotterdam	Dublin	SSS	55.24	1539	326.28	124.32	7.46	458.05
		Dublin	Ballina	Rail(D)						
2	**1**	Rotterdam	Duisburg	Road	24.77	1740	956.52	640.97	3.34	1600.83
		Duisburg	Stockholm	Rail(E)						
	2	Rotterdam	Goteborg	SSS	46.08	1402	374.80	186.19	6.22	567.21
		Goteborg	Stockholm	Rail(E)						
	3	Rotterdam	Travemunde	Road	29.03	1397	3176.50	547.83	3.92	3728.25
		Travemunde	Trelleborg	Ferry						
		Trelleborg	Stockholm	Road						
3	**1**	Rotterdam	Duisburg	Rail (D)	41.33	2530	478.70	275.39	5.58	759.67
		Duisburg	Wels	Rail (D)						
		Wels	Istanbul	Rail (D)						
	2	Rotterdam	Istanbul	SSS	270.76	6979	1279.52	123.79	36.55	1439.86
	3	Rotterdam	Budapest	Road	41.87	2765	6941.26	1227.66	5.65	8174.57
		Budapest	Istanbul	Road						

Rail (E): Rail powered by electric locomotive Rail (D): Rail powered by diesel locomotive
SSS: Short Sea Shipping Load on-Load Off container vessel
Ferry: Ro-Pax ferry

The summary of the three routes with its case studies are shown in Table 7.10.

The ‘time costs per hour’ are the sum of the value per tonne, the interest rate per hour and the deterioration costs per hour. Value, interest rate and deterioration rate were all positively related to time costs per hour.

The ITCM evaluated the road haul transit time assuming the vehicle had two drivers. This allowed for a ‘simpler’ computation by removing the issues of ‘resting’ times regulation. This was in line with other calculations, where the model evaluated the total transit time as the sum of each transit distance only. There was no scheduling or other delays assumed along the transhipments.

In general, ‘time costs per hour’ depended on the given type of goods and was independent of transport mode and distance. However, the choice of mode was influenced by goods which demand special/specific transport modes (refrigerated containers for frozen food/goods; specialised gas containers for gases liquefied under pressure, etc.).

7.6.1 Results: Route 1: Rotterdam to Ballina

Table 7.11 shows the ITCM results for Route 1 and the three case studies, with different alternatives between the Europe main-land to western hinterlands of Ireland. The freight unit, RoRo Trailer was parked at areas marked by the port, depending on its status (Revenue/customs inspection, hazardous/non-hazardous/security codes, etc.) awaiting loading on the LoLo berths or the RoRo berths. The actual cargo operations were based on the turnaround of the container vessel for LoLo operations (container terminal) and the RoRo operations at the ferry terminals.

The outbound marine links from port Rotterdam starts from the ferry terminal at Hook of Holland on the northern bank. The terminals on the south bank along the New Waterway and eastwards along New Maas canal leads to the other terminals in the Maasvlakte, eastwards to Europort to containership terminals and the intermodal rail links. The choice of terminal depended on the specific freight service and the size of the ship (the length and the draught) offered by a shipping agent/shipper.

Case study 1.1 evaluated the transit between Rotterdam to Ballina, of a RoRo trailer, across the UK land bridge from Felixstowe/Holyhead. The trailer unit was collected with a short pre-haul distance from the origin to the port area. The Ro-Ro trailer was transhipped in Rotterdam onto a RoPax ferry bound for Felixstowe, England. On loading, the vessel sailed for Felixstowe, Harwich, UK port of discharge. For the UK port operations, the terminals were dependent on the types of vessels; conventionally the LoLo vessels berth at Felixstowe and the ferries at Harwich. From Harwich the unit was transported to Holyhead, Wales for transhipment on a ferry for Dublin, Ireland. At Dublin port the trailer unit was discharged and resumed on its transportation to its destination directly to Ballina.

In this case study there was no post haul section. The total transit time calculated was at 28.42 hours and the total costs were Euro 2676.05.

Case study 1.2 evaluated the transit between Rotterdam to Ballina, of a RoRo trailer, transiting between Rotterdam, via Kingston upon Hull onto the ferry link at Holyhead. The Ro-Ro unit was delivered to Rotterdam terminal for loading onto a RoRo ferry service to Kingston upon Hull. On loading the vessel departed for Kingston upon Hull, in East Yorkshire. From Hull, it was transported to Holyhead, Wales by road. At Holyhead the unit was loaded onto a RoPax ferry for Dublin, Ireland. On discharge at Dublin port, the trailer unit was discharged and resumed its final transit to Ballina by road. On this case study there was no post haul section. The total transit time calculated was at 30.54 hours and the total costs were Euro 2310.88.

*Table **7.11** Route 1 Case Studies from Rotterdam to Ballina, Ireland.*

Route	Case Study	Origin	Destination	Mode	Distances	TIME	DISTANCE	COSTS			
						Hours	Kms	Internal	External	Time	Total
1	1	Rotterdam	Felixstowe	Ferry	(5+) 185	28.42	1088	2286.60	385.61	3.84	2676.05
		Felixstowe	Holyhead	Road	547						
		Holyhead	Dublin	Ferry	111						
		Dublin	Ballina	Road	241						
	2	Rotterdam	Hull	Ferry	(5+) 370	30.54	1079	1986.07	320.69	4.12	2310.88
		Hull	Holyhead	Road	353						
		Holyhead	Dublin	Ferry	111						
		Dublin	Ballina	Road	241						
	3	Rotterdam	Dublin	SSS	(10+) 1243	55.24	1539	326.28	124.32	7.46	458.05
		Dublin	Ballina	Rail(D)	276 (+ 10)						

Note: Road drayage figures within brackets

Case study 1.3 evaluated the transit between Rotterdam to Ballina, of a 6.06m (20 foot) container unit, from Rotterdam to Ballina, with a combination of short sea sailing connecting to a rail link from Dublin to Ballina. This case study incorporated both the alternate two main hauls of short sea shipping and rail connection.

The container was delivered by road over a short pre-haul distance from the origin to the port area. In the port the container was shifted to the preload area prior to the arrival of the container ship at the container terminal. On completion of the loading operation, the ship sailed from Rotterdam directly to the port of Dublin. On discharge at the port of Dublin container terminal, the unit was transhipped to the Irish Rail intermodal terminal for loading onto a rail flatcar. The freight train with 20 containers, powered by a diesel locomotive, left Dublin for the rail freight terminal at Ballina, Co Mayo, in the west of Ireland. On discharge at Ballina, the final post haul was by road to its destination. The total transit time was 55.24 hrs at a cost of Euro 458.05.

7.6.2 Results: Route 2: Rotterdam to Stockholm, Sweden.

This ITCM route 2 was with the origin from the port of Rotterdam to the destination in Stockholm, Sweden. The summary of Route 2 is shown in Table 7.12.

Case study 2.1: The trailer unit was delivered with a short pre-haul distance from the origin and to the main haul road terminal depot at Rotterdam. The freight unit was transported from Rotterdam to the inland intermodal terminal at Duisburg, Germany by road. At Duisburg the unit was delivered at the intermodal rail terminal and transhipped onto a connecting rail freight service from Duisburg to the intermodal rail terminal at Stockholm. The final post-haul transport was by road to its destination. The total transit time calculated was 24.77 hrs and the total costs were Euro 1600.83.

Table 7.12 *Route 2 Case Studies from Rotterdam to Stockholm, Sweden.*

Route	Case Study	Origin	Destination	Mode	Distances	TOTAL		COSTS			
						Hours	Kms	Internal	External	Time	Total
2	1	Rotterdam	Duisburg	Road	(10+) 250	24.77	1740	956.52	640.97	3.34	1600.83
		Duisburg	Stockholm	Rail (E)	1470(+10)						
	2	Rotterdam	Goteborg	SSS	(5+) 937	46.08	1402	374.80	186.19	6.22	567.21
		Goteborg	Stockholm	Rail (E)	445(+15)						
	3	Rotterdam	Travemunde	Road	(5+) 570 (+1)	29.03	1397	3176.50	547.83	3.92	3728.25
		Travemunde	Trelleborg	Ferry	220 (+1)						
		Trelleborg	Stockholm	Road	240 (+5)						

Note: Road drayage figures within brackets

Case study 2.2 evaluated the transport of a freight container, from Rotterdam to Stockholm with a combination of short sea shipping road and rail as the main haul.The trailer unit was delivered with a short pre-haul distance from the origin to the deep sea container terminal at Rotterdam. On loading, the vessel sailed for the port of Gothenburg. At the port of Gothenburg the container was transhipped by road to the intermodal rail terminal. The container unit was transferred onto a connecting rail unit bound for Stockholm. There was post haul transport, by road, to the destination. The total transit time calculated was 46.08 hrs at a cost of Euro 567.21.

Case study 2.3 evaluated the transport of a freight container, from Rotterdam to Stockholm, primarily by road with a short RoPax ferry transit between Travemunde (Germany) and Trelleborg (Sweden) and the final transit by road to Stockholm.

The trailer unit was delivered with a short pre-haul distance from the origin and to the road terminal at Rotterdam. The first main haul was by road from Rotterdam to the ferry port of Travemunde, Germany. The freight unit was discharged and transhipped on to a RoPax ferry bound for the port of Trelleborg in Sweden. The freight unit was discharged at Trelleborg and was transported to Stockholm by road. The total transit time was 29.03 hours and the total cost was evaluated at Euro 3728.25.

7.6.3 Results: Route 3: Rotterdam to Istanbul

This route evaluated three unimodal transits with the main transport modes, namely short sea transit, road and electric powered locomotives, in the transport of a freight container from Rotterdam to Stockholm, Sweden. The summary of Route 3 is shown in Table 7.13.

Route 3.1 evaluated the transport of a freight container, from Rotterdam to Istanbul, Turkey. This transport was wholly completed by the single main haul mode. The container unit was delivered, with a short pre-haul distance from the origin and to the main haul intermodal rail terminal at Rotterdam. The freight unit was transferred on to a road-rail Combined Transport (CT) unit.

The ITCM evaluated the rail services offered by the RNE combination. The first transit was assumed to be along the RNE corridor 03 to Hannover. At Hannover the CT unit was disconnected and reconnected to a rail train on the RNE 04 corridor to the rail terminal at Munich, via Wurzburg. At Munich, the CT unit was disconnected and attached to the RNE rail unit on corridor 11.

This rail service was a part of the original collected rail services passing through Central and Eastern European countries. The freight train terminated at Svilengrad, Bulgaria, passing through Salzburg, Ljubiana, Zagreb, Belgrade and Sofia. At Svilengrad the CT was disconnected and reconnected to Turkish and Bulgarian operated service to Istanbul. This route is being upgraded to an electrified, in sections, ending at Istanbul. At Istanbul, the freight unit was transferred on to road trailer for the final post haul with delivery to the destination. The total transit time calculated was 41.33 hrs and the total costs were Euros 759.67.

Route 3.2: evaluated the transport of a freight container, from Rotterdam to Istanbul by short sea shipping. The trailer unit was delivered with a short pre-haul distance from the origin to the Port of Rotterdam awaiting the preloading procedures at the container terminal Rotterdam. On completion of loading the container vessel commenced its sea transit from Rotterdam to the port of Istanbul. This route had the added rigour of complying with the new ECA regulations; the mandatory use of low sulphur fuel, from the port of Rotterdam up to 5˚ West longitude. On passing this longitude, marine fuel oil with higher sulphur content could be used for main and auxiliary engines, until change over for operational purposes. The container was discharged at the port of Istanbul.

Table 7.13: Route 3 Case Studies from Rotterdam to Istanbul

Route	Case Study	Origin	Destination	Modes	Distances	TOTAL		COSTS			
						Hours	Kms	Internal	External	Time	TOTAL
3	1	Rotterdam	Duisburg	Rail (D)	(5+) 240	41.33	2530	478.70	275.39	5.58	759.67
		Duisburg	Wels	Rail (D)	700						
		Wels	Istanbul	Rail (D)	1580 (+5)						
	2	Rotterdam	Istanbul	SSS	(5+) 6969 (+5)	270.76	6979	1279.52	123.79	36.55	1439.86
	3	Rotterdam	Budapest	Road	(5+) 1400	41.87	2765	6941.26	1227.66	5.65	8174.57
		Budapest	Istanbul	Road	1360						

Note: Road drayage figures within brackets

After routine administration by the local Customs and Revenue the container unit post haul, was by road, to its destination. The total transit time calculated was 270.76 hrs and the total costs were Euros 2260.69.

Route 3.3 evaluated the transport of a freight container, from Rotterdam to Istanbul where the full transit was done using a unimodal approach, by road. In this case study there was no pre or post haul stage, as the road unit collected the container from the origin and transported directly to the destination. This ITCM case study does include the issues under the EU regulations on 'rest periods'. This case study model included two drivers for the transit. This was to ensure a continuous passage and to avoid the added computation for the rest periods, etc. as per the legislation requirements. There would an added labour costs arising from the second driver, to ensure no 'rest stoppages' during the transit. The total transit time calculated was 41.87 hrs and the total costs were Euros 8174.57.

7.7 Summary

This chapter summarises the nine case studies within three transport corridors. The nine case studies showed clear trends on all the three transport corridors where in all three corridors in Europe, the general total costs for the intermodal system offered the most competitive commercial advantage. There was a consistency on all the three corridors with road transport showing the highest total costs. However, an additional negative consideration will be raised by the introduction of toll tax for road transport reflecting a combination of distance, tonnage and engine size. This changed situation will be applicable to the entire sample of corridors considered.

For all the evaluated figures, there is a need to clarify some of the numbers. The load factor on trucks and ships were averaged in the ETIS results and probably reflects the general situation both in road and SSS transport. The road vehicles in the ITCM were all assumed to be performed by Euro V technology trucks. This is currently not mandatory and the Euro V truck is not representative of the current truck fleet, which also consists of older types, complying with less stringent EURO standards particularly relevant for PM and NOx for road traffic. For the SSS/Ferry sector, the recent efforts toward introducing lower sulphur content fuel does reduce the marine related climate change pollutants but does not reflect the improvements road engine technologies, over the past decade. The SSS sector does have lower CO_2 emissions and may achieve the European CO_2 emission reduction objectives. In the overall analysis, when other external costs are taken into account, SSS performs better than road for 2 out of 3 routes. This is mainly due to high external congestion costs in the road routes.

