ENVIRONMENTAL MANAGEMENT OF THE LOGISTIC CHAIN -

with specific reference to ports and noise

A Thesis Submitted for the Degree of Doctor of Philosophy of Cardiff University

by Antonios Michail

Department of Earth and Ocean Sciences
Cardiff University

September 2008

DECLARATION/STATEMENTS

DECLARATION

This work has not previously been accepted in substance for any degree and is not concurrently submitted in candidature for any degree.

Signed .... (candidate) Date ....01/10/08........

STATEMENT 1

This thesis is being submitted in partial fulfilment of the requirements for the degree of ....PhD.............. (insert MCh, MD, MPhil, PhD etc, as appropriate)

Signed .... (candidate) Date ....01/10/08........

STATEMENT 2

This thesis is the result of my own independent work/investigation, except where otherwise stated.

Other sources are acknowledged by explicit references.

Signed .... (candidate) Date ....01/10/08........

STATEMENT 3

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed .... (candidate) Date ....01/10/08........

ABSTRACT

The logistic chain has evolved from being a concept of integrated transport activity to that of a fully functioning, dynamic, and complex multi-component system with the primary function of delivering effective management of freight mobility. Whilst humanity is faced with the challenge of reducing the impact of transport on the environment without losing the benefits to society and economies, a holistic approach to the environmental management of the logistic chain emerges as a necessity. The thesis follows a multi-method and interdisciplinary, phased pathway in order to (1) assess the feasibility and practicability of delivering sustainable development through such a chain, (2) address the challenges inherent to its implementation, and (3) develop a model that guides the development and delivery of an environmental management system specifically focussed on the logistic chain.

Following an environmental management based methodology, the significant environmental aspects of the logistic chain operations are identified and analysed. Focus is then placed on the major players in the chain (transport buyers, providers and operators) and, in particular, on selected practices that have the potential to improve chain environmental performance and guide the future trends of the sector's response. Seaports are selected for purposes of evaluation and validation of various options as they arguably represent the major and most complex of the logistic nodes in terms of intense intermodal and multi-actor interest. The evolution and trends in the field of integrated seaport area management are evaluated by specifically designed surveys and case studies. Similarly, noise is selected as a multi-source, trans-boundary and complex issue in order to examine the potential options for control of significant environmental aspects of the logistic chain. The feasibility of integrated noise management throughout the chain is assessed through the demonstration of available management response options. The results and the major observations are finally synthesised in order to propose a generic model suitable for addressing the challenges of integrated environmental management of the logistic chain.

ACKNOWLEDGEMENTS

The production of a thesis is an extensive task, smoothed by the help of many people. Several people contributed in their own way to the completion of this thesis. I would especially like to thank my supervisor, Chris Wooldridge not only for his guidance, advice, unending encouragement, assistance and inspiration throughout the four years but also for being a supportive and sincere friend. I would also like to thank my second supervisor Hance Smith for his shared wisdom, interest and strategic advice. I wish to pay respect to the intellectual endeavour which was the Department of Earth, Ocean and Planetary science and particularly to the Marine and Coastal Environment research group. I am most grateful for the input of many academics during my student years which provided me with the enthusiasm to embark on this research.

I would like to thank my good friends Lia, Fabio, Alice, Cesar, Dimitris, Hugh, Kieron, and Matthew for their love and support and for making Cardiff a great place to be. Many thanks to my office colleagues Tim and Joe with whom I shared the joys and challenges of research life. Special thanks to my colleagues in the EC research and development projects ECOPORTS and NoMEPorts for data validation, professional feedback, and beautiful memories from research symposiums all over the Ports of Europe. In particular, I would like to thank Chrisanthi Kontogiorgi (Port of Piraeus), Basil Tselentis (University of Piraeus), Paul Bokdam (Lloyds Register), Rob Witte (DGMR), Ton van Breemen (Port of Amsterdam) and Herman Journée (ECOPORTS Foundation) for their input in various parts of the thesis. Finally, Michali, Loukia, Leon, thanks for everything!

CONTENTS

INDEX OF FIGURES

INDEX OF TABLES

ABBREVIATIONS

ACC	American Chemistry Council
ASECAP	European professional association of tolled motorways companies
BLICC	Business Leaders Initiative on Climate Change
BSR	Business for Social Responsibility
CEECs	Central and East European countries
CPRE	Council for the Protection of Rural England
DEFRA	Department for Environment, Food and Rural Affairs
DG TREN	Directorate General of Energy and Transport
EC	European Commission
ECMT	European Conference of Ministers of Transport
EDP	Electronic Data Processing
EEA	European Environmental Agency
EMAS	European Eco-Management and Audit Scheme
END	Environmental Noise Directive
EPF	EcoPorts Foundation
EPI	Environmental Performance Indicator
ERF	European Union Road Federation
ESPO	European Sea-Ports Organisation
ETS	Emissions Trading Scheme
EU	European Union
FHH	Free and Hanseatic City of Hamburg
GDP	Gross Domestic Product
GRI	Global Reporting Initiative
HCs	Hydrocarbons
HGV	Heavy Goods Vehicle
HGV	Heavy Goods Vehicle
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation

ICCA	International Council of Chemical Associations
ICS	International Chamber of Shipping
IMO	International Maritime Organisation
INE	Inland Navigation Europe
IPCC	Intergovernmental Panel on Climate Change
IRF	International Road Federation
IRU	International Road Transport Union
ISO	International Organization for Standardization
JIT	Just In Time
OECD	Organisation for Economic Co-operation and Development
PRIOS	Port Railway Information and Operation System
RCMS	Responsible Care Management System
SDM	Self-Diagnosis Methodology
SEA	Strategic Environmental Assessment
SEAs	Significant Environmental Aspects
SOSEA	Strategic Overview of Significant Environmental Aspects
TEN-T	The multi-modal Trans-European Transport Network
TERM	Transport and Environment Reporting Mechanism
TEU	Twenty Foot Equivalent Unit
UIC	International Union of Railways (Union Internationale des Chemins de Fer)
UIRR	International Union of combined Road-Rail transport companies
VOCs	Volatile Organic Compounds

GLOSSARY OF TERMS

Anthropogenic: Derived from humans or arising as a result of human activities

A-weighting: A frequency response used in sound measurement devices to take account of the way the sensitivity of the human ear varies with frequency.

Best practice: A proven practice that results in significant change towards a desired direction (proven to be the "best" between good practices)

dB(A): The unit of sound pressure level, weighted according to the A scale, which takes into account the increased sensitivity of the human ear at some frequencies.

Decibel (dB): The logarithmic ratio of a sound pressure compared to a reference sound pressure in decibels, dB. For audible sound A-weighted decibels are commonly used, dB(A).

Environmental aspect: Element of the Port Authority's activities, products or services which can interact with the environment

Environmental Impact: Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organisation's activities, products or services.

Environmental Issue: A generic term for all natural and commercial resources, environmental impact or effects and user /operator conflicts relevant to management.

Environmental Management System: The part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.

Environmental Objective: Overall environmental goal, arising from the environmental policy, that an organization sets itself to achieve, and which is quantifiable where practicable.

Environmental Performance: Measurable results of the environmental management system, related to an organization's control of its environmental aspects, based upon its environmental policy, objective and targets.

Environmental Performance Indicator (EPI): A specific expression providing information about an organisation's environmental performance

Environmental Policy: Statement by the organization of its intentions and principles in relation to its overall environmental performance which provides a framework for action and for the setting of its environmental objectives and targets.

Environmental Target: Detailed performance requirement, quantified where practicable, applicable to the organization or parts thereof, that arises from the environmental objectives and that needs to be set and met in order to achieve those objectives.

Geographical Information System (GIS): A computer system specially designed to manage information with a geographical relationship. The information is stored digitally and can be represented visually as maps.

Good practice: A practice targeting change towards a desired direction with regard to the environmental context that it is used.

Grid: Noise calculation software is able to predict noise levels at discrete locations. One way of representing locations is to create a grid of regularly spaced noise levels at defined intervals.

LAeq,T: Noise indicator expressing the notional A-weighted equivalent continuous sound level which, if it occurred over the same time period, would give the same noise level as the continuously varying sound level. The T denotes the time period over which the average is taken, for example LAeq,16h is the equivalent continuous noise level over a 16 hour period.

Lday: Noise indicator expressing the long term A-weighted average sound level over the day period (07:00-19:00)

Lden: Noise indicator expressing the day, evening, night level. Lden, is a logarithmic composite of the long term A-weighted day noise level, the evening noise level +5 dB and the night noise level +10dB.

Levening: Noise indicator expressing the long term A-weighted average sound level over the evening period (19:00-23:00)

Lnight: Noise indicator expressing the long term A-weighted average sound level over the night period (23:00-07:00)

Significant environmental aspect: A significant aspect is an aspect with a significant impact on the environment. Screening for significance: can be based on legal requirements, policy statements and risk analysis of the impact of the aspect. If an impact is regarded to be significant (e.g. opinion of stakeholders), the aspect has to be regarded as significant.

TEU (Twenty-foot Equivalent Unit): Standard unit for counting containers of various capacities and for describing the capacities of container ships or terminals. One 20 foot ISO container equals 1 TEU. One 40 foot ISO container equals two TEU.

1 Introduction

This chapter introduces the field of research – environmental management of freight transport systems – and defines some of the important terms used in the thesis. The chapter justifies the need for research in the field, presents the research aims and objectives, and outlines the focus and scope. It concludes by outlining and explaining the structure of the thesis.

1.1 Background

Focusing on transport as a critical element of the Supply chain, the logistic chain may be defined as the network of the successive physical and conceptual links involved in the transport and placement of goods. Intermodality, the process of transporting freight by means of a system of interconnected networks involving various combinations of modes of transportation, lies at the heart of the concept of the logistic chain. The chain (figure 1) consists of successive links between movement patterns (transport modes) and nodal points (logistic nodes) in an integrative intermodal concept from point of origin to point of consumption.

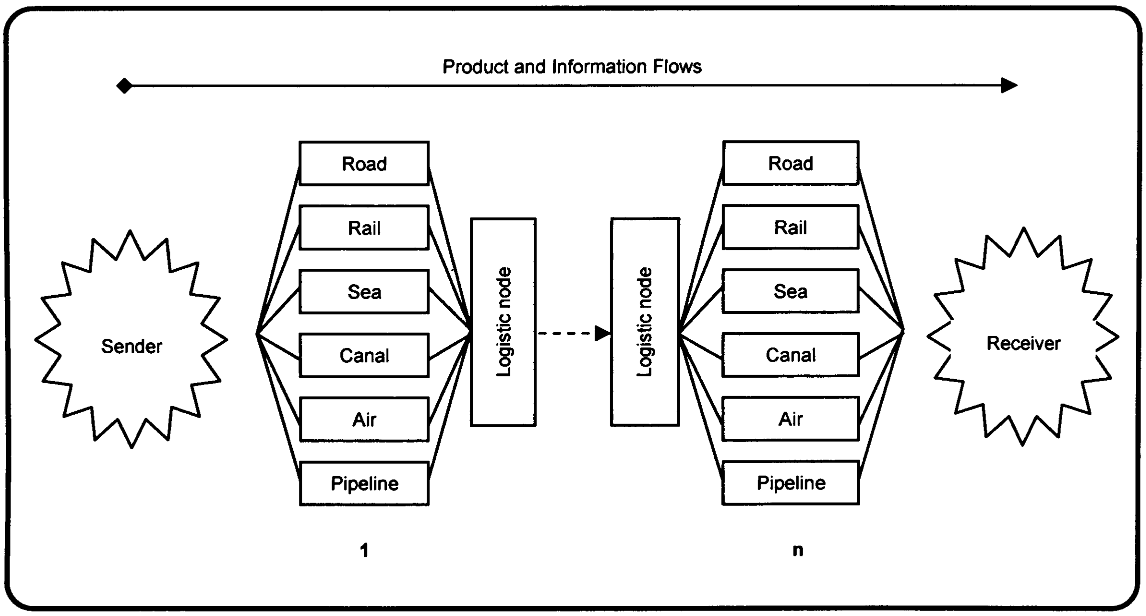


Figure 1: The logistic chain

The environmental impact of the logistic chain represents the sum-total impact of all the embraced functions, activities and operations in the process of moving goods from their point of origin to their final destination. In other words the impact of the logistic chain is the sum-total of the impacts of all its elements and includes all transport modes, transport systems, logistic nodes and related operations. Elements of the chain's activities, products and services interact with the environment, affecting air, water and soil quality, ecosystems, landscape and biodiversity. In this context, the concept of the environmental management of the logistic chain can be seen as addressing the required functional organisation and the available management options in order to minimise the environmental impact arising from the operation of intermodal transport systems. The concept recognises the physical and economic links associated with an integrated transport system, or chain, specifically designed to transport or deliver goods in a cost-effective and sustainable manner. The environmental management of the logistic chain embraces two concept areas: (1) the environmental management of freight transport, and, (2) the logistic chain as a holistic way of examining freight transport systems. Of equal significance are the questions that arise from such an approach, namely, why there is a need for environmental management of freight transport?, and why follow a holistic logistic chain approach?