In practise, each transport solution was a result of combination of operational and commercial trade-off curves; each was relevant to the unique network assignment, modal share rate, the point (or range) could be found which was offered by the shipper and accepted by the freight owner. Furthermore, the three ITCM scenarios with three same O-D sets reflected trade-offs resulting from restraints (capacity, infrastructure, etc) showed that the trade-off curves had almost a linear relationship. The external costs (low environmental emissions, noise, congestion, etc.) were lower on routes where road alternatives formed a major part or fully implemented. For a fuller evaluation of the factors, both external and internal, a detailed and a comprehensive evaluation of the factors and their attributes need to be fully considered (i.e. O-D sets, capacity and availability of freight systems, cost structure, CO_2 estimation and so on).

The next chapter reviews the case studies with reference to the literature on transport studies. The chapter discusses the similarities and the dissimilarities between the available literature and the actual model outcomes.

Chapter 8

Relating case study outcomes to findings from the literature review

8.1. Introduction

This chapter analyses the results from the literature review and compares them with the results of the case studies. The review of freight transport literature, a multi-disciplinary environment, reveals a very diverse range of findings arising from the different methodologies, different transport markets that consequently influenced the estimates and possibly the results. The tabulated results of the case studies show different factors considered, within parameters, their appropriate use in modelling and as benchmark references in earlier studies. The new research design was tested and employed to evaluate the total transport costs across three TEN-T corridors.

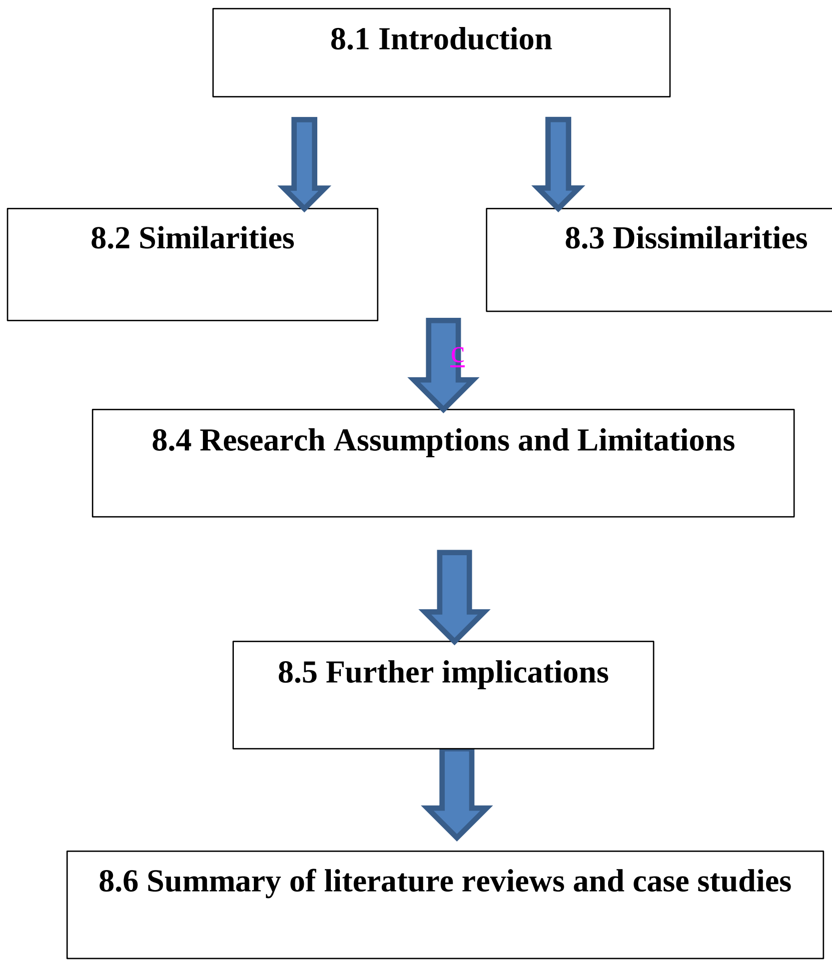

Figure 8.1 Lay out of Chapter 8

8.1.1. Chapter layout

This chapter analyses the results of the case studies and compares them to the literature reviews to determine the similarities and the dissimilarities.

The following sections review the findings relating to case studies compared to the literature review. Following from the introduction, the second section outlines the similarities found in the literature regarding the status of the issues in freight transport research, especially in respect to transport models, generalised transport costs and the acknowledgement of 'polluter pays' with regards to transport generated negativities. The third section outlines the dissimilarities based on the same three issues considered in the earlier section. The fourth section reviews further implications arising how how results of the study may affect scholarly research, within the transport industry theory and practises. Further effects and the trends influencing the academia will be mentioned in the passing. The final section summarises the chapter.

The following subsections present the items of similarities found between the case study results and the literature reviews. This research is a contribution to an established line of theory and empirical research and attempts to set out to compare the similarities with the existing knowledge and the new contributions enriching the theoretical and the empirical perspectives.

8.2. Similarities

This section analyses the findings from the literature and the research and collates the similarities between them.

8.2.1. Transport model concepts and their combinations

Modelling in transport research had been primarily based on the passenger sector. The history of demand modelling in the passenger sector was primarily based on the four step model (FSM) (McNally 2007). In transport theory, travel was considered as a 'demand derived' activity participation, however in practice has been modelled with trip-based rather than activity-based methods. The main data records are mainly 'trip origin-destination (O-D)' based rather than activity surveys (McNally 2007). With the increase in transport issues and variables different research and investigations have been evolving based on O/D trip tables. The FSM evolved to deal with this complexity by formulating the process as a sequential four step model (**Figure 8.2**). In *trip generation*, the measures of trip frequencies and scheduling are designed to accommodate the travel volume. Trips are recorded as trip ends, productions and attractions, which are estimated separately.

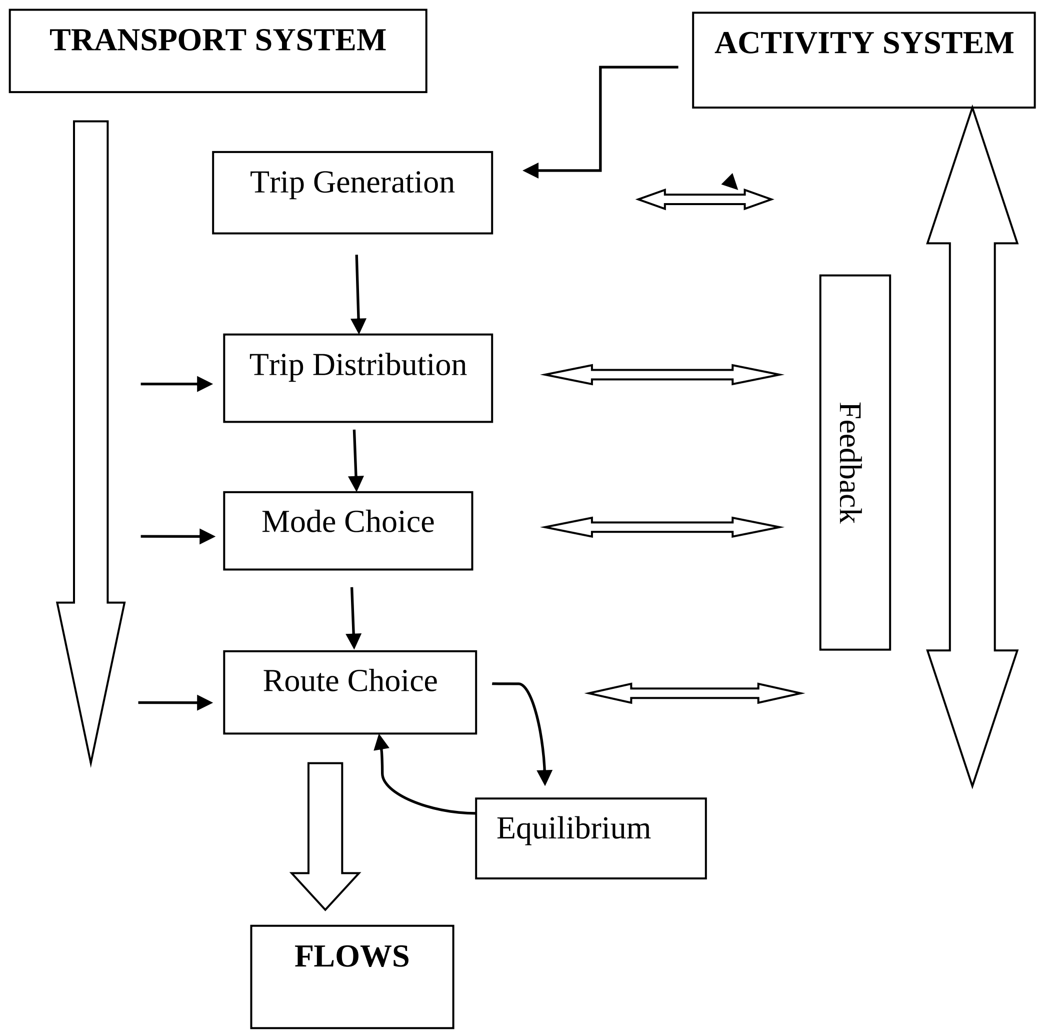

Figure 8.2 Four Step Model
Source: McNally 2007

In *trip distribution*, trip productions are distributed to match the trip demands distribution reflecting the underlying travel hurdles and restrictions (time and/or cost), giving tables of passenger trip need data.

In *mode choice,* trip tables are essentially factored to reflect relative proportions of trips by alternative modes.

Finally, in *route choice*, modal trip tables are assigned to mode-specific networks. The time dimension (time of day) is typically introduced after trip distribution or mode choice where the production-attraction tables are factored to reflect observed distributions of trips in defined periods (such as the morning or evening peaks).

Here performance characteristics were first introduced, thus, the FSM in its basic form only equilibrates route choices.

There have been several approaches in measuring effectiveness. This research model evaluates on basis of total transport costs. This could be influenced through generation, distribution, mode choice, and time-of-day models route. The FSM feedback balanced travel times to the mode choice and/or trip distribution models for a second pass (and occasionally more) through the last three steps, but no formal convergence is guaranteed in most applications.

Conventional transport modelling frameworks included four steps: trip production, trip distribution, mode choice and route choice. Tavasszy (2006) traced the evolution of transport models connecting three different layers of industry framework offering enhanced efficient services with these alternatives:

1) A consistent description of trade-economy linkages,
2) The introduction of inventories as determinants of geographical demand patterns,
3) Consistent treatment of transport mode and route choices.

In the early studies most of the cost based freight transport studies were based on road transport; due to its volume and popularity; studies showed that operating costs were one of the main considerations in the choice of route, etc. Improved economic conditions offered new opportunities to widen the extent of transport applications and opened up research exploiting new forms of transport (Morlok and Spasovic, 1994; Feo and Gonzalez-Velarde, 1995; Nozick et al 1997; Powell and Carvalho, 1998; Newman and Yano, 2000); concerns from transport related social and environmental pollution raised issues towards paying in the clean-up of the polluting effects and finally seeking alternatives to unimodal road concepts, as in intermodal transport systems. The selection of an intermodal system over the available unimodal system (mainly road) has been a contentious topic (McKinnon 1989). Hayuth (1992) linked increased freight volumes to the negativities from increased congestion on the roads adding pressure to the logistic issues of modal transport. There were similar transport models proposed by Beresford (1999) which opened up new options (see Sections 4.3.1 and 5.2) and reviewed by Komini (2015).

Increasing freight transport studies expanded on the transport models, addressing new issues. Janic (2007) developed a model for calculating the full costs of a given intermodal and road transport networks. The model showed that on intermodal transport networks the full and internal costs decreased more rapidly with increasing distance when compared to road haulage. A later model, an analytical concept for evaluating performance of long intermodal freight trains, was based on the operational, economical, and environmental characteristics of long and conventional intermodal freight trains operating in railway-road intermodal modes of freight transportation system (Janic 2008). The model's internal costs included freight collections, transhipment, handling of goods moved within a transport network. This allowed the comparing and investigating the influences of the European

Union (EU) policies. Additionally, the model applied transit solutions to ‘break-even distances’ concepts and was applied to evaluate intermodal alternatives.

Brooks et al (2012) introduced new applications examining the Australian domestic freight transport market focussed on the decision-making process by which cargo interests and their agents make mode choice allocation decisions between land-based transport and coastal shipping. Their study introduced the concept of ‘willingness to pay (WTP) for the various scopes of modal options on specific transport corridors. It was the authors’ understanding that these would be a precursor to assess the likely impact of changes to transport prices arising from the introduction of carbon pricing or other regulatory factors. Brooks’ model prioritised freight shippers’ preferences for components of services offered by freight transport providers across modes with distinct characteristics (that is, mixes of speed (transit time), frequency of departure, reliability (two measures) and cost) in three corridors. The study narrowed down the options to seven preferred choices: frequency, transit time, freight distance, direction (head haul/backhaul), reliability as measured by delivery window, reliability as measured by delay and price offered by the operator. The study analysed the trade-offs relevant in shippers’ choice of mode on the specific corridors under investigation in a more complex mode choice model than explored in previous research. It also examined what will likely happen if there are price rises as a result of carbon pricing regulation.

The research ITCM extends the conventions based on the existing transport total costs (internal, external and time) based on the new realities. The main concept of the ITCM evolved from the earlier models proposed by Beresford, de Jong, Tavazssy, etc. The transport model evolved from the FSM concept, altered by the radical suggestions proposed by Beresford and Dubey (1990) and the subsequent improvments Beresford (1999). Earlier national transport model studies (Belgium, the Netherlands, United Kingdom, Finland and Sweden) considered vehicle trips for transport network using route choice models (Beuthe et al 2001; Swahn 2001). Later transport models have introduced multi-modal transport chains (see Pattanamekar et al, 2009 and Tavasszy et al, 2007). New demands adapted the model with additions suggested by de Jong, Tavasszy and Komini.

Analyses of realier transport model studies have stressed the relevance and importance of having a clear and thorough understanding of influences of all the factors in transport costs. The ITCM main research is based on transport costs, which is one of the top priorities of the transport users (Matear and Gray 1993; Brooks et al 2012; etc.). Eqn 5.5 (page 123) represents the basic relationship between the ITCM and the three main factors making up the total transport prices, namely internal, external and time costs. These factors in the transport model have direct influences on: modal choice; mode shift; improving operations (loading/unloading) efficiency; improving logistical infrastructure, etc. The ITCM design incorporated the three factors in transport costs based on mode speeds, freight tonnages and operating costs (transport costs in tonne-kilometres, vehicle kilometres), coefficients of external costs (transport and related emissions) and finally the transit time per commodity. The new demands from the environmental lobby introduced new 'polluter pays' incorporated into the traditional model. The ITCM incorporates all costs of transport related costs including the negativities. Combining the attributes provides new realities to the traditional transport models.

8.3. Dissimilarities

This section analyses the findings from industry practises and the research data, which are dissimilarities to the previous section.

The sub-section will analyse the same topics as in the previous section, namely, transport models, generalised transport costs and transport efficiency.

8.3.1. Dissimilarities arising in the evolutionary process on model concepts

The concepts of the freight transportation market have evolved through several trends. Post the economic crisis of 2008 demanded a rethink of the solutions to the growing markets and the widening customer base. Market conditions urged industries to reduce the total costs and improve overall performance. Research and studies showed the need for efficient and effective transportation, as the transportation cost share in the supply chain is significant (Ghiani *et al* 2013). Consequently the shippers, carriers, and Logistics Service Providers (LSPs) were urged offer competitive services at lower costs while still maintaining high quality (*SteadieSeifi et al 2014*).

Chapter 5.2 traced the evolutionary changes to the transport models brought about by legislations, regulations, consolidations, etc., new market demands (taxes, tolls, technologies, etc). The model evolved with introducing the multimodal door-to-door freight transport delivery concept, with lower costs and strict scheduling (Beresford et al. 2007). The novelty of Beresford's cost model was that it factored in operating costs, time, distance, transport mode and intermodal transfer for each mode and as a whole in the transport process. However, it did not consider the added impact of the mitigating costs of the externalities on the total costs of the transport transit.

Evolving from early transport models, which were primarily based on road transport and its operations, new transport models reflected new the new realities of transport issues within the total supply chain network. Improved delivery times and costs opened up the more studies on intermodal and other freight transport networks. Initial studies were based on the comparison of 'break even' distances between road and intermodal systems. The model by Janic (2007) considered a simplified configuration of costs of the impacts on both, society and the environment (local and global air pollution, congestion, noise pollution and traffic accidents) with simplified inputs from the European freight transport system. This model introduced new ideas showing that the total costs in both decreased more than proportionally as the transit distance increased suggesting economies of scale. Further it found that the full costs of intermodal transport decrease and those of road transport remain constant as the volume of loads increases; the breakeven distance shortens at a decreasing rate.

8.3.2. Opposition to accepting the concept of 'total costs'

Earlier transport studies covered the issues arising from transport, namely generated pollution, types of and amounts of pollutants. Subsequent studies compared the advantages arising from cleaner transport systems and with lower costs (Hart, 1995). Even with the proactive promotion of sustainable transport systems, recent literature records a poor implementation level of environmental practices (Léonardi and Baumgartner, 2004; Perotti et al., 2012). Reviews freight transport studies, with a focus the environment notes that ... "*business needs to take a much more fundamental perspective on the challenge of climate change than could be observed"* (Wolf and Seuring, 2010, p. 99). — "*Only 22 Fortune 500 companies have begun blunting their supply chains impact on the environment* "(Golicic et al., 2010, p. 47), and — "*operationalization of environmental areas are often met with reluctance"* (Abbasi, 2012, p. 55).

Analysing the reluctance to adopt intermodal systems shows <u>three</u> broad arguments:

Firstly, Woxenius (1998) maintained that the managing of five different flows between multiple transport agents made intermodal transport services inherently complex: physical, logical, contractual, financial and relational considerations were hindered because of perceptions that restricted efficient 'flow through' (Reis, 2010).

Secondly, there were incompatible infrastructures with inadequate regulatory frameworks (Slack, 2001); lack of transparent intermodal liability regimes (Asariotis, 1999) and failure to standardise a common system between the various national transport networks (Leinbach and Capineri, 2006). Lack of common procedures reduced efficiency measures, increased production costs and thereby failed to create market opportunities for intermodal transport systems to create market opportunities (Rich et al., 2011).

Thirdly, governmental and intergovernmental policy focused narrowly on the promotion of medium to long-distance intermodal transport. The EU 2011 White Paper on Transport proposed a 30% modal shift from road freight to other modes (rail or waterborne transport) for distances above 300 km by 2030. Below 300 km, the predominance of road transport was implicitly assumed and accepted (European Commission, 2011).

Recent study in New Zealand, found that the transport users were unlikely to consider environmental factors when choosing a freight transport mode as they voiced their uncertainty about the effect of each transport mode on climate change (Kim, H.C. 2014 pp. 200). However, a small proportion did agree to consider a change to sustainable alternatives, if the same quality of service, at no greater costs and with matching eases of management. This is viable *only if and when the infrastructure is available!*

8. 3.2.1. **Paucity of models including environmental issues relating to total costs**

There have been several studies that have acknowledged a reluctance to shift towards cleaner and sustainable transport systems and so have not considered the consequences of the users paying more.

Recent academic studies reflect the increased emphasis on environmental issues in the transport area; however, some studies have not included environmental factors as a part of their main mode choice factors. There has always been a difficult in understanding each of the actor's role and impact on the system and the reason in selecting a 'transport bundle' is very complex.

Becker et al (2012) referred to an earlier report (Baum, et al., 2008), which stated that traffic costs within the EU 27 clearly refuted the frequent claim "that cars cover all their internal and external costs". The TUD report referred to the abundance of printed literature on "external effects". However, the study concluded that it was:

> '*.... made clear that the question of internalizing external costs into user prices is a key element of all approaches to make the European Union less unsustainable in social, environmental and economic respect. From an economic perspective, it is not "a key element"; it is "the key element" of efficiency and fairness'*.

The few studies offering improved cost and transit time factors, incorporating improved transhipment with lower terminal costs would advance the case for intermodal systems over unimodal road services (Behrends & Flodén 2012). Further changes could be promoted in mode choice (from road mode to other preferred alternatives) by altering economic price settings and regulatory measures, framework settings and (land use) planning measures Becker et al (2012). The results from the research model provide the tool in selection of a sustainable mode choice based on total transport costs. It would require investments on improved transport infrastructure, a lowering 'user consumer prices' and incentivising greater usage of the road alternatives could possibly change the behaviour substantially. This might be the cheapest option, but it would need political intervention.

8.4. Research Assumptions and Limitations

This research offered new knowledge and added to the present transport knowledge base. In the research design of the model, the assumptions and limitations are stated in Chapter 5 section 6 and mention the two main areas of study and their possible impacts on the results and future research directions to be taken.

The ITCM evaluated the total costs on three transport corridors with a total of nine case studies analysed, which to an extent makes results dependent on the data used for evaluating CO_2 emissions. This does limit the extent of internal extrapolation of the results; since the results obtained can be related to these specific case studies. It is nonetheless valid that the tools are flexible ones and suitable for every application. Moreover, it is possible to generalize the finding of the study, at least for the Irish corridors, where similar situations on the scarce role of intermodal transport are witnessed. It is worth remembering that some general considerations on the limited development and competitiveness of intermodal transport can also be extended to the Irish side of some important European TEN-T corridors connecting to European infrastructure.

8.4.1. Research assumptions

The research focuses on the prevailing situation in North Europe, with special regards to Ireland. The research findings indicate that they may apply elsewhere, that is to say that they have relevance to the situation in other countries. The results of the ITCM, within its limitations, are clear. However, the results deal with complex logistical options combined with the vagaries of the Irish freight industry and the shippers' behaviour in choosing between the alternative mode options.

The main assumptions of the issues influencing mode choice, with particular reference to intermodal transport concepts are:

- The elasticities affecting the supply/demand are equal
- The schedules are not affected by weather and labour issues
- There is no delay in the cargo transfer at the intermediate terminals
- The truck mode has two drivers and there are no 'rest delays'
- The influence of time is primarily commodity dependent and not mode dependent.

- The unit costs (€/tonnekm) are assumed to be the same across NW Europe (EU15)
- Improved technical installations: salt water scrubbers on SSS vessels in line with the environmental emissions requirement
- Rail in Ireland is a diesel powered locomotive and there is a greater usage of electric powered locomotives in Europe.
- Tonne-kms as the output measure used for freight transport: Most of the data sources for freight transport invariably express environmental emissions for CO_2 as a ratio of tonne-kms, i.e. weight transported multiplied by the distance travelled. However, for some modes and commodities the industry practises are based on volume rather than weight, so a volume basis would be more appropriate. Insufficient data on volume based records make this difficult (McKinnon 2007).

The transport solutions adopted in North West European countries are a reflection of their different unique circumstances. Ireland's unique characteristics include:

- Geographical, economic and social conditions (Ireland, being an island on the periphery of Europe, requires the short sea connecting corridor to European markets);
- Ireland's regulatory environment for transport operations;[92]
- Ireland's capital investment priorities in transport infrastructure and services;
- Ireland's social and political priorities regarding other aspects of transport policy.

Modelling the full costs of an intermodal and equivalent road transport network involves developing the model, collection of data, and the model application. Developing the model includes identification of the relevant variables and their relationships. The variables reflect the type and format of data needed for the model application. Data collection is particularly challenging.

[92] Inland waterways are not included as there is not enough tonnage transported in Ireland

Estimations of external costs involve the four-stage process: quantification of emissions/burdens and estimation of their spatial concentration; proceeding with an estimation of the prospective damages; finally ending with putting monetary values on short and long-term damage. In both networks, data on the internal and external costs refer to particular parts (segments, actors) operating under different technical/technological, market and environmental-spatial conditions. The results are then aggregated.

The model is based on a set of assumptions:

- Main haul between two terminals
    - Headways between successive departures of the main mode's vehicles between two intermodal terminals are constant; this reflects the standard schedule, regular weekday services of non-road transport operators in Europe.
    - The inter-terminal vehicles are of identical capacity, whether rail or road.
    - The average speed and the anticipated delays of the main mode are constant and approximately equal.
- Transhipment, collection and distribution
    - Similar vehicle capacity and load factors in a given zone.
    - Operations of each vehicle as denoted by types (Chapter 5) at performances as per speeds (as Chapter 5: Table 5.7).
    - The collection step, with the initial drayage commences at the Origin, which can be anywhere within the 'shipper' area and ends at the origin's intermodal terminal. The distribution step starts from the destination intermodal terminal to the Destination, at the reception area at the last receiver.

- Scheduling between the arrival(s) unit and the departure(s) of the successive vehicles (thus the freight load) at the origin and from the destination intermodal terminal, respectively, are approximately constant and independent of each other.

This research is one of very few to evaluate mode choice models, based on total costs for the industry. There were no similar studies or data for the evaluations and consequently results cannot be compared. The model could be transposed for similar transport research, thus widening the understanding of factors which affect the total costs of the freight mode choice and how they affect that choice. This would provide a wider platform for freight transport policy decisions. These results could be extended to include a move to a ‘willingness to pay’ for a sustainable transport solution.

The model has been calibrated for a case study of container transport between the Netherlands and Ireland using real-life supply and demand data. The results provide new insights into the interrelationships of the infrastructure network, service network, and regulatory policies, as well as the interaction among the different actors.

The model was further validated and tested on two other corridors. The ITCM was seen to be generically be applicable to freight transport infrastructure network design in terms of architecture, methods, and algorithms. The research model’s inclusion of externalities acknowledges both the environmental (CO_2) and GHGs (SOx, NOx) and socio-economic components such as noise and traffic incidents/accidents. The model’s design objectives could easily be re-engineered in accordance with the model application. Evaluation of the network costs could be carried out at the link, terminal, regional and/or network level, per mode, per commodity type and/or a combination of the former.

8.4.2. Research Limitations

This research has a few inherent limitations. This section will be set out in three sections. The first section identifies the types of issue that were considered as limitations and their effect on the research, including possible impacts on the results, and future research directions are discussed. The second section examines the topics and expands the nature of these issues and justifies the choices made during the process. The third section 'looks forward' and allows suggestions to overcome these limitations in future research.

8. 4.2.1. Initial limitation issues

Analysis from the literature from the previous studies, this research, or the model design is more directly focused on the evaluation of the transport cost model rather than other transport issues.

There are primarily three types of limitations:

- Data source
- Data details
- Potential errors arising from incomplete data

8. 4.2.2. Detailed descriptions of initial issues

- Data source
  - Records: This research model evaluates the case studies based on the data collected from EU and ETIS sources. The limitations arise from the discernible lack of earlier total transport cost data for comparisons. This further highlights that the EU data inherently 'dilutes the data' (EU15/EU 27).
- Data details: In predicting trends and/or extrapolating from the ITCM findings there were the following types of research data issues:

- Costs: It is difficult to obtain financial data from both private and public transport operators. However, data was obtained from Irish Rail, Shipping Company (BG Freight) and Freight owners/operators (EUCON) and these were compared with EU15 and EU27 figures for compatibility
- Transit times: ETIS data was accepted; isolated time transits were included for comparison and verification.
- The transport infrastructure for the ITCM case studies, within each transport corridor, is similar;
    - The tonnages are collated from the ETIS research (See Ch. 2.6 and Chapter 4.4 section 4). The tonnage figures are collected and averaged over a very large number of trips between selected O/D. There was no way to ascertain numbers and tonnages of loaded (in tonnages or volume) and empty containers. The potential errors could lead to incorrect valuation of €/tonnekm.
    - Transhipment costs are included with each transport sector
    - Insufficient data on ‘time’: The major uncertainty arises from the lack of time-data at the intermodal terminals, arising from actual transhipments; scheduling incompatibilities; missing connections/connecting modes; labour issues; weather issues; etc.
    - The costs arising from the tolls, taxes and SECA influences are limited to the standard operations for all the modes

- Potential errors arising from incomplete data

The accumulated sum of the errors from the above two potential sources could possibly be either very high or possibly cancel each other out. The limitation is in the uncertainty.