The justification for the environmental management of freight transport arises from the wide variety of associated health, safety, security and environmental impacts and the whole debate on sustainable development. Freight transport, often referred to as industry on wheels (Hensher and Button 2003), makes a vital contribution to the economy and society, and is at the heart of globalisation. Its dramatic growth though, especially in the road sector, is rapidly taking away the benefits through impacts such as congestion, noise, air pollution and demand on energy. It is timely and topical to examine the current practices with regard to the environmental management of freight transport because of the density of traffic and the significance of environmental issues in terms of politics, planning, and the whole debate on sustainable development.

Traditionally, environmental management practices of a given organisation have covered issues within the legal responsibility of the organisation under question. Nowadays, and in line with the concept of corporate responsibility, firms are logically expected to exercise their influence over their outsourced products, operations and activities. In the same way that companies exercise their influence over their partners in achieving cost reduction and increased efficiency in their supply chains, they can reasonably be expected to act towards the direction of improving their environmental performance. The concept of the environmental management of the logistic chain opposes a fragmented sector by sector approach and it is in line with modern, responsible corporate practices. It acknowledges the significance and contribution of the environmental management of each sector or each player in the transport chain but it goes one step further in examining and integrating the links and interfaces between the different sectors and players. In that way it places the focus on the transport system or chain as a whole arguing that such an approach offers opportunities for environmental improvement and contributes to the operation of more sustainable transport systems.

The necessity for a holistic approach while tackling the environmental performance of transport systems is supported by recent research on the field. Hensher and Button (2003) argue that transport systems should be examined holistically focusing on the total system outcomes rather than traditionally emphasising on single sectors such as the different transport modes. "Setting constraints on particular forms of transport to achieve desirable environmental outcomes must be evaluated within a broader set of ways to satisfy opportunities offered by "high-tech" and "high-touch" industries". Mintcheva (2005) argues that, following the developments in supply chain management and environmental policy integration, a holistic approach for successfully addressing the environmental challenges becomes necessary (Mintcheva 2005).

1.2 Research aims

The focus of the research is placed on freight transport systems and their interaction with the environment. The topic studied is the environmental management of the logistic chain. The thesis argues that a holistic approach with regard to the environmental management of freight transportation, placing the focus on transport as a whole system or chain, embracing all different functions and players, offers significant opportunities for environmental improvement and contributes towards a more sustainable transport system operation. The overall aims of the research are: (1) to assess the feasibility and practicability of a framework or system for the integrated environmental management of the logistic chain with particular reference to ports (as major logistic nodes) and noise (as a major environmental aspect), (2) to derive the principles and preconditions that would allow the establishment of such a framework, and (3) to provide the main axes of such an attempt in the form of a generic model that could be applied. In order to achieve the overall aims specific phased objectives are outlined as following:

- to investigate the format, function, and organisation of the logistic chain,
- to demonstrate the interaction between the logistic chain and the environment, highlighting the challenges, policies and responses,
- to provide a methodology for the identification of the significant environmental aspects of the logistic chain,
- to demonstrate and assess the interests and practices of the major players,
- to demonstrate integrated logistic nodes' environmental management practices focussing in particular on the example of seaport areas,
- to investigate and demonstrate management response options throughout the logistic chain focusing in particular on the example of environmental noise management,
- and to synthesise the findings of the above phased objectives in order to address the overall research aims.

Each of the phased objectives above is addressed within a separate chapter (chapters 3-9) as it is explained in section 1.4 where the structure of the thesis is outlined. The first two are addressed within the broad literature review (Chapters 3 and 4), while the following ones within the main results chapters of the thesis (chapters 5-9).

1.3 Focus and scope

The environmental management of the logistic chain is a wide and complex field of research. It embraces many different disciplines such as, environmental science, environmental management, transport management and logistics, economics and political sciences. Logistic chains spin their webs over continents connecting sites of extraction of raw materials of every kind with production sites, nodal points (e.g. logistics centres, warehouses, seaports and airports) and products' final markets. They link together a plethora of different actors with distinct interests and aspirations but nevertheless all profited by smooth logistic chain operations. The associated environmental considerations are also varying from very locally based in nature to global problems such as climate change. Additionally, the transport sustainability debate is challenging by nature, as confronting long established socio-economic concepts with environmental protection imperatives.

The research aims at maintaining a holistic, interdisciplinary perspective in order to make a contribution towards an environmental management framework or system for the logistic chain as a whole. This does not necessarily imply that all of the chain's components, functions and associated operations are dealt with by applying the same level of detail. The in depth analysis of all elements embraced within the complex logistic chain system would not be feasible even within the framework of a doctoral thesis. The holistic perspective is achieved by acknowledging and outlining all the embraced elements first within the literature review. The scope of the literature review is extended so that it covers and acknowledges the broad spectrum of chain components (transport modes, and logistic nodes) and functions (transporting, warehousing), the different players and organisational patterns, and the wide range of environmental aspects and impacts. Therefore, the review establishes the broad boundaries of the logistic chain.

Then, the focus is placed on selected components, expressions and environmental aspects. Those include the analysis of the major players' interests and practices (chapter 6), integrated seaport area environmental management (chapter 7), and environmental noise management (chapter 8). The study on those research areas places the focus from the strategic general picture to the selected component or aspect. The generic principles established within the literature review are tested and validated through the exemplary studies and the case specific findings are then projected back to the general picture. As a result, although some chain components are dealt within the thesis with a disproportional level of detail in comparison to other, the research pathway maintains a holistic perspective and enables the drawing of conclusions for the logistic chain as a whole system.

The scope of the research in terms of transport geography covers all the freight transport modes and all the transport systems that integrate those modes into multimodal or intermodal structures. All the physical links and interfaces in a transport system or chain are taken into consideration within the literature review. Specific reference is made to seaport areas acknowledging their core significance as the major logistic nodes in the freight transport system. Most of the case studies and surveys are focussed on seaport areas. In terms of physical geography, the study is primarily taking a European perspective, although most of the findings are relevant and representative of the global picture. From an environmental management point of view the scope of the research acknowledges and discusses the wide variety of environmental impacts of transport operations on the physical, chemical and biological environment (chapters 4 and 5). Noise is selected (chapter 8) as a major environmental aspect of transport operations and serves as the example for the demonstration and validation of the introduced concepts. Field measurements, monitoring and modelling examples were carried out by the author as planned components of the research pathway.

During the period of research the author was personally responsible for the design, execution and reporting of selected components of research activity in support of wider EC research programmes including the ECOPORTS and NoMEPorts projects.

1.4 Structure of the thesis

This chapter has established the field of the research and defined some of the important terms associated with the environmental management of the logistic chain. It introduced to the research aims, rationale and initiated the discussion on the logistic chain concept.

The thesis is divided in three main parts, namely (1) Setting up the analysis, (2) Results and Analysis, and (3) Summary and implications. The first 4 chapters of the thesis constitute the first part that sets up the analysis and synthesis to follow on parts two and three respectively (see figure 2 for the general schematic structure of the thesis). Chapter 2 focuses on the research approach. It clarifies the philosophical concepts and discusses the central research hypothesis and the arising research areas. It then demonstrates the selected multi-method approach and research pathway in order to investigate and validate the central hypothesis. Chapter 3 reviews the literature with regard to the concept of the logistic chain, its main components and the major players. It provides an understanding of its nature, format, function and organisation. Having established the concept and identified the physical manifestation of the logistic chain, the thesis in chapter 4 researches the interaction between transport systems and the environment. The chapter highlights the emerging transport sustainability debate and formulates the challenge of operating "greener" or more sustainable logistic chains. The transport policy and regulation framework response in this context is discussed mainly taking a European perspective. In addition, the chapter introduces a generic over-arching environmental management framework that is further shaped and adapted through the findings of the forthcoming chapters in order to take its final form in the concluding chapter 9 of the thesis.

Chapter 5 starts the second part of the thesis on the results and their analysis. The chapter supports the phased development of the research partway that aims towards the establishment of an environmental management system for the logistic chain. First step in this direction is the identification of the significant environmental aspects of the chain, in other words the elements that need to be addressed by the environmental management. Following established environmental management techniques the chapter develops an analytical tool in order to demonstrate and then manage those elements.

Chapter 6 places the focus on the major players in the logistic chain, investigating their efforts and practices while they face the challenge of managing those previously identified elements. The catalysts and forcing mechanisms that motivate the major players, namely shippers and transport operators, to act towards the operation of a "greener" chain are discussed. The results of a survey aiming to demonstrate current interests, common and best practices are analytically presented. The chapter concludes by assessing the current practices and the potential for environmental improvement by implementing the good practice examples at a larger scale.

Chapter 7 researches the environmental management of logistic nodes as core components of the logistic chain. Between the nodes, seaports are selected as the major and arguably most complex ones. Drawing on the results of a series of selected surveys and case studies, the chapter argues mainly that (1) the environmental management of seaport areas is a core component of the environmental management of the whole chain, (2) that the major observations regarding the progress in the field over time can be transferable to the environmental management of the whole chain, and (3) that the trends demonstrate potential for further integration as ports undertake the role of facilitators in the logistic chain.

Chapter 8 concludes the second part of the thesis on the results and their analysis. It selects to place the focus on environmental noise, one of the major, and arguably one the most complex to control environmental aspects, associated with transport and the logistic chain. Noise serves as the example for demonstrating the functional organisation and the available management options required throughout the chain, in order to minimise the arising environmental impact. A series of case studies demonstrate options and tools for integrated noise management, such as noise monitoring and mapping and their contribution to noise action planning and management system.

Chapter 9 synthesises the findings of the previous chapters in order to address the overall research aims and objectives. The main observations and the implications regarding the feasibility and practicability of integrated environmental management of the logistic chain are discussed and the identified challenges are addressed. An EMS model specifically designed to deliver continual environmental improvement of the performance of logistic chain operations is presented and analysed. The EMS model draws on the generic framework that was introduced in chapter 4 and it is shaped by the findings of the results chapters of the thesis (chapters 5, 6, 7, and 8). It is validated through the selected exemplary studies in the fields of integrated port and noise management. The chapter provides the final conclusions and recommendations and assesses the potential of further research in the field.