8. 4.2.3. Considerations in the limitations

The issues suggested in Section 8.4.2.1 as the possible issues leading to the limitations in the collection and collation of data in this research. In sourcing of freight tonnages data, there are differences in the manner and type of data issued by the ports, transport service providers, State records (export/import/transhipment/etc). It is possible that with more research on total or generalised transport costs (with internal and external) would make available a wider range and more detailed layers of costs (operating and transhipment, weather, labour, cargo-related, etc) in freight transport.

Since this research is one of the early attempts in the evaluation of total transport costs on the three TEN-T corridors, there are understandably no similar/previous results to compare, as figures, for trends or tracing the policy simulation effects. However, further comparable research on transport costs would be refine the ITCM model and rationalise the understanding of relevant factors that affect, both directly and indirectly, freight mode choice; how they affect that choice and provide a sound basis for freight transport policy decisions.

8.5. Summary of literature reviews and case studies

Increasing economic activity and the corresponding increase transport activity is adding to the transport led negativities, as in traffic injuries and fatalities, congestion, air pollution and petroleum dependence (Kahn-Ribeiro et al 2007). The growth of transport volumes and its dependence on the burning of fossil fuel (95% of world transport energy is from petroleum) has been a growing concern (Van Essen 2008; OECD 2008).

The research model focussed primarily on the evaluation of transport costs as a tool for the transport users choosing an alternative mode choice system. The research evaluated the total transport costs as a tool in the selection of a sustainable and cheaper transit.

8.5.1. Summing up literature reviews

A review of the literature shows the extent of limitations and the assumptions made in a number of previous transport studies. Important conclusions are as follows:

- Following the economic crisis of 2008 the freight transport industry worldwide experienced a rationalisation of the main factors in transport research and publications. The fundamental factors relevant to this research are transport models, their concepts and constructs and transport costs.
- Transport hubs: Earlier models of transport development have adopted a unimodal approach in which road and rail projects were planned and constructed separately without much consideration for their possible future integration. Intermodal/multimodal transport uses more than one mode of transport and delivery of goods from origin to destination (Hanaoka et al 2011). Such transport has been studied in detail by policy makers and transport planners, who are undertaking various policy initiatives to promote the concept and implementation of intermodal/multimodal transport.

Improvement in transport volumes have followed with improved transport links such as highways, railway networks and inland waterways. Embedded along these transport highways are transport hubs such as airports, seaports, logistics intermodal terminals and dry ports, which have co-evolved in order to improve the new demands from intermodal links. These hubs, airports and sea ports, have hugely improved the logistic distribution of freight and passengers in Europe as well as being a huge asset to national economies. Inland dry ports have become important transport nodes, particularly for landlocked countries (Notteboom and Rodrigue 2009). The development of these dry ports in hinterland areas cannot only promote intermodal transport but also provide improved transhipment functions along with customs-clearance facilities. With the spread of the concept, several definitions have been established for inland transfer points/dry ports and inland terminals. Various interchangeable terms are used to refer to dry ports: inland ports, inland container depots, freight terminals, etc.

- Transport Models: The literature review on transport costs showed the majority of the freight transport models were mainly based on road transportation. It reflected that about 76% of inland transportation was carried out by road transport (EC 2010). Very recent literature reflects the definite increase in transport models based on internalising the negativities. These trends include the port infrastructures, supply chain logistics and the freight transport infrastructure.
- The main options for CO_2 reduction in international road and rail freight transport (Van Essen 2008):
    - International road freight transport:
        1. Technical measures
        2. Non-technical measures
    - Measures for CO2 reduction in international rail freight transport
    - General measures for CO2 reduction in international surface freight transport:
        3. Biofuels and other alternative fuels
        4. Measures aimed at volume reduction and modal shift

Pollutant emissions on long-distance freight transport could be effectively reduced by further tightening of vehicle emission standards. Other measures considering a move away towards alternatives to the road transit may contribute to a reduction of pollutant emissions, e.g. a shift towards electric rail transport in combination with a shift to greening electricity production.

- Transport costs: The challenges have been towards seeking a rational format and comparing costs across the different modes was difficult because of lack of reliable and consistent data (e.g., lack of real-time data), differences in units of measurement (e.g., km/h vs. mph), data from ports (global versus regional) for some modes of transportation (e.g., aviation and shipping) and limited responses to the technological advances (e.g., electric vehicles).

- Macro factors: Analysis of transport studies revealed several areas of similarity and especially in internalising the externalities for environmental pollution and GHGs (Demir et al., 2015). However, other negative externalities (noise and water pollution) presented quantifiable difficulties in determining the effects on the public. The effects of congestion and accidents involved very complex issues and impacts.
- Micro factors: Internalising the external factors
- Reconsidering freight tonnages and/or freight volumes in the evaluations
- In practise, the polluter pays principle has been superseded by the Cheapest Cost Avoider approach, where the "polluter pays" is one possible option, but generally not applied. This reflects a move away from the 'polluters pays' concept towards a 'cheapest cost avoider approach' (Ronald Coase).

8.5.2. Summing up the case study results

The results of the nine routes across the three transport corridors reveal very similar data. This allowed the ITCM to evaluate compared freight delivery transport systems between a road-heavy system and an intermodal alternative, based on total transport costs (a sum of internal, external and time costs). The evaluations of the three separate routes on each of the transport corridor studies clearly showed that the route with the higher road transit had the higher total transport cost. This offers an opportunity to the industry (service users and providers), policy makers and the academic community to consider transport cost based studies towards internalising the externalities costs:

- The main socio-economic negativities were considered in the model was environmental, noise, congestion, accidents, water pollution and land use (manufacturing and construction; transport infrastructure and power generation).
- Estimations reflected a top-down approach in the practice of internalizing negative externalities. This was because of the complexity of measuring individual entities in the transportation networks e.g. the impact of tonne-kilometres rather than other related parameters (e.g., type of vehicle and road) which are typically measured in the pricing literature.
- There were very few studies that incorporated internal, external and time costs evaluating a total transport cost model for an efficient sustainable delivery system. This revealed that some shippers were unlikely to consider environmental factors when choosing a freight transport mode (Kim, HC 2014).
- The model confirms that intermodalism involves the combination of its three attributes: transport links, transport nodes, and the provision of efficient services (Hanaoka and Regmi (2011:16).
- The model shows definite correlation on the three corridors of lower total costs with lower pollution coefficients.
- Further research is required on:
    - To co-ordinate technical aspects along the regional highways, railways, and seaports. Inland dry ports remain at an early stage of development.
    - Infrastructure in terminals servicing intermodal transport links and nodes, which include ports, airports, river ports, and inland dry ports, as well as improvement in the efficiency of transport services. Compatible intermodal transport terminals would improve the transhipment process and thus the overall costs and efficiency within a sustainable environment.
        - Evaluation of costs in financial terms and overall time amounts.

Chapter 9

Conclusions and Recommendations

9.1. Introduction

This final chapter sums up the thesis and highlights its overall contribution to the literature and industry. It concludes the research relating to the initial issues raised Chapter 1 about the primary objective and research questions formulated. Research into freight transport was initially carried out and an analysis of the relevant literature is found in chapters 2 and 3. The methodology philosophy and strategies and also process planning are set out in Chapter 4.

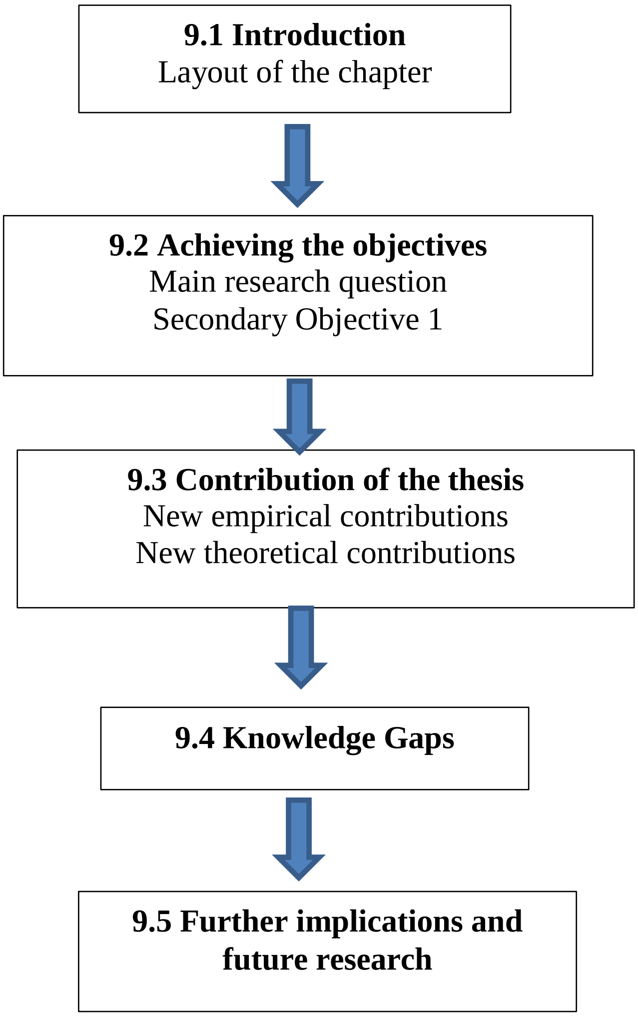

Figure 9.1 Layout of the Chapter 9

The model design is discussed in chapters 5 and 6. The ITCM was tested and the analysis of the evaluations is given in chapter 7. Chapter 8 describes the assessment of results with regards to the existing knowledge and the new findings that are derived from the model.The contribution of the thesis to the understanding of total transport costs within the intermodal concepts management literature is then presented and its empirical and theoretical contributions highlighted. Finally, the potential for future research is outlined.

The layout of this chapter is in five sections (Fig 9.1). The first section merely introduces the chapter. The second section refers to the issues and objectives raised in Chapter 1. The third section sets out the contributions made by this research. The research results offer new insights into the key influences on total general costs providing an added tool for mode choice to the freight operators.

The purpose of the research was to evaluate the total transport costs of intermodal freight systems by comparison with the predominant alternative truck-only systems.

Previous published literature examined, based on costs, freight transport (road, rail and sea) considered only the operational costs and there were very few published papers on freight transport considering the internal, external and time costs within total general costs functions. The few studies that considered the internal and external costs were primarily to optimize and improve the intermodal system performances without necessarily a full comparison as a mode choice tool.

The intermodal systems offer adaptable alternatives to long range freight haulage issues. Within the haulage parameters, the threshold indicators for distance makes intermodal options the preferred alternative over road, considering that the costs for pre-haul, post haul and long-haul by road are known. In cases where the main haul is by road, the pre and post road haul vehicles and driving conditions may be different to the main haul road vehicle(s) and conditions. The research model evaluated the total costs incorporating a number of factors for the internal costs, external costs and the time costs for industrial/manufactured freight (For internal costs: tables 5.3 road, 5.4 rail and shipping 5.5; time costs for commodities table 5.6; for external costs road/rail table 5.16, Shipping 5.17). Data was collated from existing recorded and published sources to evaluate the ITCM and presenting with new empirical results. A caveat in respect of the research is that the findings were new; hence there were no previous records to compare with. However, the findings offer a base for further research.

9.2. Achieving the objectives

This section presents evaluations of the objectives set out in Chapter 1. The ITCM design incorporated total transport costs and was applied to case studies on routes with direct road transportation and intermodal transportation. The analyses of the results from the nine case studies indicated that the total costs on the intermodal routes were decidedly lower than the comparable road route costs. The model accounts for cost, carbon emissions and modal shift and enables an analysis of the relationship between these different parameters.

Irish shippers' perceptions of factors influencing a mode choice model were extended to cover nine case studies, including cost, time, reliability, loss and damage, accessibility and service frequency were considered, allowing an investigation of broader factors influencing shippers' perceptions.

The aim of this research was to explore and present freight transport modes available to the Irish transport users (buyers) as a tool to and determine the most appropriate transport mode. This gave rise to the research question:

How can a comprehensive working model assess general freight transport costs, including economical and environmental costs, which allow transport stakeholders to make informed decisions on mode selection to achieve efficient freight delivery?

In order to respond categorically, the solution must include the other transport options, based here on total transport costs. In order to answer the research question, two further objectives were identified and expressed as follows:

1) In the light of current industry trends, it is necessary to determine the economical and environmental competitiveness of intermodal transport systems by comparison with unimodal systems.
2) Given the consequence of internalisation on the competitiveness of intermodal transport, relevant factors within total transport costs were collated. This required:
    a) Evaluating intermodal corridors, intermodal transport choices and the determinants defining the multimodal markets within the transport corridors
    b) Investigating the main factors in respect of intermodal transport costs.

In order to achieve the objectives of this research, the research included the determination of the freight networks and transport patterns along the major Irish and European freight corridors.

9.2.1. Answering the main research question

The main research question required a working model that evaluated total transport costs to be delivered. The model could be applied to existing corridors in order to offer mode selection or choice for the routes. The application to other routes would substantiate the robustness of the model. Clearly, if the model proved to be robust in its ability to predict freight transport costs for Ireland and Europe, it would have relevancy in a wider international context.

The following steps were taken in designing the research model (ITCM):

- A review of recent literature on transport models, collect and collate the relevant transport mode cost attributes for internal, external and time cost factors for commodity (industrial manufactured goods).
- Identify the various costs attributes and development of the model for evaluating total costs. Hence
    - The determinants of shippers' or agents' perceptions of mode choice at each stage in a supply chain and the possibility of mode substitution were investigated.
- Consideration of Trade Corridors
    - Identification of existing route characteristics and stochastic attributes and shippers' choices, in freight mode choice.

The outcomes of case study 1 (with three routes) and the extension of the model to the other two case studies (consisting of six routes in total) displayed results that confirmed the robustness of the ITCM.

9.2.2. Secondary objective 1 was stated as:

In the light of current industry trends, it is necessary to determine the economical and environmental competitiveness of intermodal transport systems by comparison with unimodal systems.

For a wider application of the model, the ITCM was employed with combinations of transport modes, with its specific internal, external and time costs that:

- Generated a multimode route of typical operation patterns
    - The ITCM evaluated the total costs (internal, external and time costs) for each of the routes for applicable transport modes.

Further, it evaluated the routes used primarily for road transport and developed alternative transport solutions with alternative modes having lower external costs, moved by rail or coastal shipping rather than road

- Analysed the results to assess trends and implications for transport policy.

9.2.3. Secondary objective 2 was stated as:

Given the consequence of internalisation on the competitiveness of intermodal transport, relevant factors within total transport costs can be determined. This will require:

- Evaluation of intermodal transport routes with three separate routes
    - Determination of three separate transport combinations for each route within each transport corridors;
    - Collation of the various aggregates for each transport mode
    - Collation of the factors for evaluating the internal, external and time costs

Analysis of the results in respect of the three routes, within each case study of intermodal transport costs. The results were compared and interrogated for trends shown in the first case study.

9.3. Contribution of the Thesis

This section concludes the thesis with a summary of the key findings and highlights the contributions of this research to the academic body of knowledge as well as to industrial practice. The potential limitations of this research were also recognised and directions for further enquiry identified. Analysing the results of the research and thoroughly investigating future trends in freight volume variables, factors shaping them and the complex inter-relations between these factors and variables, highlights the significant contribution to the generalised intermodal transport costs literature and the general body of knowledge. No previous study has focused specifically on evaluating the combined internal and external costs on nine main routes along three prime transport corridors. Relevant literature links transport volumes to generic economic indices such as GDP. Within transport research it has been agreed that need to extrapolate the analytics between the links of generic economic indicators and freight transport volumes (e.g. McKinnon, 1998b, Voordijk, 1999, Drewes-Nielsen et al., 2003). However, there have been no previous attempts to design a tool to evaluate the generalised transport costs combining the three factors of internal, external and time costs. However research model and the results allow the industry an added tool for mode-choice to opt for a lower cost with green credentials.

The literature in Chapters 2 and 3 provided a comprehensive review of generalised transport costs and issues relating to intermodal transport concepts. The theoretical framework links adopted in the previous studies with the new advances proposed in this research. The ITCM provides a functional tool that links variables with an optimal main output but also includes the main structural, commercial, operational, functional, product-related and external factors into the equation. These choices are most likely to be a combination of personal preferences and decisions made at different levels in the decision-making hierarchy. The research results links the management of freight transport to management theory and constitute a formal assessment framework showing how various decisions will affect the key logistics variables and, in turn, impact on outputs such as traffic levels, fuel consumption, etc. based on alternatives to main road haul.

Chapter 4 sets out the methodological perspective; the philosophical approach considers a new approach, away from the traditional positivistic approach and adopting the critical realism paradigm to add depth to the exploration of factors behind the investigated phenomenon. This is an innovative approach to transport research, representing a new attitude in the consideration of a critical realist approach to freight modelling. Detailed data collections strategies involve the process of triangulation and the evaluation involves the formulation of the variables onto spreadsheet applications.

The contribution of Chapters 5 and 6 narrows the remit of transport costs based on an in-depth investigation of factors in the key variables behind internal and external costs. The ITCM provides a functional tool that links variables with an optimal main output but also includes the main structural, commercial, operational, functional, product-related and external factors into the equation. These choices are most likely to be a combination of personal preferences and decisions made at different levels in the decision-making hierarchy. The research results links the management of freight transport to management theory and constitute a formal assessment framework showing how various decisions will affect the key logistics variables and, in turn, impact on outputs such as traffic levels, fuel consumption, etc. based on alternatives to main road haul.

The modelling work presented in Chapter 7 represents a major contribution to the literature by offering a new model for an ITCM. The existing freight delivery system, based on road transport is of particular importance here, as it represents a baseline or reference projection of future transport costs, not previously available in the literature. The testing using a pilot study, within the remit of the hypothesis was carried out on the first case study between Rotterdam/Felixstowe/Holyhead/Dublin and Ballina. The pilot study was a small scale preliminary study conducted before the main research, in order to check the feasibility and to improve the design of the research. This Chapter also shows the magnitude of transport savings and reduced costs from the transport related negativities. This clearly adds to the existing body of knowledge and will be of value to policy and decision makers. This and other practical implications of the research are discussed in the next section.

9.3.1. New empirical contributions

The increasing concerns about the influence of climate change from industry based pollution have made the decision makers increasingly aware of mitigating the environmental burden that freight transport activities impose. Hence this thesis has potentially a high practical relevance. Firstly, it provides policy makers with an operational tool towards mitigating the costs of existing and future emissions from freight transport. It presents a framework for assessing the likely changes to these baseline scenarios resulting from various policy measures. The research widens the understanding of these trends which, from the industry perspective, are likely to exert the greatest influence on the Irish and EU freight transport sector. In broad policy options, it extends the concepts of toll taxes and extends to 'willingness to pay' by users to consider the implications of lower emission transit (Brooks et al 2012).

The evaluations of the research model offered clear empirical data showing lower total costs for the alternatives to road main haul in all the transport corridors. The overarching limitations are that the evaluations were based on distances transited and it was assumed there were no technical or structural differentiations along the corridors and in respect of infrastructure. The new total cost evaluations for rail and short sea transits showed total lower costs along the same transit sections thus offering a far more sustainable and efficient transit.

The ITCM allows greater flexibility of the transport delivery, within the remit of the limitations and assumptions. Based on the total transport costs, this model allows the widest possible choice of options for lower total costs, from the existing or business-as-usual transit and with subsequent transits with options with reduced main road sections. This research sought to provide a methodology for a new model in evaluating total transport costs as the sum of internal, external and time costs. The new model incorporated existing data and added new concepts and technologies within freight transport studies and research into intermodal options. Hence, some significant aims of the thesis were to:

- Define the limits of the available freight modes
- Define the parameters of the new model (ITCM) from the literature review
- Review existing transport corridors and offer new mode combinations as alternative on existing ‘road heavy’ routes.
- Define the concept of total transport costs for the remit of the research.
- Review the literature and compare it with present findings regarding the practise and preference of alternate mode choices.

The research offered new solutions to satisfy the regulatory demands resulting from added tolls and taxes in order to ensure that the industry paid for its share of pollution, both environmental and social. The few published articles and other literature sources reflecting these concerns had shown that transhipment technologies were closing the gap between intermodal transport and unimodal road haulage in respect of transport cost over short and medium distances and that they also contributed to reducing emissions. It is important that transport quality, especially regarding reliability and punctuality is ensured. These aspects require practical and operational testing, which is why a demonstration project is recommended. This is particularly crucial regarding novel transhipment technologies.

This confirms that the results have already entered the policy-making process. The framework presented in this thesis can also be applied at the micro-scale, to serve the needs of an individual company. It links delivery of freight volumes of products moved to lower freight costs with lower external emissions. It can partner and develop a sustainable transport strategy and improve environmental performance. This research allows quantifying the costs, with increased awareness of future trends influencing the transport sector. The research provides companies with a better base for a long-term planning, partnering in the development of carbon reduction strategies and at lower overall transport costs.

9.3.2. New theoretical contributions

Theoretically, this research brought forward new defines new concepts of total costs. Based on the existing knowledge on freight transport costs, this ITCM extended and redefined the concepts of total transport costs by combining the external, internal and time costs. This allowed the methodology to investigate, design the ITCM for evaluating total costs and its influence on the industry (forwarders, shippers, etc) as a tool in the mode choice decision-making process. The model offers clearly identified relationships between the general costs and the advantages of intermodal alternatives over comparable existing road-based systems. Recent legislative and regulatory changes at supranational levels indicate that a move toward implementing a sustainable transport system would be favourably accepted. The results offer substantive cost benefits in transits over short pre-post haul distances offering competitive advantage in mode selection.

9.4. Knowledge gaps[93]

In the analysis of the literature review and reiterated in sections 9.3.1 and 9.3.2, the knowledge gaps that are unaddressed by the development, testing and application of the ITCM are identified. Clearly, the remit of this research was to create an effective tool for realistically costing different transport modes that combined pertinent environmental costs with internal costs, thereby allowing stakeholders to make informed decisions on

[93] This section presents the knowledge gaps identified by the literature review only and may not address all knowledge gaps pertaining to intermodal freight issues. There may have been other gaps noted and not discussed here, as they were not identified as relevant in the scope of the literature review.

mode choice. Hopefully, further research can be undertaken to address knowledge gaps and build on this research. A good starting point was to address the knowledge gaps identified by in the literature review, primarily for the Ireland/Europe mainland corridor:

- *Policy issue:* Regulatory and legislative interventions and improvements of existing infrastructure for easy multimodal transfers from pre-haul road stages onto the main-haul intermodal stage(s). This may be achieved with a two-pronged approach
    - Implementing infrastructure at intermodal freight terminals, in ports, railways
    - Consider charges in mitigating the environmental and social pollution cost.
- *Standardised approaches or guidelines*: Towards developing an institutional framework for identifying, designing and evaluating intermodal transportation projects.
- *Demand:* Detailed information about the ultimate origin and destination of freight movements and about the modal choices; market demand for freight transportation; freight transportation forecasts by origin and destination.
- *Transportation intermediaries*: Assessment of the role of Irish and European transport intermediaries: freight industry, academic and policy makers promoting alternative frameworks aiding compliance to regulations and operational procedures;
- *Information transfer*: Focused and detailed knowledge about the nature of the information being discussed within the freight industry and assessment of possible approaches for national government to play a role in facilitating the seamless transfer of information.

Despite a substantial amount of literature, the total costs options for mode choice in the UK and Ireland remains largely under researched and, to some extent, ignored. Literature on mode choices, with sea and rail as potential alternatives, has rarely discussed the impact of drayage distance and the pollution created within urban surroundings. However, it is still to be demonstrated that modal distance, by itself, does not influence the mode choice process. Hence, the current practice may be incorrect; since findings obtained for a given transport study based on the mainland distance are not necessarily transferable to other situations (Iannone 2011). Further research concerning the influence of intermodal terminal and mode choices on total costs is required.

Summarising the literature review promoting intermodal freight reveals several structural impediments to intermodalism. Earlier US (GAO/NSIAD-96-159, TCRP 1996) and European studies (Marchal et al 2006) indicate that the weakest links were the intermodal terminals, which suffer from very poor support and there is lack of clarity in respect of alternative modal options. At the EU level, policies and legal directives promoted intermodality as viable in terms of the long-term sustainable freight transport sector (De Jong et al 2013). Most ‘distance based’ freight transport research reflects land based solutions seeking the ‘breakeven point’ offered by rail over trucks. Transport policy studies have incentivised medium to long distance (above 400 km) operations and neglected the short to medium freight transport market (Reis 2014). There are very few intermodal transport studies with solutions for improving the short distance market share for rail and short sea trips.

9.5. Further implications and future research

9.5.1. Further implications

Most freight transport research has relevance for two potential audiences: the industry and the academic peers. Within the industry sector are the practioners and the policy makers. There is a growing awareness amongst the practioners, as the main decision makers, of the responsibility in sharing the environmental burden imposed by the negativities from freight transport. The transport industry is characterised by an energy intensive activity and thus is generally emission intensive. Freight transport is a strategic economic sector that also enables international trade, underpins global supply chains and allows access to markets by linking consumers and producers, importers and exporters. Maritime freight accounted for over 80% of global merchandise trade by volume and over 70 % by value in 2015 (UN 2014), promoting seamless door-to-door continuity of trade flows. There have been increasing concerns regarding the costs of clean-up regimes for the environmental pollutions and the socio-economic negativities resulting from transport.

The future implications should include the realities of short-term and mid-term technological changes and improved planning towards reducing the negativities of road transport options. The reduction of the carbon footprint could extend to all transport modes and embrace supply logistics at intermodal terminals with storage situations, materials handling, order picking and packing etc., being subsequently linked.

Firstly this research provides the transport industry with a tool to assist in the choice of route with possible alternatives to road transport.

Secondly it provides a framework for the policy makers with a tool to consider options for investment in transport infrastructure with regulations and legislations ensuring the ‘polluter pays’ their share of the negativities. The research analysis improves understanding of these alternatives and provides insight into which will exert the greater influence on the North West European freight transport sector. This confirms that the results have already entered the policy-making process (introduction of tolls in Germany, the Netherlands and Belgium). The research framework presented can also be applied at the micro-scale, to serve the needs on a single corridor and or route. The model links the freight moved with total costs including the environmental and socio-economic pollutions. The ITCM can be used as a part of sustainable logistics strategy offering cheaper transit with lower transport environmental negativities

9.5.2. Future research

This research has based its initial findings on a literature review of earlier transport publications. The earlier trends were recognised by Robinson (2002) as a new paradigm shifts in port studies. This research has collected and collated subsequent trends and suggests a paradigm platform for subsequent transport research reflecting the importance of sustainable transport solutions.

Evolving models have incorporated the traffic simulators inputs, both microscopic and macroscopic, showing realistic transit operations, network utilisation and avoidance of congestion by comparison with the traditional model (Patrick and Ehlert 2001). Analysing recent intermodal freight models (SteadieSeifi et al. 2014) shows definite eco-efficient advantages and sustainable alternative over road transportation. However, the majority of papers focused on a pure cost minimisation model to assess if intermodal transportation could compete against road transportation. The literature that incorporates carbon emissions within costs is scarce. The resulting cost includes the impact of the networks on society and the environment (Bouchery and Fransoo 2015).

The case study results combines the quantitative and the qualitative and offers conceptual options for future research, especially empirically driven, to evaluate the links in the intermodal framework further to support the developed hypotheses. New ITCM based research could incorporate the logistic dynamics changes, in service demand and supply.

The research could include the dynamics between transport demand and transport costs. New research could follow from concepts based on new paradigm platform:

- Intermodal terminals operations: agile framework could be developed covering the freight transport as a whole. The model could illustrate the consequences singular, modular or changes made to the whole freight transport system, helping to optimise its overall performance.
- Improved infrastructure concepts with better governance (at intermodal terminals, ports, etc) and improved technological vehicle specifications (EURO V for road vehicles, low sulphur fuels and electric powered locomotives, driverless drones, etc) operating within a sustainable transport policy.