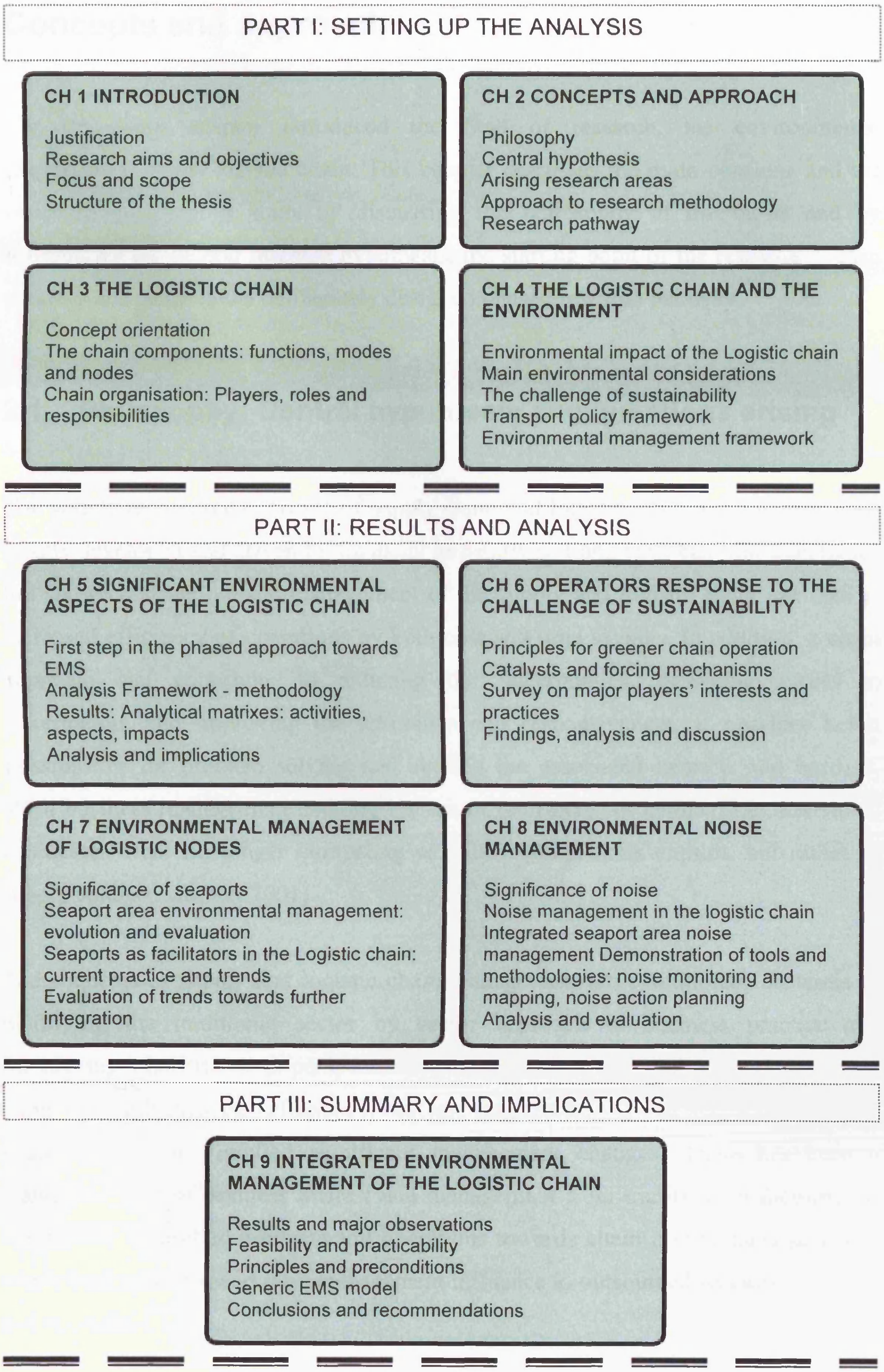


Figure 2: Structure of the thesis

2 Concepts and approach

The preceding chapter introduced the field of research, the environmental management of the logistic chain. This chapter discusses the main concepts and the research approach. It starts by discussing the philosophy of the thesis and by formulating the central research hypothesis, the starting point of the research. It then presents and justifies the deliberately designed phased research pathway.

2.1 Philosophy: Central hypothesis and questions arising

The widely recognised concepts of supply chain and logistic chain management were mostly developed and driven by financial imperatives. Long term business experience has shown that the holistic management of the supply and logistic chain can lead to increased efficiency of operations by both cost and time savings. In addition, a chain approach can contribute to reducing the uncertainties, providing access to information, and improving the reliability and responsiveness. It provides better possibilities for problem solving and sharing the associated benefits and burdens. With business management entering the era of inter-network competition, individual businesses were no longer competing as solely autonomous entities, but rather as supply chains (Lambert 2001).

The concepts of supply and logistic chain management are evolutionary in terms of modifying the traditional sector by sector approach in business practice and introducing a holistic chain perspective where all chain partners think and act as one aiming towards increased efficiency, cost and time savings. On an individual business practice basis this implied significant management changes. There has been a significant shift of business interest and management from traditionally focusing on the directly controlled products and operations towards chain management practices where businesses expand their management influence to outsourced services, products and operations.

Transportation services play a central role in supply chain operations, moving materials from supply sites to manufacturing facilities, repositioning inventory among different distribution centres, and delivering finished products to customers. Research in the field of supply chain management argues that transportation often represents one of the chain's weaker elements (Stank and Goldsby 2000). Focusing on transport as a critical element of the supply chain, the logistic chain may be defined as the network of the successive physical and conceptual links involved in the transport and placement of goods. Freight transport and all related activities, services, products and operations are closely managed on what concerns their efficiency and economic performance. The holistic management of the logistic chain in terms of efficiency and cost effectiveness is a reality in modern business management.

Freight transport makes a vital contribution to the economy and to the well being and sustenance of society in general, and is at the heart of globalisation. However, the trend of its dramatic growth over recent years, especially in the road sector, is widely perceived as having produced unacceptable effects on the environment through such impacts as congestion, noise, air pollution and demand on energy. With the growing concern for the environment, a new perspective is added to logistic chains - their environmental management. It can be argued that in line with the expected economic and efficiency related benefits, a holistic chain management approach offers opportunities towards environmental efficiency and contributes towards a more sustainable transport system.

The environmental management of the logistic chain addresses the functional organisation and use of appropriate response options necessary to minimise the environmental impacts arising from the operation of intermodal transport systems including all the embraced activities, operations and services. The concept recognises the physical and economic links associated with an integrated transport system, or chain, specifically designed to transport or deliver goods in a cost-effective and sustainable manner. The challenge is to minimize the environmental impact of the chain by adding the environmental component into the decision-making and the management of its operations. Examining and assessing options towards this direction is the main aim of the current research. The thesis examines the feasibility and practicability of establishing an environmental management system or framework for the logistic chain. It argues in favour of such a system, it establishes its principles and preconditions, and develops a generic model that could be applied.

Summarising, the **central research hypothesis** is formulated as:

An environmental management framework or system for the logistic chain can deliver continual environmental improvement and gradually respond to the challenge of striking a balance between the socio-economic benefits of transport and its adverse environmental effects. Such a system is technically feasible and practicable and its realisation is subject to overcoming challenges primarily in the fields of administration and organisation.

2.2 Approach to research methodology

The research can be generally characterised as exploratory. Commonly encountered in management research (Easterby-Smith, Thorpe et al. 1991), an exploratory study is applying a multi-method approach in order to "find out what is happening; seek new insights; assess phenomena in a new light" (Saunders, Lewis et al. 1997). The current research seeks to assess the environmental management of freight transport under the "light" of a holistic logistic chain approach. Research in the field of the environmental management of the logistic chain is clearly multi-disciplinary. It involves elements of environmental, social and economic science, environmental management and planning, transport management and engineering. A multi-method approach is therefore dictated in order to tackle the various research areas under examination and to bring environmental science and management into the technocratic field of transport planning and management with all the related socio-economic considerations. Such a multi-method approach consists of both social science techniques, such as case studies, surveys, interviews, observation, literature research, expert panel and analytical approaches, and operations research techniques, such as simulation and monitoring. It also combines qualitative and quantitative approaches.

The research scope is kept broad, as the aim is to make a contribution towards more sustainable transport systems or chains, in a scale that is not limited by geographical or technical factors. One of the tools to achieve that is the exercise of moving from strategic to specific aspects, from the general picture to the detail and vice a versa. The strategic study of the logistic chain and its interaction with the environment serves the development of strategic models and concepts with regard to its environmental management. Then by placing the focus on very specific aspects of the chain, the study examines the application, adapts and validates the general models and concepts. Moving back to the strategic overview the main observations and the findings from the study of specific aspects are integrated. The focus of the study therefore moves, from the broad range of identified environmental aspects of the logistic chain to the detailed examination of very specific aspects, such as noise, and from the broad spectrum of elements and functions of the chain to the research of seaports, and selected good practices and initiatives of even single firms.

2.3 Research Pathway and investigative line

In this section the phased approach of the research pathway is presented and justified. The starting point is the central research hypothesis as formulated in section 2.1. The research pathway consists of logical interconnected research areas that provide information in order to support, question, control and validate the hypothesis. Those research areas, the phased conceptual steps towards the validation of the main hypothesis, are separately discussed in terms of their focus, objectives, methods used and output. Especially with regard to the methods used it should be noticed that only an overview is provided. The in depth analysis of the selected approaches and methods is individually discussed per research area at the relevant chapter of the thesis. This structure has been dictated by the followed multi-method approach and due to reasons of coherence.

The general research pathway is presented on the following figure 3.

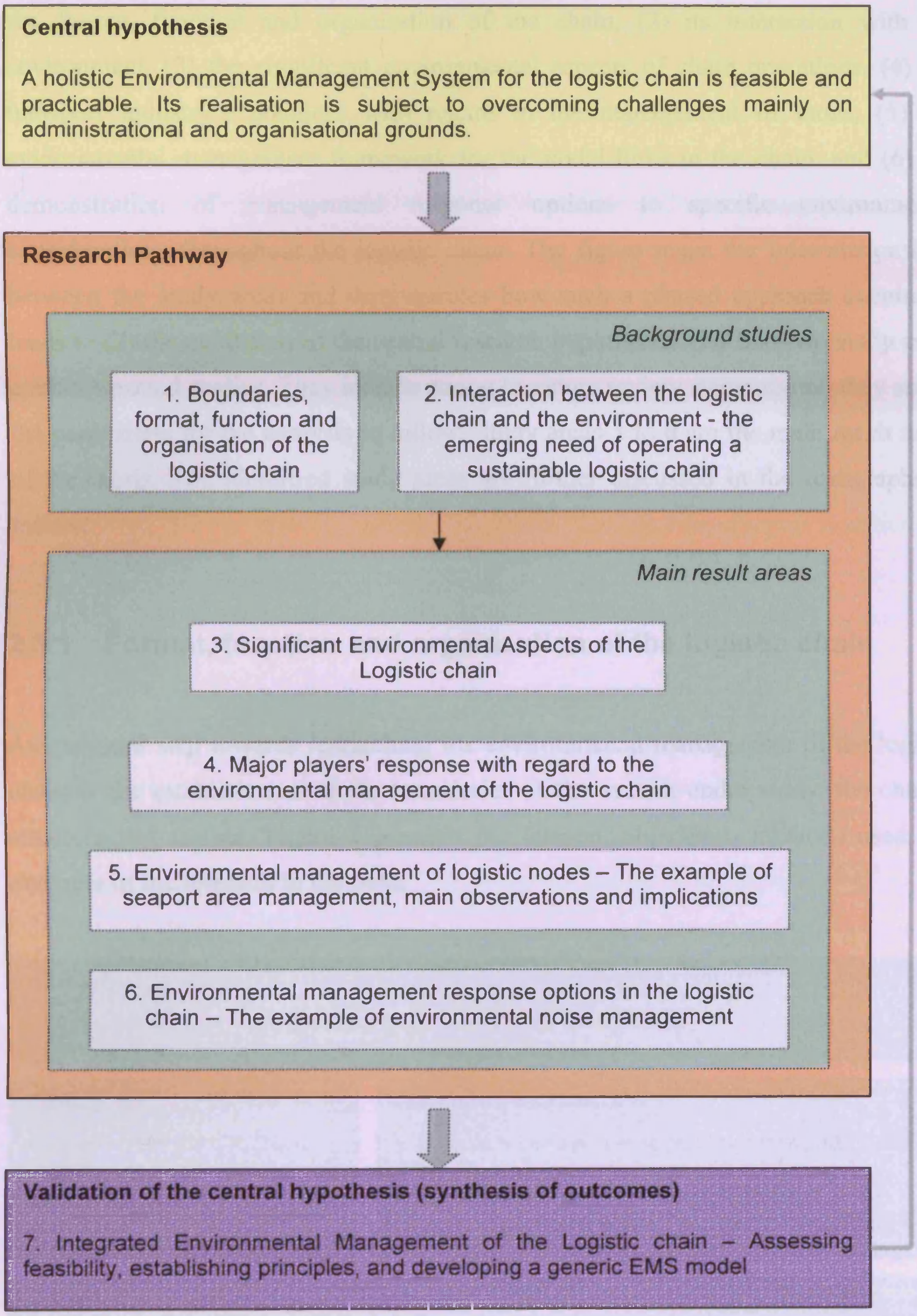


Figure 3: Research pathway and investigative line

In order to first examine the feasibility and practicability, and then establish the principles of an environmental management system for the logistic chain, the following conceptual steps and study areas were considered to be of significance: (1)

the format, function and organisation of the chain, (2) its interaction with the environment, (3) the significant environmental aspects of chain operations, (4) the transport industry's practices with regard to the management of those, (5) the environmental management framework for the nodal links in the chain, and (6) the demonstration of management response options to specific environmental considerations throughout the logistic chain. The figure maps the interrelationships between the study areas and demonstrates how such a phased approach eventually leads to (7) the validation of the central research hypothesis. The first two study areas are background studies. They include strong literature review elements and they set up the parameters for the analysis to follow. Study areas 3 to 6 are the main result areas of the thesis. The identified study areas are further discussed in the paragraphs to follow.

2.3.1 Format, function and organisation of the logistic chain

An essential step towards researching the environmental management of the logistic chain is the establishment of the boundaries of the system under study, the chain's structure and format. Figure 4 presents the interest, objectives, methods used and outcome of the research in the field.

Interest

The logistic chain, its components and the major players involved

Objectives

- Defining the logistic chain
- Analysing its components
- Discussing its organisation

Methods and approach

- Literature review (transport geography, transport management, logistics management)
- Personal communication with experts (industry, policy makers, academics)

Output

An understanding of the format, function and organisation of the logistic chain

Figure 4: Format, function and organisation of the logistic chain

The logistic chain, its components and the major players involved are dealt within chapter 3 of the thesis. The chapter is part of the literature review and specifically focuses in the fields of transport geography, transport management and logistics. The state of knowledge on the logistic chain is examined including its origins, definitions, key concepts, theories, ideas, major issues, debates and political standpoints. Sources of information include academic literature (benchmark papers on concepts and principles), industrial press (industrial practice and standards), mainstream sources and internet resources (quality assurance is necessary). Due to the dynamic characteristics of those science and management fields, personal communication with expects (industry, policy makers and academics), in the form of interviews, friendly talks and meetings, provided the means of validation for the established concepts. Overall, the study in the field provides a useful insight of the format, function and organisation of the logistic chain. It is demonstrated that the logistic chain is already a complex and highly dynamic system even without the environmental component.

2.3.2 Interaction between the logistic chain and the environment

The interaction between the logistic chain and the environment is the second core study area of the research pathway. Assessing the degree of sustainability of current transport systems is of significance as it demonstrates the rationale and the need to undertake research in the field of environmental management of the logistic chain. The main addressed questions are:

- How does freight transport impact on the environment?
- What is the environmental significance of modal choices?
- What is the impact of the trends in logistic strategies?
- Why current transport systems cannot be considered sustainable, what is the challenge?
- What is the response of the regulators to the challenge of sustainability?
- How could environmental management respond to the challenge?

Figure 5 gives an overview on how this study area is approached in chapter 4 of the thesis.

Interest

The interaction between the logistic chain and the environment

Objectives

- Conceptualising the chain's environmental impact
- Establishing the main environmental issues associated with freight transport
- Evaluating the significance of modal choices
- Evaluating the trends and impacts of logistic strategies
- Formulating the challenge of sustainability and discussing the concept of environmental management of the logistic chain
- Reviewing the regulative and legislative response framework

Methods and approach

- Literature review (environmental science, environmental management, environmental policy, transport and the environment)
- Personal communication with experts (industry, policy makers, academics)

Output

The range, scale and nature of environmental considerations and the challenge of operating a sustainable logistic chain

Figure 5: Interaction between the logistic chain and the environment

The study of those issues includes elements of literature review in the areas of environmental science, and both environmental and transport management and policy. With regards to the methods used, the same approach is followed as in the study of the format, function and organisation of the chain. The outcomes of the study include:

- An overview of the ways that the logistic chain impacts on the environment
- The formulation of the challenge of sustainability, that is the need to strike a balance between the positive socio-eco impacts of transport and its adverse environmental effects
- An overview of actual and potential policy response options

2.3.3 Significant environmental aspects of the logistic chain

The identification of the environmental aspects of logistic chain operations refers to the identification of those elements of the embraced activities products and services that might impact on the environment. Those elements are the ones that need to be addressed by the environmental management, and therefore, the identification process can be seen as the first essential step towards the development of an environmental management framework for the logistic chain.

Interest

The range of environmental aspects associated with logistic chain operations

Objectives

- Demonstrating the range and nature of potential environmental impacts
- Identifying the causal mechanisms of environmental impacts
- Identifying the elements of activities, products and services that may impact on the environment and therefore need to be addressed by environmental management

Methods and approach

- Literature review (environmental science)
- Environmental management based methodologies in analysing the environmental effects of the logistic chain (activity-aspect-impact analysis)

Output

An analytical tool for identifying and demonstrating the significant environmental aspects of the logistic chain

Figure 6: Identifying the significant environmental aspects of the logistic chain

The process of identifying the environmental aspects of the logistic chain is dealt within chapter 5 of the thesis and it is schematically presented in figure 6. Following an established management based methodology, suggested by all major environmental management standards such as ISO and EMAS, an analytical tool is developed that identifies, demonstrates and forms the basis for the management of the significant environmental aspects of the logistic chain.

2.3.4 Major players' response to the sustainability challenge

After establishing the significant environmental aspects of the logistic chain, another emerging area of research interest is the actual response of the major players as they face the challenge to manage those aspects and to operate a sustainable logistic chain. Figure 7 presents schematically the interest, objectives, methods, and outcomes of the study in this field.

Interest

The response of the major players as they face the challenge of controlling and operating a sustainable logistic chain

Objectives

- Theorising green logistic chains
- Examining the catalysts for actions and the forcing mechanisms
- Demonstrating and evaluating major players' good practices with regard to the environmental management of the logistic chain
- Demonstrating and evaluating collaborative industry driven initiatives

Methods and approach

- Personal communication with experts (transport industry, shippers, trade organisations, policy makers, academics)
- Survey (web-based research and interviews) on selected major players in the logistic chain on their interest and practices with regard to the environmental management of transport
- Survey (web-based research and interviews) on industry's collaborative initiatives bringing together different players in operating a sustainable logistic chain

Output

An overview of good practice examples and evaluation of their potential for improving the environmental performance of the logistic chain

Figure 7: Major players' response to the sustainability challenge

The major players' response to the sustainability challenge is discussed in chapter 6 of the thesis. The focus is placed on both the identification of those catalysts and triggering mechanisms that guide the major players' actions, and on those actions themselves. Demonstrating common and good or best practices of the main industry players, namely shippers, carriers, and third party logistic service providers, is the main objective. The methods used consisted of social science techniques such as surveys and personal communication in the form of interviews, meetings, and expert panels. The methods are analytically presented and justified in chapter 6. The outcome is an overview of good practice single firm or collaborative examples and the evaluation of their potential for improving the environmental performance of the logistic chain.

2.3.5 Environmental management of logistic nodes

While examining the components of the logistic chain, the critical role of logistic nodes as key links in the chain is highlighted. The research on the environmental management of logistic nodes emerges then as a necessity in the phased development of the research pathway towards the feasibility assessment and potential establishment of an environmental management framework for the whole chain. Firstly, logistic node operations embrace significant environmental aspects and influence the environmental performance of the whole chain. Secondly, the main observations and findings regarding environmental management practices in areas that are characterised by a high degree of complexity, such as seaport areas, and where the integration of multiple activities, interests and players is a reality, could be significant in the process towards broader chain integration. The skeleton of the research on logistic nodes is schematically presented in figure 8.

Interest

Discussing the role and contribution of logistic nodes, especially seaports as the major ones, in the operation of sustainable logistic chains

Objectives

- Demonstrating the significance of seaports as major logistic nodes
- Examining progress and best practice in seaports' environmental management
- Discussing the concept of seaports acting as "facilitators" in the logistic chain and the arising opportunities in terms of environmental performance
- Examining whether experiences from integrated seaport area management could be transferable in integrated logistic chain management.

Methods and approach

- Statistical meta-analysis of seaport environmental management and performance data
- Survey (web-based research and interviews) on selected European and World seaports on their interest to undertake a role of "facilitating" the operation and the environmental management of the logistic chain
- Personal communication with experts (interviews, meetings, experts panel)

Output

Current practice and future trends regarding the contribution of logistic nodes, and seaports in specific, to the environmental management of the logistic chain

Figure 8: Environmental management of logistic nodes – the example of seaports

The environmental management of logistic nodes is discussed separately within chapter 7 of the thesis. The focus is placed on seaport areas that are selected as the major and arguably most complex between the logistic nodes. A multi-method approach is used for answering the emerging research questions. It consists of qualitative (survey, interviews, meetings, experts panels) and quantitative (statistical analysis of primary and secondary data) social science based techniques. The synthesis of the outcomes provides an analysis of the evolution in port environmental management with an eye on the future and the potential for further integration of area and linear components in the logistic chain.

2.3.6 Environmental Management response options

The sixth study area in the research pathway is the actual demonstration of management response options to environmental challenges throughout the logistic chain. For this purpose, environmental noise is selected as one of the major environmental aspects of chain operations. The actual way that an environmental aspect, such as noise, is controlled in different levels and by different parties provides an understanding of its management and reveals the potential for environmental improvement via an integrated holistic approach. The research on environmental management response options focussing in particular on the example of noise is discussed within chapter 8 of the thesis. The following figure 9 presents the objectives, methods used and outcomes of the research in the field.

Interest

Environmental noise management as a demonstrative example of management options throughout the logistic chain

Objectives

- Demonstrating the causal mechanisms of environmental noise
- Demonstrating noise management options, tools and methodologies
- Demonstrating and evaluating noise monitoring, predicting and mapping in seaport areas

Methods and approach

- Noise monitoring and measurement
- 3-dimensional mapping
- Simulation (noise mapping software)
- Personal communication with experts (interviews, meetings, experts panel)

Output

An overview of noise management tools, methods, and response options that are applied in seaport areas and throughout the logistic chain

Figure 9: Environmental Management response options – the example of noise

The methods used were mostly operation research oriented and involved noise monitoring studies, 3D noise mapping, and noise simulation using current (2007) state-of-the-art equipment and software. The study benefited from the collaboration with an extensive panel of experts in noise management (NoMEPorts project). The main outcome is the demonstration, and evaluation of analytical tools, methods and response options for noise management in seaport areas throughout the logistic chain.

2.3.7 Integrated environmental management of the logistic chain

The concluding study area of the research pathway is the validation of the central research hypothesis via the synthesis of the outcomes of both the background studies and the result areas that have been presented in the preceding paragraphs. This synthesis takes place within chapter 9 of the thesis. The aim is to assess the feasibility and establish the principles of an environmental management system for the logistic chain. The following figure 10 gives an overview of the objectives, methods and outcome of the study.

Interest

The integrated environmental management of the logistic chain

Objectives

- Assessing the feasibility and practicability of integrated logistic chain environmental management
- Establishing the principles, challenges and preconditions
- Developing a generic EMS model

Methods and approach

- Synthesis of the results of the different study areas
- Personal communication with experts (interviews, meetings, experts panel)

Output

A generic EMS model that can deliver integrated environmental management of the logistic chain

Figure 10: Integrated environmental management of the logistic chain

The end result of chapter 9 and the thesis itself is a generic model of an environmental management framework or system for the logistic chain, specifically designed to deliver continual environmental improvement, thus driving a gradual move towards the operation of more sustainable intermodal transport systems.

2.4 Conclusion

This chapter discussed the research philosophy and approach. The central research hypothesis was formulated and the phased approach of the research pathway was presented and explained. The following chapter focuses on the concept of the logistic chain. It provides an overview of the format, function and organisation of the chain.

3 The Logistic chain

As established in the introduction, the literature review (chapters 3 and 4) maintains a broad scope aiming towards outlining and discussing the main elements of the logistic chain. In this way, the boundaries of the logistic chain system are defined providing the holistic framework against which the findings of the specific result areas of the thesis (chapters 5-9) will be projected and validated. This chapter drives the analysis of the concept of the logistic chain by summarising the literature review outcomes mainly in the fields of business and transport management. The components of the chain, its physical links and its main embraced functions are discussed and analysed. The focus is then placed on the major players, the dynamics between them, and the implications arising with regard to the organisation of the logistic chain. The chapter is divided in three sections, namely: concept orientation, chain components and chain organisation. Its aim is to provide an understanding of the format, function and organisation of the logistic chain, the central concept of the thesis.