Extending the research model to other corridors would add to the knowledge (McKinnon and Leonardi 2009, Piecyk and McKinnon, 2009), resulting in some interesting comparisons between different parts of Europe or even other continents. The final line of further enquiry would be to investigate in greater detail the policy options for reducing CO_2 emissions. Although measures offering the potential to improve the environmental performance of the sector were briefly presented in Chapter 7, there still persists a certain amount of uncertainty about their impact and cost-effectiveness. Thus future studies focusing on quantification of the potential impacts of mitigating through policy measures could be interesting.

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Appendices

Appendix 1: Table A1.1: ISO Container dimensions and specifications

Overall	6.1m (20') standard		12.2m (40') standard		12.2m (40') high cube		13.6m (45') high cube	
	Imperial	Metric	Imperial	Metric	Imperial	Metric	Imperial	Metric
Length	19'10½"	6.058	40' 0"	12.192	40'00"	12.192	45'00"	13.716
Width	8'00"	2.438	8' 00"	2.438	8'00"	2.438	8'00"	2.438
Height	8'06"	2.591	8' 06"	2.591	9'06"	2.896	9'06"	2.896
Max Gross	66139 lb.	30400 kg	66139 lb.	30400 kg	68008 lb.	30848 kg	66139 lb.	30400 kg
Empty Weight	4850 lb.	2200 kg	8380 lb.	3800 kg	8598 lb.	3900 kg	10580 lb.	4800 kg
Net Load	61289 lb.	28200 kg	57759 lb.	26600 kg	58598 lb.	26580 kg	55559 lb.	25600 kg

Source: Several sources.

Appendix 2: Table A2.1 Dimensions for a EURO pallet

EUR pallet type	Imperial	Metric	ISO alternative
EUR, EUR 1	31.5” x 47.24”	800 mm x 1200 mm	ISO1 or same EUR
EUR 2	47.24” x 39.37”	800 mm x 1200 mm	ISO 2
EUR 3	39.37” x 47.24”	1000m x 1200mm	
EUR 6	31.50” x 23.62”	800mm x 600mm	ISO 0 or half EUR

Note the height of the pallet is 144mm.

Appendix 3: Table A3.1: Summary of literature on externalities for transport modes

Authors	AP	GHGs	WP	NP	Congestion	Accidents	Land Use	Modes
ECORYS (2004	X	X		X	X	X	X	Road/Rail/ Sea/Air
Maibach et al. (2008)	X	X	X	X	X	X	X	Road/Rail/ Sea/Air
McAuley (2010)	X	X		X	X	X	X	Road/Rail/ Sea/Air
Delucchi and McCubbin (2010)	X	X	X	X	X	X	X	Road/Rail/ Sea/Air
VTPI (2013)	X	X	X	X	X	X	X	Road/Rail/ Sea/Air
Korzhenevych et al. (2014)	X	X		X	X	X	X	Road/Rail/ Sea/Air

Source: van Demir et al (2015)
(AP: Air Pollution; GHG: Green House Gases; WP: Water Pollution; NP: Noise Pollution)

Appendix 4: Table A4.1 Descripions of earlier literature reviews

Authors	Description of the literature
ECORYS (2004)	Marco Polo project was initiated by the European Commission with an aim to reduce road congestion and pollution. This study summarised the various externalities of the different transport modes for the project. The study incorporates the Marco Polo calculator, which presents the environmental/social impacts (e.g., air pollution, global warming, noise, accidents, congestion, and infrastructure) of four transport modes road, rail, inland water ways, and short sea shipping for companies to assess alternative solutions. The cost indices (in €/tkm) used in the calculator reflected the marginal cost estimates resulting from earlier research (e.g., UNITE 3, RECORDIT4). Maritime mode (includes both inland waterway and short sea transport) have the smallest overall index value (e.g., 0.01 €/tkm and 0.009 €/tkm respectively) which is the sum of the individual environmental/social index values of relevance.
Maibach et al. (2008)	This study reviewed the transport related environmental impacts, accidents and congestion. Without policy intervention the mitigating costs or these so called external costs were not incorporated into total costs leading to incorrect and incomplete costs paid by the users leading to welfare losses. The EU project handbook estimating external costs in transport sector externalities in the Internalisation Measures and Policies for All external Cost of Transport (IMPACT) was published. The handbook combines a number of studies done by acknowledged firms/institutes producing a reliable and a comprehensive set of external cost figures. The study provides as detailed information of externality cost indices for different types of vehicles and fuels in road transportation, congestion costs depending on VOT, emissions of air transportation varying in flight distance categories. In addition, case studies are provided in the handbook for details of using such

	information. Other research programs were (UNITE, HEATCO5 and GRACE6) to determine unified costs for transportation.
McCauley (2010)	Examples of the external costs of freight transportation in Australia refer to primarily road and rail transportation modes. The externalities (e.g., accidents, GHGs, noise, and congestion) costs for the transportation modes are presented with ranges (e.g., the maximum and minimum unit costs) between the major Australian cities (e.g., Sydney, Brisbane, Melbourne, and Perth) are presented. The paper concludes that in the Australian scenario the road freight has lower externality costs compared to the average road freight values due to better road conditions.
Delucchi and McCubbin (2010)	The study summarised the external costs for the United States with all transport modes and the corresponding externalities priced for both freight and passenger transportation. However, estimates for some (air freight and maritime modes) were not included because of lack of reliable estimates on freight transportation than for passenger transportation. The authors collated results based on the cost figures available in scientific articles. There were a few estimates provided by the authors.
VTPI (2013)	This study reviewed transport literature from 1975 to 2012) on transport costs and especially focusing on freight costs. 18 categories of main externalities costs were discussed (e.g., accidents, congestion, air pollution, climate change). The review was a very detailed study on transport related accidents (covered by 30 articles), whereas land use is the least ‘quantified’ cost category with only six articles.
Korzhenevych et al. (2014)	This study records the updated version of the earlier handbook Maibach et al. (2008) incorporating recent scientific studies and best practices. There updates included new databases on noise; accidents and emission factors; new internalization models; improved input values; recent research outputs on the environmental/social impacts; the account of existing taxes and

	charges; and more case studies. There were no additional literatures (between 2008 and 2014) in way of evaluating external congestion costs for rail, air, or maritime transportation. There was a greater focus on the road sector reflecting greater volume road usage and external costs. There were updates in costs estimates of other industrial environmental impacts, including the external costs (e.g., pollution) from energy generation; transport builds production /maintenance/disposal/infrastructure/construction. Additionally, marginal infrastructure costs are provided in the handbook.

Appendix 5: Table A5.1 Selected environmental effects by transport modes

Mode	Environment	Water resources	Land resources	Solid Waste	Noise	Accidents	Other
Air	Air pollution	Modification of water tables, river courses, and field drainage in airport construction	Land taken for infrastructures; dereliction of obsolete facilities	Aircraft withdrawn from service	Noise around Airports		
Marine and inland water transport		Modification of water systems during port construction and canal cutting and dredging	Land taken for infrastructures; dereliction of obsolete port facilities and canals	Vessels and craft Withdrawn from service		Bulk transport of hazardous substances	
Rail			Land taken for rights of way/terminals; dereliction of obsolete facilities	Abandoned lines, Equipment and rolling Stock	Noise and vibration Around terminals and along railway Lines	Derailment or collision of freight carrying hazardous substances	Partition or destruction of neighbourhoods, farmland and wildlife habitats
Road	Air pollution -CO, NO, particulates and fuel additives) Global Pollution (CO_2, GHG)	Pollution of surface water and groundwater by surface run-OR, Modification of water systems by road building	Land use for infrastructures; extraction of road building materials	Abandoned spoil tips and rubble from road works; road vehicles withdrawn from service; waste oil	Noise and vibration from cars, motor-cycles and lorries in cities, and along main roads	Deaths, injuries and property damaged from road accidents; risk of transport of hazardous substances, risks of structural failure in old or worn road facilities	Partition or destruction of neighbourhoods, farmland and wildlife habitats; congestion

Source: Linster (1990); Greene et al (1997).

Appendix 6: Emission Control Areas

The Emission Controlled Areas established are:

1. Baltic Sea area – as defined in Annex I of MARPOL (SO_x only);
2. North Sea area – as defined in Annex V of MARPOL (SO_x only);
3. North American area (entered into effect 1 August 2012) – as defined in Appendix VII of Annex VI of MARPOL (SO_x, NO_x and PM); and
4. United States Caribbean Sea area (entered into effect 1 January 2014) – as defined in Appendix VII of Annex VI of MARPOL (SO_x, NO_x and PM).

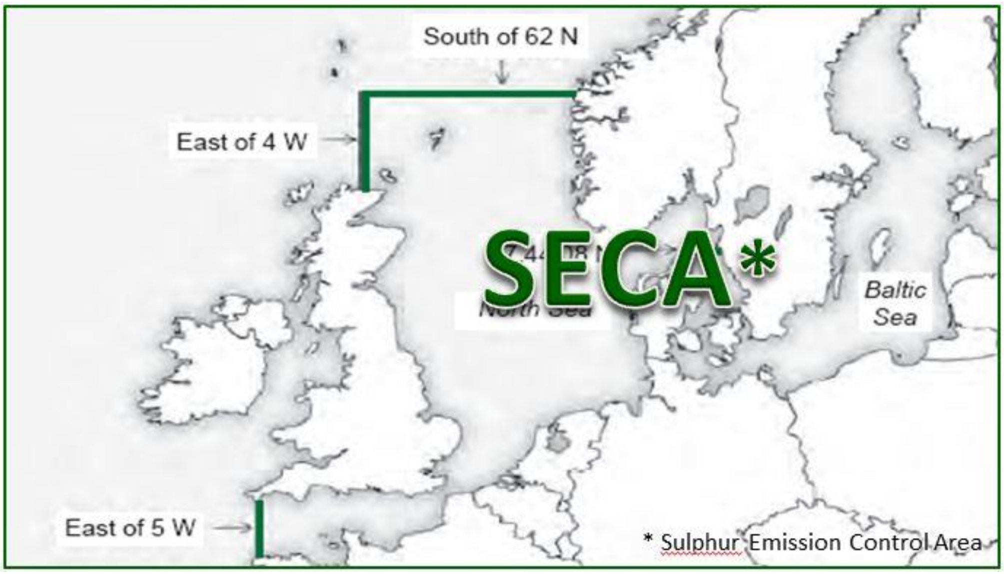

Figure A6.1: Map showing SECA demarcation zones.[94]

Regulation 2.9 defines the SO_x and particulate matter emission controls, applies to all fuel oil combustion equipment and devices on-board (include main and all auxiliary engines together with items such boilers and inert gas generators). These controls divide between those applicable inside Emission Control Areas (ECA) established to limit the emission of SO_x and particulate matter and those applicable outside such areas and are primarily achieved by limiting the maximum sulphur content of the fuel oils as loaded, bunkered, and subsequently used on-board.

Table A6.1 shows IMO's fuel oil sulphur limits (expressed in terms of % m/m – by weight). These are subject to a series step changes (regulations 14.1 and 14.4):

[94] http://www.shiptonorway.no/News/178/Lines%20reveal%20their%20plans%20for%20SECA

Table A 6.1: Schedule for reduction of fuel sulphur content in fuel oil

Outside an ECA established to limit SO_x and particulate matter emissions	Inside an ECA established to limit SO_x and particulate matter emissions
4.50% m/m prior to 1 January 2012	1.50% m/m prior to 1 July 2010
3.50% m/m on and after 1 January 2012	1.00% m/m on and after 1 July 2010
0.50% m/m on and after 1 January 2020*	0.10% m/m on and after 1 January 2015

* Depending on the outcome of a review, to be concluded by 2018, as to the availability of the required fuel oil, this date could be deferred to 1 January 2025.

Ships that operate inside these ECA must operate on low sulphur fuels to comply with the respective limits. In such cases, prior to entry into the ECA, it is required to have fully changed-over to using the ECA compliant fuel oil, regulation 14.6, and to have on-board implemented written procedures as to how this is to be undertaken.

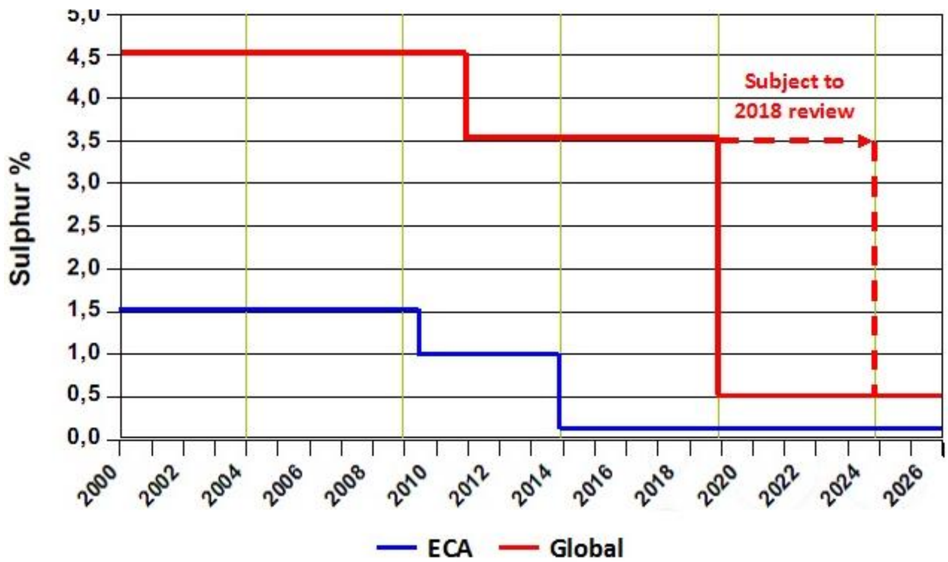

Figure A6.2: Fuel Oil Sulphur limits

Source: IMO

Figure A6.2 shows the agreed schedule for the lowering of sulphur content through the using of ECA compliant fuel oil. At each change-over, the ECA there is a management procedure of fuel oils recording quantities on-board, together with the date, time and position of the ship, prior to entry or commencing change-over after exit from such areas. These are managed as prescribed by the ship’s flag State.