An essential step towards researching the environmental management of the logistic chain is the establishment of the boundaries of the system under study, the chain's structure and form. The analysis that follows demonstrates the complex and highly dynamic nature and organisation of the logistic chain. Although the environmental component is intentionally ignored in this chapter, to be analytically and separately studied in chapters 4 and 5, the analysis has implications with regard to the environmental management. The logistic chain is already a highly complex system even without the environmental component.

3.1 Concept orientation

One of the most significant paradigm shifts of modern business management is that individual businesses no longer compete as solely autonomous entities, but rather as supply chains (Christopher 1998). Business management has entered the era of inter-network competition. Instead of brand versus brand or store versus store, it is now suppliers-brand-store versus suppliers-brand-store, or supply chain versus supply chain (Lambert 2001). The supply chain may be defined as the network of multiple businesses and relationships (Lambert 2001) that guide the flows of goods and information from raw material to end consumers, from suppliers to customers. The chain embraces all the flows (material, cash, resource, and information) and functions (including manufacturing, assembly, transport, cargo handling and warehousing). The target is to enable the "seamless supply chain" in which all players think and act as one so as to satisfy the end customer in terms of service, quality, total lead-time, total cost and health, safety and the environment (The Logistics Systems and Dynamics Group (LSDG) 2004).

The supply chain is not a chain of businesses with one-to-one relationships, but a network of multiple businesses and relationships. Executives are becoming aware that the successful co-ordination, integration and management of key business processes across members of the supply chain will determine the ultimate success of the single enterprise (Hagelaar and van der Vorst 2002). Figure 11 (Stank and Goldsby 2000) is a representation of the supply chain and its main components. The gears represent the multiple supply chain entities in a channel. Each gear is dependent upon its predecessor to keep the machine in operation. The supply chain is only as strong as its weakest component. Should any one gear fail, the entire machine fails (Stank and Goldsby 2000).

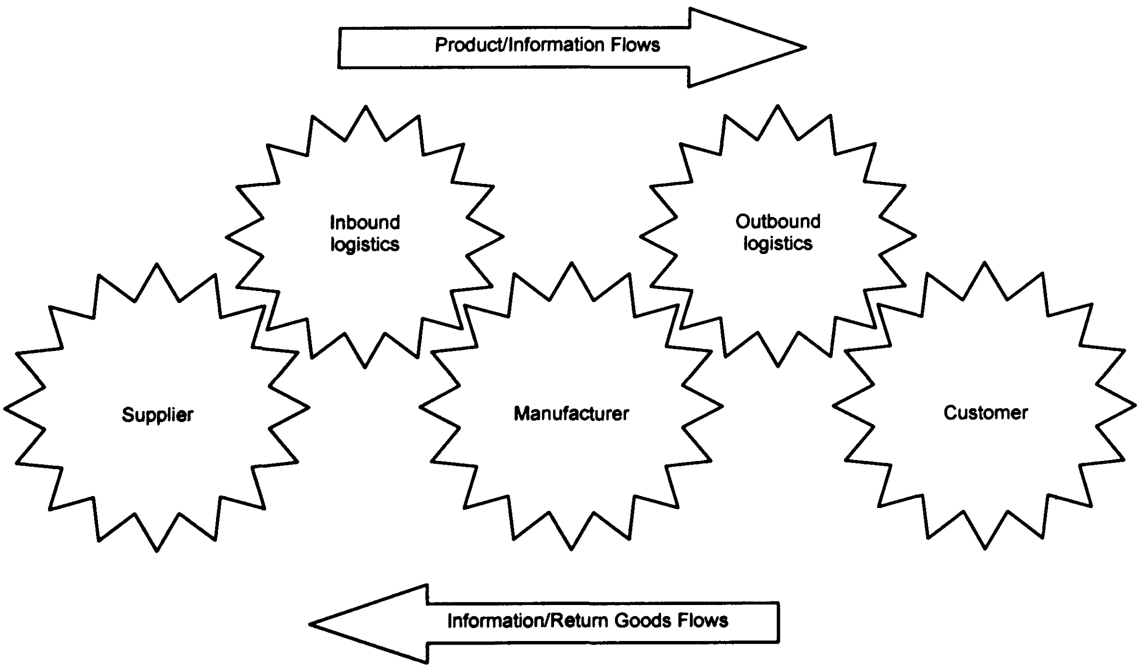


Figure 11: The Supply Chain

Effective management is required in order to synchronise the different entities of the network enabling "the seamless supply chain" as defined above. Logistics Management is that part of Supply Chain Management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements (Council of Logistics Management 2004). Logistics is business but furthermore it can be also seen as the art of optimising production and distribution (Karamitsos 2004).

Transport in figure 11 is represented by the entities of inbound and outbound logistics. Inbound logistics covers activities associated with the receiving, storing, and movement of raw materials. Management decisions involve freight consolidation, mode and carrier selection, materials handling and warehousing. Outbound logistics refers to physical distribution activities such as collecting, storing, and distributing products to buyers and involves warehousing, materials' handling, network planning and management, order processing, and vehicle scheduling and routeing. The main difference between inbound and outbound logistics is the different product characteristics. Inbound logistics deals with raw materials while outbound logistics typically deals with finished goods. It can be argued that outbound logistics has more options and is more complicated than inbound due to the higher product values and stringent delivery requirements (Wu and Dunn 1995).

Transportation often represents one of the supply chain's weaker elements (Stank and Goldsby 2000). Transportation management accounted for 57% of US firms' logistics costs in 1997 (Berg 1998). Additionally, transport is the single largest source of environmental hazards in the logistics system (Wu and Dunn 1995). From an environmental policy perspective logistics management is offering an opportunity towards a more sustainable, more efficient, less polluting and less demanding on resources transport system (Karamitsos 2004).

Focusing on transportation as a critical element of the supply chain;

> *"the logistic chain may be defined as the network of successive links involved in the transport and placement of goods (Eye for Transport 2004)"*

Figure 12 is a representation of the logistic chain and it is developed after the conceptual work by (Taylor 1997; Stank and Goldsby 2000; Lambert 2001). The chain consists of successive links between movement patterns (transport modes) and nodal points (logistic nodes) in an integrative intermodal concept from point of origin to point of consumption. The chain embraces major functions such as transport, cargo handling and warehousing and flows of material and information. Freight is transported by a combination of transport modes and via a number of logistic nodes from supplier to manufacturer and then from manufacturer to end customers. Several parties are involved in this process and they work together in order to ensure an efficient logistic chain operation. The analysis of the components (movement patterns, logistic nodes, functions, and flows) of the logistic chain follows in section 3.2. The analysis of the major market players and their contribution in the organisation of the logistic chain is discussed in section 3.3.

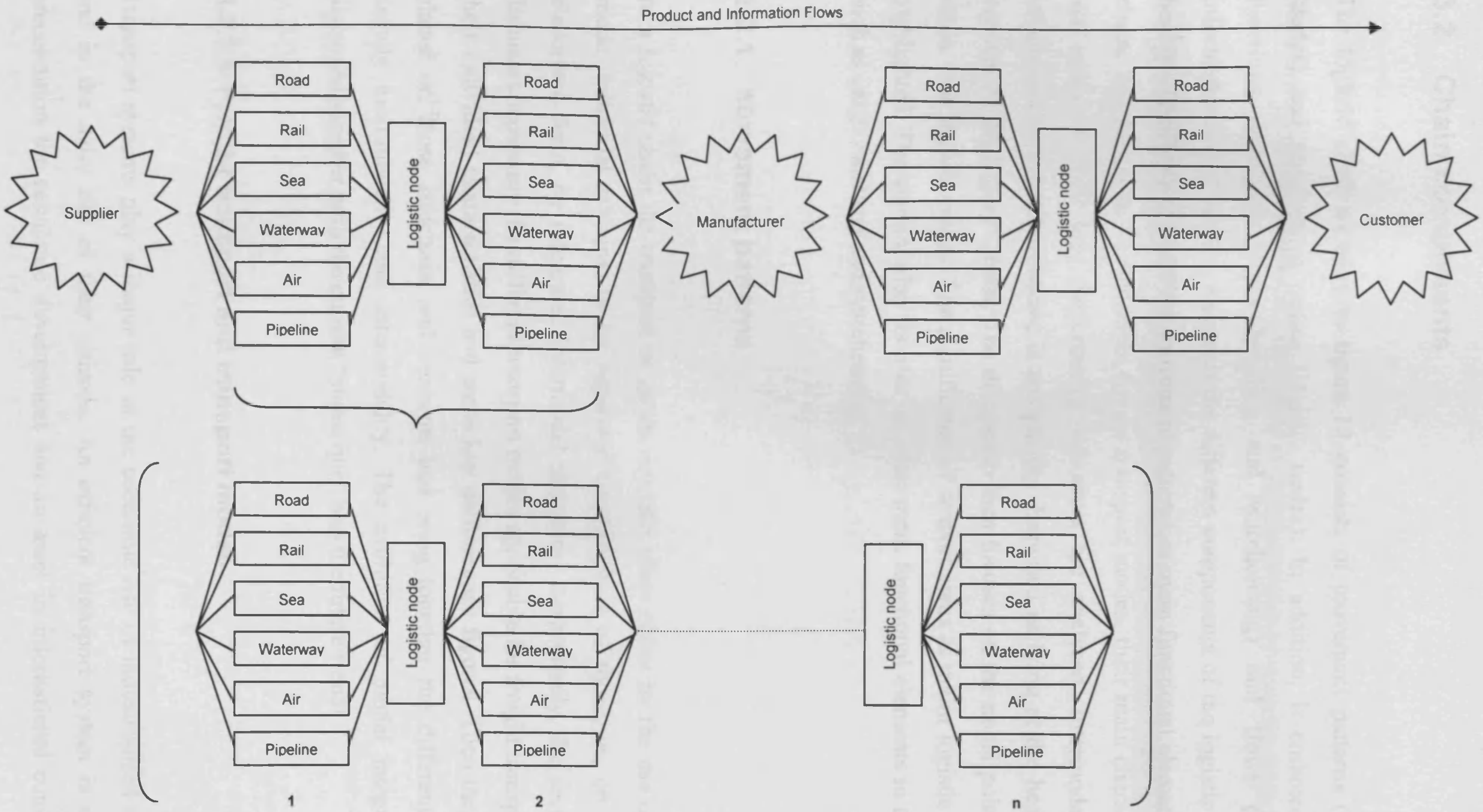


Figure 12: The logistic chain

After Taylor 1997; Stank and Goldsby 2000; Lambert 2001

3.2 Chain components

The logistic chain as seen in figure 12 consists of movement patterns (transport modes) and nodal fixed points (logistic nodes). In addition, it embraces major functions (transport, cargo handling and warehousing) and flows (material, information). This section discusses the different components of the logistic chain. It begins with the analysis of the movement patterns as main functional elements of the chain. In this context the different freight transport modes, their main characteristics and some of their key performance indicators are analysed. Intermodality, the integration of transport modes, is analytically discussed as lying at the heart of the concept of the logistic chain. The discussion then focuses on the nodal points in the chain - the logistic nodes. The significance of seaport areas as major logistic nodes is highlighted. The section also focuses on other main functional elements in the chain such as cargo handling and warehousing.

3.2.1 Movement patterns

In a logistic chain the transport of goods can take place either by the use of single-mode, unimodal systems, or by separated combinations of those, or, on its most elaborated form, by integrated intermodal structures. Respectively, the section first discusses separately the different transport modes applicable for freight transportation, their individual characteristics and some key performance figures. Then the focus is placed on those structures and concepts that bring together the different modes; namely multimodality and intermodality. The evolution of modal integration is discussed together with the current "status quo" and the future trends.

3.2.1.1 Freight transport and transport modes

Transport systems play a major role in the economic life of industrialised countries and in the daily life of their citizens. An efficient transport system is a crucial precondition for economic development and an asset in international competition.

Transport is essential for the functioning of modern societies. A well-developed transport system enables the free movement of goods, services and people, and promotes inter- and intra-regional communication (European Environmental Agency 2003).

In the European Union, the transport service industry accounts for about 7 to 8 per cent of the gross domestic product (GDP) (Stanners and Bourdeau 1995) and employed about 8.2 million persons in the EU-25 in 2004 (EC DG-TREN 2006 d). The freight logistics industry in the United Kingdom is responsible for some 6% of the GDP and employs in the region of one million people nationwide (Williams 2007). The volume of freight transport has been growing in the European Union at an average yearly rate of 2.8% for the period between 1995 and 2005 (EC DG-TREN 2006 d).

Transport comprises various modes which together constitute a system or a chain. Collectively, transport meets the demand for the movement of people and goods but the nature and the circumstances of these demands differ widely (Faulks 1999). There are six major transport modes used for freight transport:

- Road transport
- Rail transport
- Sea transport
- Inland waterway transport
- Air transport
- Pipelines

Road, rail, inland waterway and pipelines are often grouped under the term land or inland transport modes. Each transport mode has its own characteristics which determine suitability for the conveyance of different commodities or people over different journeys. The main features that motivate modal choice in freight transportation are cargo characteristics (type, weight and size), required speed of delivery, destination and cost (Faulks 1999; Freight Forward International 2004).

The following paragraphs summarise some of the key characteristics and performance indicators of the different transport modes.

3.2.1.1.1 Road transport

Figure 13: Road transport

The main characteristic of road freight transport is its high flexibility and its unique ability to provide door-to-door services. From a logistic chain point of view it is hard to imagine any transport chain without the use of road transportation. It is argued that travel by any transport mode requires travel by road at the extremities (Faulks 1999). Road transport (figure 13) is suitable for all types of traffic and cargo and its presence is strong in local, regional, national, international and intercontinental logistic chains.

The whole economy and society depends heavily on an efficient road transport network. In the European Union road transport services account for 1.6 % of the GDP and employ around 4.5 million people (EC DG-TREN 2007 e). The road freight transport industry alone employed more than 2.5 million people in 2004 (EU-25). It is the most commonly used mode for freight transport inside the European Union with more than the 44 % of the goods being transported by trucks (EC DG-TREN 2006 d).

Road transport clearly dominates the European inland freight transport market accounting for the 72.6% of the total volume transported by the four land transport modes (road, rail, inland waterways and pipelines) in EU-25 in 2005 (EC DG-TREN 2006 d). The comparative figure from the United States of America is significantly reduced at around 33% indicating a more balanced inland transport market. The sector also shows the highest growth in absolute transported cargo volumes with an average yearly growth rate of 3.3% during the last decade (EU-25). Similarly, around 3% is the average yearly growth encountered in the U.S.A. in the decade from 1990 to 2000 (EC DG-TREN 2006 d).

3.2.1.1.2 Rail transport

Figure 14: Container train handling

Rail transport is characterised by a lower degree of flexibility in comparison to road transport. It makes use of specialised vehicles (locomotives and wagons) on specialised and limited networks (railways). Specialised terminals are also required together with control and signalling systems to ensure the safe flow in the railway network. Although not limited by nature in terms of types of traffic and cargo, rail transport is considered to be more suitable for coping with high density cargo flows, heavy surges of traffic and over relatively long distances (Faulks 1999; OECD Environment Directorate 2002). This is due to its high capital, maintenance and operational costs.

Although rail transport employs Europe-wide around a million people (EC DG-TREN 2006 d), the sector has seen a decline for more than thirty years now, especially in the area of freight transport (EC DG-TREN 2007 a). Rail's share of the total freight market has declined considerably, primarily due to strong competition from road haulage (OECD Environment Directorate 2002). The decline can be observed not only in the relative modal shares but also in terms of absolute volumes figures. In comparison with the absolute figures of 1970, rail freight transport volumes dropped by about 10% and 20% for the 15 and the 25 member states respectively in 2005 (EC DG-TREN 2007 a). This decline in absolute volumes transported by rail in combination with the overall freight transport growth during the same period led to the decline of the modal share of rail transportation to the currently observed levels of 10% in 2005 (EU-25) (EC DG-TREN 2006 d).

With regard to the inland European freight transport market it is observed that the share of freight transport by rail for all land transport modes (road, inland waterways, rail and pipelines) dropped from 30% in 1970 to 13.2% (EC DG-TREN 2007 a) and

16.8% (EC DG-TREN 2006 d) for the 15 and the 25 EU member states respectively in 2004. The comparative modal share of rail freight transport in the USA is substantially higher accounting for as much as 42.3% in 2003 and leading the inland (four land transport modes) freight market (EC DG-TREN 2006 d).

3.2.1.1.3 Maritime transport

Figure 15: Maritime transport of containers

Maritime or sea transport is the oldest mode of transport (Faulks 1999). With regard to its geography the largest part of sea transport trade is international and intercontinental. Shipping is responsible for transporting 90% of the total volume of world trade (Vidal 2007). Seen as a traditionally slow mode, sea transport is eminently suitable for the conveyance of bulk and containerised (figure 15[1]) cargo over relatively long distances. Geographical reasons make it in certain cases the only applicable mode (together with air). Although there are high capital costs associated in terms of vessels and specialised terminals (ports), shipping is characterised by its economic and commercially attractive rates. Additionally, shipping has always been the transport mode least subject to economic regulations or public ownership, so that it is largely unaffected by many of the deregulation and privatisation preoccupations of other modes (Silverleaf and Turgel 1993).

Considering its geography, history and globalisation, the European Union is still very dependent on the maritime transport. Nearly 90% of its external trade and around 40% of its internal trade goes by sea (EC DG-TREN 2007 b). On the whole, nearly 2 billion tons of freight is loaded and unloaded in EU ports each year. Maritime companies belonging to European Union nationals control nearly 40% of the world

---

[1] Photo retrieved from http://www.providence.edu/polisci/students/megaport/ContainerShips.htm, on February 2007

fleet and the majority of EU trade is carried on vessels controlled by EU interests. The maritime transport sector - including also shipbuilding, ports, fishing and related industries and services - employs some 3 million people in the European Union (EC DG-TREN 2007 b). Finally, the cargo volumes transported yearly by the maritime sector have shown an average growth of 3% for the decade from 1995 to 2005 (EU-25) being close to the one of road transportation (EC DG-TREN 2006 d).

3.2.1.1.4 Inland waterway transport

Inland waterway transport is a traditionally slow mode of transport primarily suitable for containerised (figure 16[2]) cargo and non-perishables, no urgency goods, such as coal, petroleum, grain, timber, chemicals, iron and steel. The traffic is routed through specialised terminals (ports and inland ports) which are connected with a waterway system. The viability of inland waterway transport depends on the width and depth of the waterway, hence the size and capacity of the vessels in use (Faulks 1999). In comparison with other modes which are often confronted with congestion and capacity problems, inland waterway transport is characterised by its reliability and has a major unexploited capacity (EC DG-TREN 2007 c).

Figure 16: Inland waterway transport

Europe's geography appears to favour an inland waterway transportation system. More than 35.000 kilometres of waterways connect several cities and industrial regions. 18 out of 25 Member States have inland waterways, 10 of which have an interconnected waterway network (EC DG-TREN 2007 c). Fluvial transport plays a vital role in transport through the European North-west. In the hinterland of the largest seaports of the EU, the modal share of inland waterway transport can reach up to 43% (EC DG-TREN 2007 c).

---

[2] Photo retrieved from http://www.jbittner.com/germany/archives/2005_07_01_archive.html, on February 2007

Although the sector's fleet and infrastructure has been modernised continuously in the last 15 years (EC DG-TREN 2007 c), the modal share of fluvial freight transport in the whole of Europe accounted for some 3.3% of the total in 2005 (EC DG-TREN 2006 d). The observed average yearly growth of the sector, in absolute cargo volumes transported, at a rate of 1% for the decade from 1995 to 2005, appears to be almost three times slower than the total freight transport growth in the same period and therefore gradually reduces the modal share of fluvial transport over time (EC DG-TREN 2006 d).

When examining the inland freight transport market (four inland transport modes), the modal share of fluvial transport accounted in Europe for the 5.4% of the total in 2006 (EC DG-TREN 2006 d). The comparative figure in the USA was 8.6%.

3.2.1.1.5 *Air transport*

Figure 17: Milan Airport

Air transport or aviation is characterised by its very high speed, its flexibility and the direct routes that overcome other disadvantages such as the high capital and maintenance costs and the capacity limits. With regard to freight it is mainly applicable for transporting goods over long distances and therefore it is of strategic international and intercontinental importance. Air transport is also applicable for the transport of high value goods over shorter distances. Although only 5% of world freight goes by air it represents around 25% in value (Noble 1999). Geographical reasons make it in certain cases the only applicable transport mode together with shipping. Air transport makes use of specialised terminals (airports – figure 17), which are demanding in land take and are associated with time consuming terminal formalities (Faulks 1999).

Air traffic has definitely recovered after the temporary slowdown of its growth following the down turn of the world economy in general and the terrorist attacks on 11 September 2001. Estimates are that air traffic will grow by 4% a year over the next 15 years, leading to a nearby doubling of traffic by 2020 (EC DG-TREN 2007 d). Currently air freight transport in Europe has a modal share of only 0.1% and grows at a rate similar with the general freight transport growth of 2.8% yearly (EC DG-TREN 2006 d).

3.2.1.1.6 Pipelines

Figure 18: Above ground pipeline

Pipelines are unique amongst the transport modes in being at the same time the transport mode and the carrying unit. They are commonly buried in a trench with about one meter of earth cover but they can also be laid above ground in certain cases (figure 18). Submarine pipelines are also widely applicable. Pumping stations are necessary to "propel" the commodity through the pipe and are, therefore, an integral part of the pipeline installation. There are a variety of prime movers such as steam turbines, electric motors and diesel engines. Long lines use a network of intermediate boosting stations (Faulks 1999).

Pipelines are used for transporting liquids, hazardous fluids (gas, petroleum), semi-solids and solids either suspended in liquid form or pneumatically, satisfying the sustained demand between fixed points. Their most common use is connecting oilfields with refining or shipping centres. Pipelines are selective in grouping materials for conveyance through the same tube (e.g. paraffin, beer). Although considered an inflexible transport mode as their position cannot easily be altered, pipelines offer some unique advantages such as reliability of traffic, absence of packing and cargo handling, lack of return load problems, light demand on man power and being a favourable solution in harsh environments (e.g. cold, desert, tropical conditions) (Faulks 1999).

With regard to their modal share, pipelines conveyed 3.4% of the total European freight volume in 2006. In the European inland transport market (four inland transport modes) conveyance through pipelines accounted for 5.5% of the total in 2005. In the USA the relevant percentage is three times higher accounting 15.6% of the total in 2003 (EC DG-TREN 2006 d).

3.2.1.1.7 Comparative matrix

After discussing some of the major characteristics and performance indicators of the different transport modes, the matrix (table 1) in this section presents a comparison of those characteristics in selected areas of interest. The selected areas of comparison (rows of the matrix) vary from general ones, such as geography and speed, to technical, such as vessel capacity, terminals, cargo handling, and nature of transported goods, and economic ones, such as cost and viability. The matrix therefore presents an overview of the performance of the freight transport modes in different fields.

In addition, the matrix highlights some of the parameters that are taken into consideration during the decision making process of selecting which transport mode is more appropriate for the conveyance of a specific type of cargo between two known geographical points. For example, hazardous cargo, depending of course on its nature, quantity and route, might be more efficiently conveyed appointing inland waterway transport or pipelines, which are characterised by higher safety records than road transport. In other cases, when the priority is placed on speed or door-to-door services, a combination of air and road transport might be the most appropriate solution.