Appendix 7: TEN-T Corridors

A Trans-European network (TENs) (Figure A7.1) was the EU main policy instrument promoting the internal market by linking the European regions. The TENs infrastructure allowed modal interoperability (i.e. setting compatible standards by removing technical barriers).

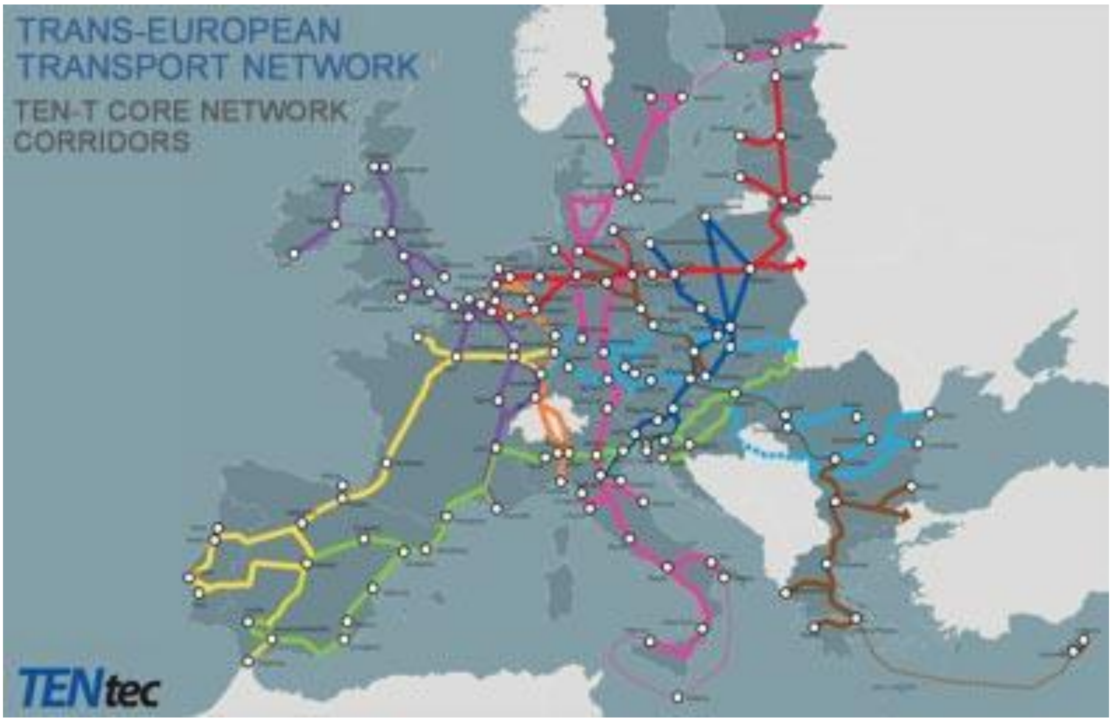

Figure A7.1 European TEN-T transport corridors
Source: Infrastructure - TEN-T - Connecting Europe[95]

The Trans-European Transport Network Executive Agency (TEN-T EA, 2006) was created to manage technical and financial implementation. It was replaced by the Innovation and Networks Executive Agency (INEA). The Agency started its activities on 1 January 2014 and initiated the following EU programmes:

- Connecting Europe Facility (CEF) [96]
- Parts of Horizon 2020 – Smart, green and integrated transport + Secure, clean and efficient energy
- Legacy programmes: TEN-T and Marco Polo 2007-2013

[95] http://ec.europa.eu/transport/themes/infrastructure/news/2015-01-15-corridors_en.htm
[96] http://ec.europa.eu/transport/themes/infrastructure/ten-t-guidelines/corridors/index_en.htm

Nine core network corridors were identified in the annex to the CEF Regulation, which included EU funding projects (period 2014 – 2020).

The core network connects:

- 94 main European ports with rail and road links
- 38 key airports with rail connections into major cities
- 15,000 km of railway line upgraded to high speed facilities
- 35 cross-border projects to reduce bottlenecks

The infrastructural and investment priorities identified in the European Commission report Trans-European Transport Network (TEN-T). Table A7.1 shows the nine main corridors:

Table A7.1: EU TEN-T corridors

	Name	Alignment
1	Baltic Adriatic Corridor	Gdynia – Gdansk – Katowice/Sławków Gdansk – Warszawa – Katowice Katowice – Ostrava – Brno – Wien Szczecin/Świnoujście – Poznań – Wroclaw – Ostrava Katowice – Žilina – Bratislava – Wien Wien – Graz– Villach – Udine – Trieste Udine – Venetia – Padua – Bologna – Ravenna Graz – Maribor –Ljubljana – Koper/Trieste
2	North Sea-Baltic Corridor	Helsinki – Tallinn – Riga Ventspils – Riga Riga – Kaunas Klaipeda – Kaunas – Vilnius Kaunas – Warszawa BY border – Warszawa – Poznań – Frankfurt/Oder – Berlin – Hamburg Berlin – Magdeburg – Braunschweig – Hannover Hannover – Bremen – Bremerhaven/Wilhelmshaven Hannover – Osnabruck – Hengelo – Almelo – Deventer – Utrecht Utrecht – Amsterdam Utrecht – Rotterdam – Antwerp Hannover – Köln – Antwerp
3	Mediterranean Corridor	Algeciras – Bobadilla –Madrid – Zaragoza – Tarragona Seville – Bobadilla – Murcia- Cartagena – Murcia – Valencia – Tarragona Tarragona – Barcelona – Perpignan – Marseille/Lyon – Torino – Novara – Milano –

		Verona – Padua – Venetia – Ravenna/Trieste/Koper - Ljubljana – Budapest Ljubljana/Rijeka – Zagreb – Budapest – UA border
4	Orient/East-Med Corridor	Hamburg – Berlin Rostock – Berlin – Dresden Bremerhaven/Wilhelmshaven – Magdeburg – Dresden Dresden – Ústí nad Labem – Melnik/Praha - Kolin Kolin – Pardubice – Brno – Wien/Bratislava – Budapest – Arad – Timişoara – Craiova – Calafat – Vidin – Sofia Sofia – Plovdiv – Burgas Plovdiv – TR border Sofia – Thessaloniki – Athens – Piraeus – Lemesos – Lefkosia Athens – Patra/Igoumenitsa
5	Scandinavian-Mediterranean Corridor	RU border – HaminaKotka – Helsinki – Turku/Naantali – Stockholm – Malmö Oslo – Gothenburg – Malmö – Trelleborg Malmö – Copenhagen – Kolding/Lübeck – Hamburg – Hannover Bremen – Hannover – Nuremburg Rostock – Berlin – Leipzig – Munich Nuremburg – Munich – Innsbruck – Verona – Bologna – Ancona/Firenze Livorno/La Spezia - Firenze – Roma – Napoli – Bari – Taranto – Valletta Napoli – Gioia Tauro – Palermo/Augusta – Valletta
6	Rhine-Alpine Corridor	Genoa – Milano – Lugano – Basel Genoa –Novara – Brig – Bern – Basel – Karlsruhe – Mannheim – Mainz – Koblenz – Köln Köln – Düsseldorf – Duisburg – Nijmegen/Arnhem – Utrecht – Amsterdam Nijmegen – Rotterdam – Vlissingen Köln – Liege – Bruxelles/Brussels – Gent Liege – Antwerp – Gent – Zeebrugge
7	Atlantic Corridor	Algeciras – Bobadilla – Madrid Sines / Lisbon – Madrid – Valladolid Lisbon – Aveiro – Leixões/Porto Aveiro – Valladolid – Vitoria – Bergara – Bilbao/Bordeaux – Paris – Le Havre/Metz – Mannheim/Strasbourg
8	North Sea-Mediterranean Corridor	Belfast – Dublin – Cork Glasgow/Edinburgh – Liverpool/Manchester – Birmingham Birmingham – Felixstowe/London/Southampton London – Lille – Brussels Amsterdam – Rotterdam – Antwerp – Brussels – Luxembourg Luxembourg – Metz – Dijon – Macon – Lyon – Marseille Luxembourg – Metz – Strasbourg – Basel

		Antwerp/Zeebrugge – Gent – Dunkerque/Lille – Paris
9	Rhine-Danube Corridor	Strasbourg – Stuttgart – Munich – Wels/Linz Strasbourg – Mannheim – Frankfurt – Würzburg – Nuremburg – Regensburg – Passau – Wels/Linz Munich/Nuremburg – Prague – Ostrava/Přerov – Žilina – Košice – UA border Wels/Linz – Wien – Bratislava – Budapest – Vukovar Wien/Bratislava – Budapest – Arad – Brašov/Craiova – Bucharest – Constanta – Sulina

Source: TEN-T and European Rail Traffic Management System (ERTMS)

The freight and passenger numbers during the 2012 to the 2013 through EU ports were more or less stable, with a 0.6 % decrease in the total gross weight of goods and a 0.5 % increase in the number of seaborne passengers (EUROSTATS 2014a).

EU funded programs such as Marco Polo, directs modal-shift projects providing supporting services which enable freight to switch from road to other modes efficiently and profitably. To further promote the overall transport operations and the reduction of transport related pollution by the integration of national transport networks, the EU set up the Trans European Transport Network (TEN-T)[97] in 2006.

New TEN-T Guidelines[98] recommend further development of cross-border transport infrastructure towards improving the fragmented transport modes by strengthening the role for intermodal and multimodal transport nodes in terms of offering greater connectivity (EC DG-MOVE NSMED Core Network Corridor, Draft Final Report 2014).

[97] http://inea.ec.europa.eu/en/news__events/newsroom/introducing_inea_innovation_and_networks_executive_agency.htm

[98] Regulation 1315/2013 and 1316/2013

Appendix 8: Transport targets up to 2050: resulting from transport policy

In the European Environment Agency's (EEA's) annual report Transport and Environment Reporting Mechanism (TERM) an overview of pressures on the environment resulting from the transport sector are presented with a selection of related impacts and policy responses. The report is based on the latest available data to assess and predict key trends of the overall progress towards meeting policy targets. The 2014 TERM report [99] had two sections; the first section shows improvements in the environmental performance of the transport system as a whole. These were based 12 TERM indicators based on their association with on-going European policy targets and data availability and reliability (see Table A8.1).

Table A8.1: Relevant transport targets up to 2050

	Target	Target Date	Source	Relevant factor	Comments
1	Transport GHG (with international aviation, without international shipping): 20 % ↓ (versus 2008) 60% ↓ (versus 1990)	2030 2050	2011 Transport White Paper (EC, 2011a), 2050 Roadmap (EC, 2011a)	TERM 02	Broader strategy sets the most cost – effective ways for 2050 Roadmap the most cost effective ways to reduce GHG emissions based on from modelling to a long-term target of reducing domestic emissions by 80 % to 95 %. The target for the transport sector was set out in the 2011 Transport White Paper on the basis of the 2050 Roadmap
2	EU CO_2 emissions of maritime bunker fuels: 40 % ↓ (versus 2005)	2050	2011 Transport White Paper (EC, 2011a)	TERM 02	n/a
3	40 % share of low-carbon sustainable fuels in aviation	2050	2011 Transport White Paper (EC, 2011a)	TERM 31	Potentially monitored through EU ETS reporting
4	Conventionally fuel cars in urban	2030	2011 Transport	TERM 34	The White Paper goal relates not to vehicle

[99] Focusing on environmental pressures from long-distance transport: TERM 2014: transport indicators tracking progress towards environmental targets in EU

	transport: 50 % ↓ 100 % ↓	2050	White Paper (EC, 2011a)		numbers but to share in urban passenger-kilometres
5	CO_2-free city logistics in major urban centres	2030			Not currently possible to monitor
6	The majority of medium-distance passenger transport should go by rail	2050	2011 Transport White Paper (EC, 2011a)	TERM 12a/b	Only indirectly monitored through modal shares
7	Road freight over 300 km shift to rail sea transport: 30 % to 50 %+ shift	2030 2050	2011 Transport White Paper (EC, 2011a)	TERM 13a/b	Only indirectly monitored through modal shares
8	10 % share of renewable energy consumption in transport sector each Member State	2020	Fuel quality directive 2009/30/EC (EU 2009b)	TERM 31	To be monitored in future indicator updates
9	Fuel suppliers to reduce life-cycle GHG of road transport fuel: 6–10 % (versus 2010 fossil fuels)	2020	Passenger Car CO_2 EC Regulation 443/2009 (EU, 2009c)	TERM27 and TERM34	Phased in between 2012 (65 %) and 2015 (100 %)
10	Target average type-approval emissions for new passenger cars: 130 gCO_2/km 95 gCO_2/km	2012-2015 2020	Passenger Car CO_2 EC Regulation 443/2009 (EU, 2009c)	TERM27 and TERM34	Phased in between 2012 (65 %) and 2015 (100 %)
11	Target average type-approval emissions for new light vans: 175 gCO_2/km 147 gCO_2/km	2014-2017	Van CO_2 EC Regulation 510/2011 (EU, 2011b)	TERM27 and TERM34	
12	70 % reduction of transport oil consumption from 2008	2050	Impact assessment in document to the White Paper (EC, 2011b)	TERM 01	This is interpreted as a 70 % drop in oil consumption in the transport sector from 2008 levels, as it is the latest data available

Source: EEA Report No 7/2014(a) page 86.

Appendix 9: Data on traffic flows and description of the model corridors

The literature review failed to offer recognised measurement indicators for transport as the data was not homogeneous and was not available from either Port Authorities or from other official sources (Grosso 2010). Most of the freight logistic data from the major European ports to their hinterland were naturally port based and 'port centric'. Often the port related freight data were fragmented, lacked universal compatibility and proved difficult to offer

Reviews of recent publications confirm that public policies (public investment in specific infrastructure or subsidies for the transport operators) have had major influences on improving the available transport modes (EEA 2014a) and infrastructure. However, policies do have an indirect influence on the generalised costs; in international lack of connecting and complementary intermodal infrastructure have a negative influence on the logistical costs between countries. Transport literature on European road connectivity presents the extent of disparity in the transport infrastructure, operating systems, administrative procedures, transport levies, etc. and the negative effects on the efficiencies of the transport sector (Braconier and Pisu 2013).