Table 1: Main characteristics of freight transport modes

	Road Transport	Rail Transport	Pipeline	Sea Transport	Inland Waterway Transport	Air Transport
Way	Specialised (roads)	Specialised (railway)	Specialised (pipes)	Natural (water)	Natural (water)	Natural (air)
Costs	Relatively low operational cost Easy to obtain a vehicle	High capital cost High maintenance cost	High capital cost Low operating costs Light on manpower	High capital cost Reasonable attractive rates	High capital cost Reasonable attractive rates	High capital and maintenance costs
Status	Freely used by all types of traffic	Private way Specialised vehicles Complete control of all movements	Both private and public functions	Both private and public functions	Both private and public functions	Both private and public functions
Speed	Severe speed limits Congestion (unreliable journey times)	Fast Reliability in time terms	Reliable traffic	Traditionally slow mode	Slow mode	Very fast Direct routes
Flexibility	High Unique physical ability to provide a door-to-door service	Naturally inflexible in comparison to road transport	Inflexible, its position cannot easily be altered Selective in grouping materials for conveyance through the same tube (e.g. paraffin/beer)	Limited flexibility	Limited flexibility	Flexible - New links can be easily and speculatively introduced
Viability	The dominant inland transport mode	Density and distance are required features due to the high cost In many cases socially and not commercially driven	Sustained demand between fixed points Unique being in the same time the transport mode and the carrying unit	Bulk carriers, containers ships and tankers carry 90% of the world trade Oldest mode of transport	Viability depends on the width and depth of the waterway, hence the size and capacity of the vessels	Increasing market shares

Vessel capacity	Capacity limits	High	High	High	Depends on the width and depth of the waterway	Capacity limits
Terminals / Cargo handling	No transfer in terminals required	Specialised terminals Time consuming commodities handling	Absence of handling No packing No return load problems	Specialised terminals Time consuming loading and unloading Intermodality of containers	Specialised terminals	Specialised terminals Extravagant in land take Time consuming terminal formalities
Nature of goods	All types of goods	Suitable for coping with heavy surges of traffic	Hazardous fluids (Gas, petroleum) Semi-solids, solids either suspended in liquid form or pneumatically	Containerised cargo Eminently suitable for the conveyance of bulk cargoes	Non-perishable / no urgency goods (Coal, petroleum, grain, timber, chemicals, iron, steel)	High value goods Goods over long distances
Geography	Door-to-door service Local, national, international, intercontinental Travel by any mode requires carriage by road at the extremities.	Frequency, density and relatively long distances	Favourable in harsh environments (cold, desert, jungle) Main use: Connecting oilfields with refining or shipping centres	Large part of sea borne traffic is international Long distances Natural reasons make it the only applicable mode (with air) in many cases	Traffic routed through ports and inland ports connected with a waterway system Traffic conveyed to and from waterside premises	Appropriate for long distances Strategic international, intercontinental importance Natural reasons make it the only applicable mode *(with sea) in many cases*
Health and Safety	Highest fatalities record between the transport modes	Specialised signalling, all the necessary apparatus to ensure safety	Superior safety records	Health and safety considerations during loading and unloading	*High degree of safety, in particular when it comes to the transport of dangerous goods*	Extensive system of navigating aids is required

The matrix synthesises data from the following sources: (Silverleaf and Turgel 1993; Faulks 1999; EC DG-TREN 2003; EC DG-TREN 2007 c)

3.2.1.2 Intermodal transport

Apart from the separate transport modes, while examining the components of the logistic chain it is important to note the core significance of modal integration as a key element for the transportation of goods from point of origin to point of consumption under a door-to-door framework. Modal integration is addressed by the concept of intermodality which lies at the heart of modern transportation systems. Logistics and supply chains depend at least in part on the advances that have been made over the last 50 years in bringing together separate modal systems into intermodal structures. Those advances have been so profound that they are characterised as revolutionary in the intermodal transport literature (Muller 1998; Slack 1998; Slack 2001). The linkage of containerisation with the through-transport concept has resulted in cargo flows being organised from door-to-door across several different modes (Slack 1998). It can be confidently predicted that intermodality is one of the forces that will help shape the world economy of the 21st century (Slack 2001).

3.2.1.2.1 Interpretations of multimodality and intermodality

In reviewing intermodal transport literature, the first observation that can be made is that no commonly accepted definition exists (Taylor and Jackson 2000; Bontekoning, Macharis et al. 2004). Table 2 lists some of the different definitions encountered in the literature. It is argued that the research field in intermodal transportation is in the pre-paradigmatic phase (Bontekoning, Macharis et al. 2004). Typical for a research field in the pre-paradigmatic phase is the lack of a consensus definition and a common conceptual model, that is the case of the intermodal freight transportation research field. The purpose of a common definition and conceptual model is to provide integrated frameworks for the analysis of the intermodal transport system in a methodical fashion.

Table 2: Definitions of intermodal transport

Source	Definitions of Intermodal Transport
(Jones, Cassady et al. 2000)	The shipment of cargo and the movement of people involving more than one mode of transportation during a single, seamless journey
(Southworth and Peterson 2000)	Movement in which two or more different transportation modes are linked end-to-end in order to move freight and/or people from point of origin to point of destination
(Hayuth 1987)	The movement of cargo from shipper to consignee using two or more different modes under a single rate, with through billing and through liability
(TRB 1998)	Transport of goods in containers that can be moved on land by rail or truck and on water by ship or barge. In addition intermodal freight usually is understood to include bulk commodity shipments that involve transfer and air freight (truck-air)
(Ludvigsen 1999)	The movement of goods in the same load-carrying unit, which successively use several transport modes without handling of goods under transit
(United Nations Economic Commission for Europe Statistical Division and European Union Eurostat 1997)	The movement of goods in one and the same loading unit or vehicle, which uses successively several modes of transport without handling the goods themselves when changing modes
(Muller 1995)	The coordinated transport of goods in containers or trailers by a combination of truck and rail, with or without ocean-going link
(Boske 1998)	Intermodality is a process of transporting freight by means of a system of interconnected networks, involving various combinations of modes of transportation, in which all the components parts are seamlessly linked and efficiently coordinated
(Panayides 2002)	Intermodal transport is the transport of unitised loads by the coordinated use of more than one transport mode so that the comparative advantages of the modes are maximised and the transport chain is guided as one unity
(D'Este 1996)	The practice of using more than one mode of transport in a co-ordinated and seamless way is usually called intermodal transport, but is also known as multi-modal transport, combined transport and through-transport
(Slack 2001)	Intermodal transport may be defined as being those integrated movements involving at least two different modes of transport under a single through rate

Although some of the above referenced definitions present similarities, it can be generally observed that there are various interpretations of the term "intermodal transport". An explanation for this variety of interpretations can be attempted by clarifying the semantic difference between multimodal and intermodal transport. Research suggests that there is confusion in differentiating the two terms (Slack 1998).

Multimodal transport refers to the flow of goods involving more than one transport mode, but it is characterised by essentially separate movements involving different modes. Multimodal transport existed for millennia but due to its disadvantages in comparison with single mode systems, such as transferability challenges and terminal handling costs, has been traditionally covering trips when the transfer from mode to mode was unavoidable (Slack 2001). Multimodal transport has been, and is, the common practice for a large proportion of all goods movements, such as for instance maritime cargo flows that require inland movement by road, rail, pipelines or barges, and rail shipments that require pick-up and delivery by road (Slack 1998).

In contrast with multimodal transport, intermodal transport is the integration of shipments across the modes (Slack 2001). The goal of intermodal transport is to remove the barriers to cargo flows which are inherent in traditional modal systems. Those include the technical limits of transferring freight between modes and the organisational and legal constraints imposed by separate rates and bills of lading. The ultimate aim is to provide a seamless system, in which the relative advantages of each mode are combined to produce the most efficient door-to-door services (Hayuth 1987). Therefore, intermodal structures, apart from the presence and use of more than one transport mode, embrace two additional key characteristics; the transferability of the transported items and the provision of door-to-door services. Intermodal transport implies that the transfer from mode to mode is performed in a single loading unit without handling the goods themselves. Fully developed intermodal systems require organisational structures that provide single liabilities, through-bills of lading and therefore integrated services throughout the entire transport chain (Slack 1998).

3.2.1.2.2 Evolution of intermodality

In examining the history of intermodal transportation it can be noticed that the development of its three key characteristics - the use of more than one transport mode, the transferability of a single loading unit and the provision of integrated door-to-door services – did not occur in parallel or in a fully integrated manner. As mentioned above, multimodality, the movement of freight using more than one transport mode, is as old as transport itself. The transferability of the unit load is an element essentially related to technological development and it has been largely achieved through containerisation, by means of which cargoes are placed in steel boxes of standard dimensions (Slack 1998). It has been since mid-fifties that the container and the container ship led the way to the increased use of intermodal transport and technological progress and innovations have been continuous since (Muller 1998). The period after the introduction of the container is characterised as a first intermodal "revolution" and it is perceived as reaching a certain state of maturity in the early 1990s (Slack 1998; Slack 2001). The second, and arguably more important intermodal "revolution", is related to the legal, technical and procedural developments that introduced the through-transport concept enabling the establishment of integrated door-to-door intermodal services (Hayuth 1987; Muller 1998; Slack 1998). Although that integrated intermodal services have and are being established in varying degrees in different parts of the world, the literature suggests that the second intermodal "revolution" has its origins in North America back in the early eighties (Muller 1998; Slack 1998; Slack 2001).

That second phase of development is characterised by placing the focus on the transport process, administration and communication between the partners in the transport chain. It is considered in the literature as the critical phase in the evolution of intermodal transportation. As early as 1987, Hayuth (Hayuth 1987) states that "as long as the transport chain is made up of a series of separate links, each with their individual ownership, pricing and liability regimes, the organisation of shipping remains fragmented". According to Brian Slack (Slack 1998; Slack 2001) the through-transport concept, in which the organisation of trade is considered form door-to-door, is the key element of what he calls "true intermodality". Muller (1998) also argues that "successful" intermodal transportation is the result of managing the process of the supply chain system rather than focusing on the hardware. The viability of intermodal freight transportation depends on coordination, continuity, flexibility and reliability. By keeping the attention on the process, innovative ways of rethinking and reorganising the pieces of transport and supply-chain management process can lead to more efficient, comprehensive, and customer-responsive services (Muller 1998).

Table 3 summarises and discusses some of the benchmark events that influenced the development of intermodal transportation during the twentieth century. It can be noticed that developments until the early 80s mostly referred to the technical side (first phase of development).

Table 3: Key developments in intermodal transportation

Intermodal Developments	Description	Period
First vehicle ferries	Captain Townsend bought and converted an old minesweeper to cater for the new market of people who wanted to take their car with them on a Continental motoring holiday. Cars were loaded onto the Dover-Calais car ferry by crane	1920s
US railway with "piggyback"	Facing growing competition from the trucking industry, several US railroads began to offer services in which truck trailers were put on rail flat cars for delivery between distant cities. Truck trailers on rail flat cars (TOFC service)	1920s
First Roll-on Roll-off car ferry in Britain	The first dedicated Roll on Roll off ramps in the British Isles were built at Lame and Stranraer in 1938 to serve the first purpose built Ro Ro car ferry in Britain, The Princess Victoria which entered service in the summer of 1939.	1939
First containers	Malcolm McLean decided to put the freight being shipped from New York to Houston into boxes of standard dimensions and convert two World War II tankers to hold the containers	1956

Establishment of common dimensions for containers	The International Organisation for Standardisation (ISO) established common dimensions for containers of 20 or 40 feet long and 8 feet high, avoiding the proliferation of competing national standards	1964
First container ship employed in international commerce	Sea-Land vessel sailed from New York to Rotterdam	1966
Removal of former limits on intermodal control in the U.S.A.	Development of intermodal rail services from the West coast ports to inland markets	Early 1980s
Introduction of the double-stack concept in the U.S.A.	Containers were placed one on top of the other on a rail car	Early 1980s
Vertical integration of intermodal transport structures	Investments made in different modes and service capabilities primarily by ocean carriers. Integration of shipping and logistics businesses has resulted in the provision of a door-to-door service through carrier-owned or – directed connecting modes and in-house logistics functions and services	Early 1980s
EU Policy supporting intermodal transport	Significant increase of intermodal services in Europe	1990s
Developments of advanced logistics information systems	The new Web-based technologies enable a much quicker and more reliable management of all information flows and interaction between all parties concerned. The improved planning opportunities lead to possibilities for integrating slow and fast modes of transport into one integrated system that can guarantee that customer requirements are met.	1990s

Sources of data: (Slack 1998; Slack 2001; Panayides 2002; Tavasszy, Ruijgrok et al. 2003; Bontekoning, Macharis et al. 2004; Irish Ships 2004; The Other Side 2004)

3.2.1.2.3 Intermodality in the 21st century

Intermodality has evolved and is continually evolving with developments being both on the technical and the administrative and organisational side. Nowadays, in examining the freight transport market it can be noticed that in practice, intermodal transport is considered as a competing mode and can be used as an alternative to unimodal transport (Bontekoning, Macharis et al. 2004). It can also be observed that there is a specialised intermodal industry for both equipment and provided services. The following table 4 presents and describes the transferable loading units that are most commonly in use in modern intermodal networks and their characteristics.