Transport service providers usually bundle transport choices with other economies, often leading to centralisation of their warehousing of the transiting transport inventories. In real terms, there is a trade-off between transport and inventory costs. Vierth (2014) argues that lower transportation costs have led to a further centralisation of inventories. Innovative logistics (as in 'just-in time) allows a reduction of in-house warehouse stock costs and allows for small and frequent deliveries of inputs, by trucks or vans. The agility of the road mode allows shippers to optimise deliveries with regard to time, volume and destination, while rail only offers to carry goods in predetermined carriers. The modal split of inland transport between 2002 and 2012 between the three modes are shown in Table 9.1. Finally, the lack of direct rail links with the intermodal terminals (SSS, inland waterways, air, etc.) necessitates road transport for the majority of the pre-haul and post-haul deliveries (Santos et al., 2010).

The general cost model included both the internal and external factors. In order to provide a comprehensive cost aspect, the maximum numbers of cost items internally and externally were considered. The initial freight transport empirical model was based on the Dublin-Rotterdam freight corridor.

Table A9.1: Freight transport modal split in tonne-km (2002 and 2012)

	2002			2012		
	Road	Railways	Inland waterways	Road	Railways	Inland waterways
EU 28[100]	75.5	18.3	6.2	75.1	18.2	6.7
BE	77.5	10.7	11.8	58.3	17.5	24.3
IE	97.1	2.9	-	99.1	0.9	-
NL	63.3	3.3	33.4	56.2	5.1	38.7
UK	89.7	10.2	0.1	87.8	12.1	0.1

Source: Eurostat: Energy, transport and environment indicators 2014 edition Pocketbooks [101]

Figure A 9.1: Major rail routes in Ireland.

Source: European rail guide[102]

[100] Excluding pipelines, Bulgaria, Croatia and Romania

- [101] http://ec.europa.eu/eurostat/documents/3930297/6613266/KS-DK-14-001-EN-N.pdf/4ec0677e-8fec-4dac-a058-5f2ebd00085e4

[102] http://www.europeanrailguide.com/maps/ireland.html

The collection and collation of data for the research was considered in three stages:

1) The transport provider's 'out of pocket costs': the daily tangible costs.
2) Factors arising from environmental and social considerations giving rise to the external cost internalizations.
3) Variables in the generalized cost functions, the qualitative elements that influence mode choice, but could be measured in monetary terms.

Recent Irish rail freight services showed an increase, even during the recession period. Rail's ecological advantages 'can play in Ireland's efforts to meet the agreed Kyoto level of carbon emissions' (Tim Casterton Handling Network 4 May 2015).

Danish transport DFDS Logistics added to their intermodal transport services in Ireland between North West Ireland to mainland Europe with Waterford Port and Rosslare (March 2013) the (Iarnród Éireann) (Figure A9.1).

Figure A9.2: Major rail routes and ferry connections in England.

Source: European rail guide

Following the 2008 global financial downturn, there was a 20% decline in the exports in 2009. There has been a steady increase in imports from the Netherlands since 2004, reaching a total value of €2.90 billion in 2009 (see Figure A9.3). Intra-industry trade has a significant role in Irish–Dutch trade relations and both the economies are vulnerable to fluctuations in world markets. The highest value export was miscellaneous manufactured articles, worth €462 million to the economy followed by office machines, professional & scientific apparatus and medical and pharmaceutical products valued at €414 million, €409 million and €304 million respectively. In 2009 about 34% of the main commodity exported by volume was metal ores and metal scrap. The last recorded figures for 2014 show combined figures of around €7.9 billion (Figure A9-3).

Figure A9.3: 2014 value of trade between Ireland and the Netherlands

Source: Port of Rotterdam information

The port of Rotterdam in the Netherlands operates as a major gateway port for Europe with multimodal connections incorporating short sea and inland waterways, rail and road links to the European hinterlands. Dublin Port total tonnages for 2013 commodities/modes figures indicates 440 million tonnes with 127.6 tonnes (29%) as containerised freight (Table A9-2).

Table A9-2: Export figures between Ireland and the Netherlands (2014)

2014 EXPORTS: Ireland – Rotterdam, Netherlands	
RoRo	1,045,109
LoLo	52,61
LoLo TEUS	3,227,635
Bulk Solids	333,977
Ores and Concentrates	4,704
Peat Moss in Bulk	1,814
Bio Ethanol	9,029.10
Fuel Oils: Gas oil, Diesel oil, Aviation	148,024.86
Petroleum Bitumen - Other Fuel Oils	23,829.57
TOTAL	4,460,145.84

Source: Dublin Port Co.

Currently there are 6 Lo/Lo operators providing short sea and feeder services and 2 Ro/Ro services between Ireland and the ports of Antwerp and Zeebrugge (Dublin Port

2013). Post 2009/2010 financial downturn brought about operational rationalisation witnessed innovative vessel sharing arrangements (VSA) on the SSS routes. This agility allowed major companies to reduce spare capacity. BG Freightline began reducing their capacity early in 2009 to cater for the fall off in demand and rationalised their services. On Belgian routes the VSA by Xpress Container line and Eucon offer BG Freightline vessels capacity of 1,724 TEU. Table A9.3 shows the connections between Ireland and near Europe (2009)

Table A9.3: Short Sea services between Ireland/Belgium

Route	Operator	Frequency per week	Capacity TEU	Vessel Sharing arrangement
Dublin-Belfast- Antwerp	Mediterranean Shipping Company	1	800	
Dublin-Antwerp	EUCON	1	972	BG Freightline-Eucon-Xpress
Waterford- Cork-Rotterdam-Zeebrugge	DFDS	2	600	DFDS/Samskip
Dublin-Zeebrugge-Rotterdam	Samskip	2	805	Samskip-Lys Line
Dublin-Belfast Antwerp	EUCON	1	750	Eucon-BG Freightline-Xpress
Cork, Esbjerg (Denmark) - Wallhamn (Sweden) - Antwerp (Belgium) - Southampton (UK) - Salerno (Italy) - Piraeus (Greece) - Izmir (Turkey) - Alexandria (Egypt) - Limassol (Cyprus) - Ashdod (Israel)-Portbury (UK).	Grimaldi	1	400	
Dublin – Zeebrugge	Cobelfret (ConRo)	2	356	
Harwich, Eemshaven, Antwerp, Lagos, Tema, Monrovia	RMR	12	12	

Source: IMDO, CSO and Dublin Port

Appendix 10.1: Different internal cost factors and attributes

	Internal Cost items	Attributes
1	Purchase Costs	A cost that all companies have to face is the one related to initial capital costs and the subsequent depreciation. Interest costs are on the outstanding loans on the capitals from the bank and interest, renting or leasing related to the vehicles and other physical assets. The annual figure depreciation or lend/rent payments is expressed in €/h.
2	Personnel	Personnel or labour costs represent one of the main cost items in any company. This includes all the personnel across the transport company administration and industrial personnel). The standard items include the total number of people employed, their wages, allowances and the deductions (taxes, social security) calculated on an annual basis to give an average amount per hours in a year and is expressed in €/h. For the road mode, maximum working driving hours allowed is 9 hours and the driver has to either have a period of rest or be replaced for the journey to continue (European Regulation 561/2006)
3	Energy	The total cost for fuel or energy, from well to wheel, either as fuel (diesel or gasoline consumption for road, inland navigation and rail transport, or electric power in rail or combined transport) is affected by the market price of the energy source. (say, for heavy road vehicle for covering 100 kilometres the fuel used is between 34.30 /36 litres (McKinnon, Piecyk 2007) The model considers the average consumption costs per kilometre and is expressed in €/Km.
4	Insurance	The insurance cost reflects all the expenses related to the civil liability for the vehicle. A vehicle’s insurance cost is not straightforward and may be considered as an annual cost depending on the specific characteristics of the vehicle.

		The industry offers either per kilometre or per hour figures. In this research the calculation is carried out for operative hours, €/h.
5	Repair & Maintenance	Annual expenses of the vehicles to cover routine repairs, maintenance and unexpected accidents or problems. It is an average, per vehicle, calculated on the basis of the kilometres covered in one year of trucks activity. No particular remarks need to be added for this cost item.
6	Overhead costs	These costs are the overall company amounts for trip management. The evaluated composite figure is the total costs divided by total service hours. Units are €/hour
7	Depreciation and interest/rent/lease	Methodologies differ as per modes and practises. For road transport it is assumed that the vehicle is purchased and therefore the asset expenses correspond to the yearly payment of interest and depreciation; while for rail and inland navigation it is assumed that the vehicles will be on a leasing contract.
8	Fixed costs	These are modal dependant and cover annual costs irrespective of tonnages carried or distance travelled.
9	Taxes, charges and tolls	Taxes refer to road tax, property tax and Euro Vignette tax and are recorded in €. Road-tolls are imposed by some states as taxes. Rates vary depending on the distance, load, engine capacity or some other criteria. Toll calculation details are taken from route planners.
10	Modal additional	Additional items that are mode dependant. Road trucks have costs of tyres. Rail mode has costs in the renewing of rolling stock.
Transhipment Costs		
1	Loading/unloading	Dependent on modes and time (load/unload) and infrastructural costs (warehouse/forklift, machinery etc)
2	Shunting	Rail only, carriages and locomotives are shunted around. These include costs/hour and added infrastructural costs.

Source: Grosso (2010), COMPASS Delhaye et al (2010)

Appendix 11: Rail Net Europe freight rail corridors

The RailNetEurope (RNE), set up in 2004, was an association set up by a majority of European Rail Infrastructure Managers and Allocation Bodies to offer new rail solutions to growing international rail traffic. The members brought about harmonising the diverse technical and operations conditions by providing solutions that benefit all RNE Members, as well as their customers and business partners.

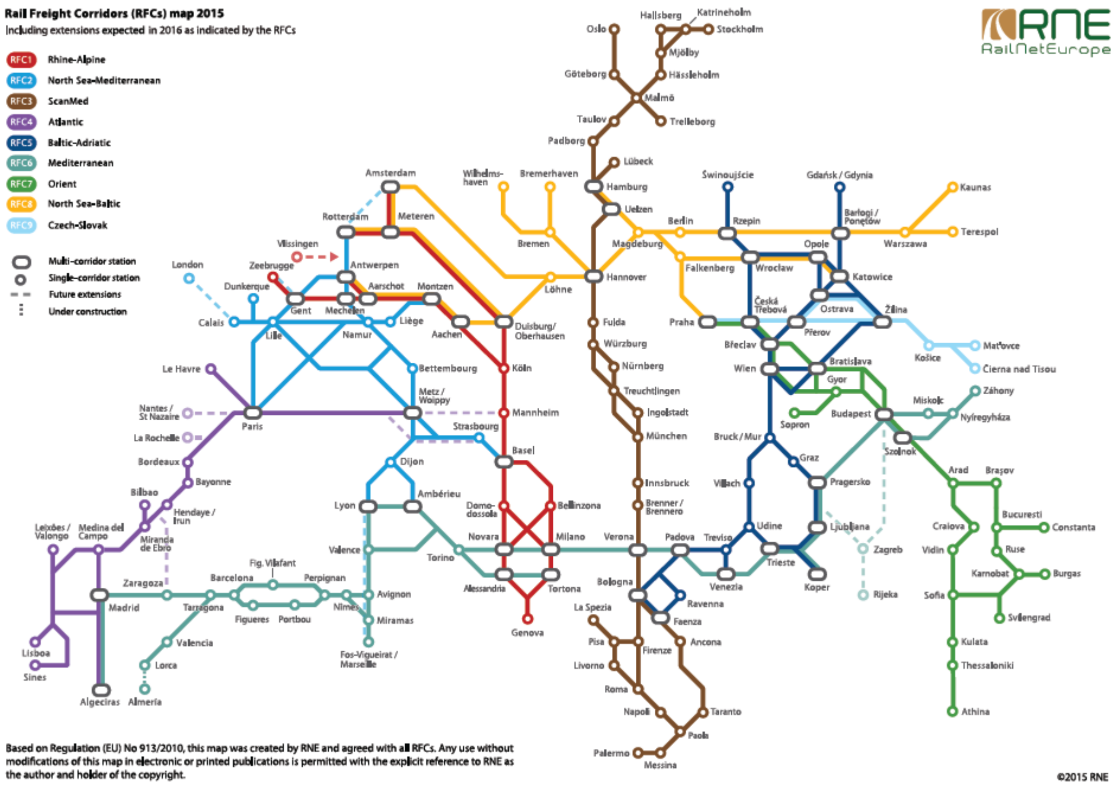

Figure A11.1 Rail Net Europe rail corridors

Source: RNE

Table A11.1 List of private and public rail operators in Europe (UIRR)

	Rail Company	Country
1.	LTE (AT) Karlauer Gürtel 1, A-8020 Graz	A
2.	Westbahn, Europlatz, Vienna	A
3.	Wiener Lokalbahnen Cargo, Vienna, Austria	A
4.	Alpha Trains	BE
5.	Crossrail	BE
6.	Ferrmed	BE – A
7.	BeWag	BE – A
8.	Bulgarian Railway Cy	BG
9.	Cargo Rail Europe	CH
10.	Bertschi	CH
11.	Hupac Intermodal SA, Chiasso, Switzerland CH-6830	CH
12.	Duisport Rail	DE
13.	AAE	DE
14.	MEV Eisenbahn-Verkehrsges	DE
15.	NetzwerkEuro.Ebahnen	DE
16.	IBS-Bahnspediteure (DE) - A	DE
17.	Captrain	FR
18.	Europorte	FR
19.	TOUAX (FR)	FR
20.	FerCargo	IT
21.	UAB "Transachema" Ruklos sen	Latvia
22.	AWT (Advanced World Transport B.V.)	NL
23.	ERS Railways	NL
24.	Rotterdam Rail Feeding	NL
25.	Samskip	NL
26.	IGTL - Izba Gozpodarcza Transportu Ladowego	PL
27.	ZNPK - Związek Nieżaleznych Przewoźników	PL
28.	Hector Rail AB Svärdvägen 27 SE-182 33	SE
29.	Danderyd	SW
30.	Freightliner Group	UK
31.	RFG-Rail Freight Group	UK - A
32.	Metallurgtrans, Pl. Lenina 1, Dnipropetrovsk	Ukraine

Source: ERFA