Table 4: Main intermodal systems

Intermodal systems	Description	Mode integration	Market
Containers	Freight into standard dimension containers	Road – Sea – Rail - Inland	Dominating the intermodal market
TOFC	Truck trailers on rail flat cars	Road - Rail	Increasingly smaller market share
Roll-on Roll-off (RORO)	System of loading and discharging a vessel whereby the cargo is driven on and off by means of a ramp.	Road - Sea	Loading-unloading advantages but wasted space between decks
Roadrailer	A truck unit that can be placed directly onto rails by a set of retractable steel wheels incorporated on the trailer	Road - Rail	Small but very lucrative intermodal market niche

Data from: (Slack 2001; Eye for Transport 2004)

The concept of intermodal transport receives significant attention in the literature due to the advantages in modal integration for transport efficiency and sustainability. Emphasis is placed on the following research areas:

- Operational and technical integration of intermodal transport (Konings 1996)
- Administrative and information aspects (D'Este 1996)
- Shipper and global carrier expectations and requirements (Semeijn and Vellenga 1995)
- Economic integration and coordination of intermodal transport (Panayides 2002)
- Environmental impacts of intermodal transport (Rondinelli and Berry 2000)
- Development of intermodal transport (Slack 1998; Slack 2001)
- Multi-actor chain management and control (Muller 1995; Muller 1998)
- Intermodal transport as a separate research field (Bontekoning, Macharis et al. 2004)

- Liabilities in intermodal transportation (Asariotis 1998)

The evolution of intermodality is ongoing and there is still progress to be made towards the integration of the different modes and the through-transport concept. It can be said that the previously mentioned second intermodal "revolution" has not yet reached its state of maturity. Although the progress achieved is widely acknowledged, several researchers point out some main remaining challenges that need to be addressed.

Tavasszy and Ruijgrok 2003 call for technical and conceptual innovations that are fully synchronised, or even engineered together with logistic chains. They mention not only the field of ICT technologies but also others, such as for example, transport and cargo handling equipment and processes. Slack (2001) refers to the organisational challenges of integrated intermodal systems, such as the liability issue, the complicated documentation procedures, and the leadership and coordination in such a multi-actor environment. The multi-actor chain management and control is also pointed out by Muller (1998) with emphasis on the lack of qualified decision-makers and technical operators who can handle the challenges and opportunities associated with the business of intermodal transport. Awareness, notes Muller, is and will be a critical element of the industry. The goal is to develop organisations and services that can continue to identify, implement, and manage new, innovative, and efficient solutions that customers will need in order to survive and prosper in a challenging business environment (Muller 1998). With regard to the liability issue, research (Asariotis 1998; European Commission 2001 b; European Commission 2001 c) demonstrates that the present legal framework determining an intermodal carrier's liability for delay, loss of, or damage to goods consists of a confused jigsaw of international conventions designed to regulate unimodal carriages, diverse national laws, and standard term contracts. Those complex legal regimes governing intermodal transport need to be simplified.

The organisational and liability challenges in intermodal transport systems and the logistic chain are discussed further in section 3.3 on the major market players and their interrelationship.

3.2.2 Logistics nodes

Logistic chains spin their webs over continents, seeking to maintain the movements of goods, information and funds. Products travelling great distances to reach their eventual markets have to halt somewhere though, often to meet up with other goods that have been manufactured elsewhere. Those halt points in cargo flows are the nodal points in the logistic chain, the logistic nodes. This section discusses the concept of logistic nodes and explains why those nodal points are of core significance for the whole logistic chain operation. Between the different logistic nodes seaport areas are separately highlighted and discussed upon due to their arguably higher degree of complexity, concentration of operations and modal integration.

3.2.2.1 Nodal points as critical links

Logistics nodes are defined as the nodal points in the transport system or chain were the functions of transferring cargo between different modes, cargo handling, warehousing and processing of the cargo take place. Logistic nodes can be dry ports, seaports, inland ports, airports, shunting yards, warehouses, stores, production and manufacturing sites. Figure 19 presents the general characteristics of a logistic node. Those include the incoming and outgoing streams of cargo and the associated cargo handling and warehousing operations. Logistic nodes are characterised by a high concentration of activities, and the presence of dense multimodal and intermodal structures. The operations take place in a usually limited and restricted to expansion physical area, which is commonly located in close proximity to urban and residential areas. Efficient management and administration is required to cope with this complex and dynamic environment.

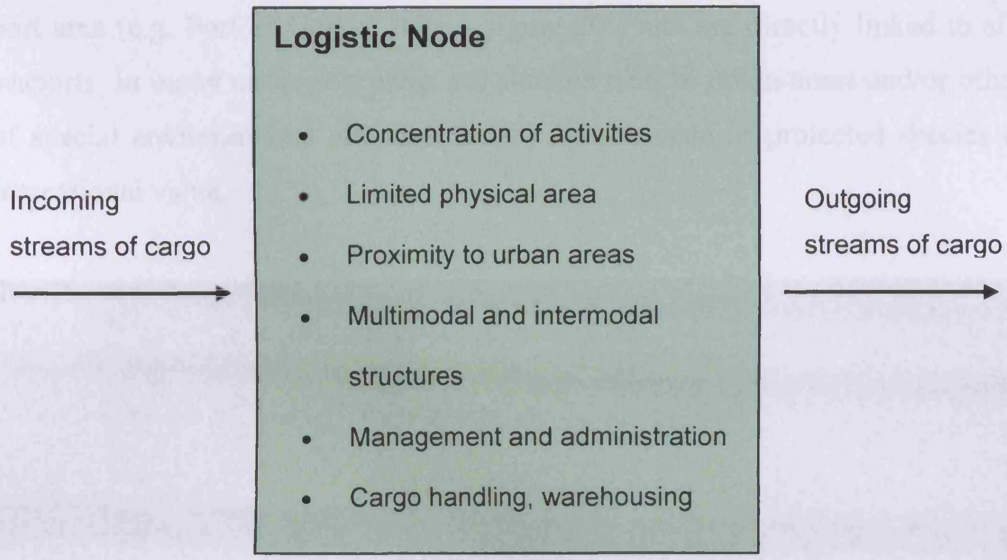


Figure 19: General characteristics of a logistic node

In any system or chain, not only in one related to transport, the nodal points receive special attention due to the higher degree of risk associated with their operation. From a safe arrival concept perspective, goods must be delivered without loss, damage or delay, and experience demonstrates that it is at the point of transhipment, namely at logistic nodes, where those three possibilities are more likely to occur (Faulks 1999). Apart from the higher degree of risk associated to the nodal points of a chain, the impact of something going wrong in a logistic node is also higher. A strike in a seaport area for example, will certainly have a greater impact on the cargo flows than a strike of the drivers of a major road carrier. Equally, an accident in a logistic node will probably have a greater impact than the one from an accident during a road haul. Attempting a parallelism with a living organism, the logistic nodes can be seen as the vital organs of the transport organism or system, while the infrastructural aspects, the freight carrying units and the embraced streams of cargo and information, as the veins and the blood or as the nerves and the neurological information respectively.

3.2.2.2 The significance of port and harbour areas

The research concept recognises the significance of the seaports as major transport nodes. A port is a hazardous area of intense multimodal activity as all the transport modes coalesce there. The transport network of the big majority of ports includes sea, road, rail and pipelines. Airports are situated in close proximity to, or even inside the port area (e.g. Port of Genoa, Italy – figure 20[3]) and are directly linked to all major seaports. In many cases port areas are situated next to urban areas and/or other areas of special environmental attention due to the presence of protected species or their recreational value.

Figure 20: Port of Genoa (example of an airport inside a port area)

Many apparent contradictions occur in a port area. On the one hand there is the great volume of cargo and passengers, the intensity and concentration of activities, the intermodality of port operations, and the great economic, social and strategic value of the port. On the other hand there exists the urban area that is very sensitive to issues such as noise, dust, air and water quality, demanding a clean and safe environment and good living conditions. The picture becomes even more complicated if the factor of risk is taken into consideration. Health, safety and even security considerations are extremely important in a port area. Volumes of hazardous cargo are handled by the ports on a daily basis. It may be suggested that the probability of occurrence and magnitude of consequence is exacerbated and indeed compounded in the port area because of the intensity of use, diversity of activities, inherently dangerous nature of certain cargoes and operations, and the natural dynamics of processes at the land-sea-atmosphere interface that constitutes the port system (Wooldridge 2004 b). Port areas

[3] Source: Google Earth

are complex areas of intense multimodal and environmental consideration. If environmental improvement through management can be achieved in such a complex environment then it might reasonably be considered achievable in the majority of the parts of the logistic chain. Therefore, and for all the above-mentioned reasons, port and harbour areas are selected as key research areas in the thesis. The environmental management of seaports is separately discussed in chapter 7.

3.2.2.3 Associated functions - Cargo handling and warehousing

The main functions associated with the operation of logistic nodes are related to the management of the incoming and outgoing streams of cargo. Cargo handling operations include loading and unloading of freight, transhipment, modal transfer from one mode to another, and appropriately directing freight volumes in the logistics pipeline. Goods can be categorised according to the required handling practices to containerised goods, Roll-On Roll Off freight, dry, solid and liquid bulk, and general cargo. Containerised goods are being transported in containers. The Roll-On, Roll Off (Ro-Ro) trade concerns all the loading and unloading of rolling freight. This means cars, trucks or even heavy lifts on trailers.

Warehousing, another major logistic node operation, is defined as the assignment of goods in a selected location, and its primary role is storage. Warehousing operations include the accumulation of primary raw materials pending distribution to other locations in the supply chain, the provisional storage of in-process inventory at various points in the logistics pipeline, the storage of finished goods inventory near to the point of production, and the storage of wholesale or retail inventory pending distribution to customers and end-users. A second role of warehousing is the implementation of flows of goods from part of the logistic chain to another, resulting today in the transformation of warehouses to distribution centres (Ackerman and Brewer 2001).

3.3 Chain organisation

The previous sections focussed on the physical components of the logistic chain together with its embraced functions and flows. This section places the focus on the parties that are responsible for operating those functional components, the major market players in the logistic chain and the dynamics of their interrelationships. Those players are the decision makers, controllers, operators, implementers, and points of contact in the chain and therefore the analysis of their role and practice is a necessity. The main aim of the section is to discuss the implications of the interaction between the different players with regard to the organisation and the management of the logistic chain. This is of significance and leads to conclusions that are transferable while examining the feasibility and practicability of establishing a holistic chain environmental management framework or system in the following chapters of the thesis.

3.3.1 Major players

A number of actors are responsible for organising, controlling and operating the logistic chain. Together they have to ensure a synchronised, seamless and sustainable chain operation (Bontekoning, Macharis et al. 2004). From the possible arrangements of moving goods the major players can be summarized as:

- Shippers (as senders and receivers of the goods);
- Third party intermediaries (Logistic service providers, Freight forwarders)
- Carriers of all transport modes
- Terminal operators (of all logistic nodes)
- Insurers (for both carrier liability and cargo insurance)

Figure 21 represents the major players and for reasons of consistency it is developed using the same structure as in figure 12. These two figures are used as the generic models for representing the chain's structure and organisation throughout the thesis.

The shippers are the clients, buyers of transport services, in the transport market. They are the owners of the cargo and they can act both as senders and receivers. The carriers are the main transport providers and operators. They own and operate the means of transport. The intermediaries are the parties that often intervene between shippers and carriers, acting on behalf of the shippers in order to undertake part of the complicated logistics associated with the efficient chain operation. The terminal operators are the parties responsible for the transhipment, cargo handling and other critical logistic nodes operations. The insurers of both cargo and liabilities are also playing an important role. Other players that do not appear in figure 21 include regulative and legislative bodies (governments, trade organisations and unions), non-governmental organisations, general public and stakeholders. The challenge faced by all the players is to gear all activities in the chain to one another, to provide timely information and communicate the right things at the right time. This is related to the daily management of transport activities, but also to strategic choices such as standardisation, or use of information technology systems.

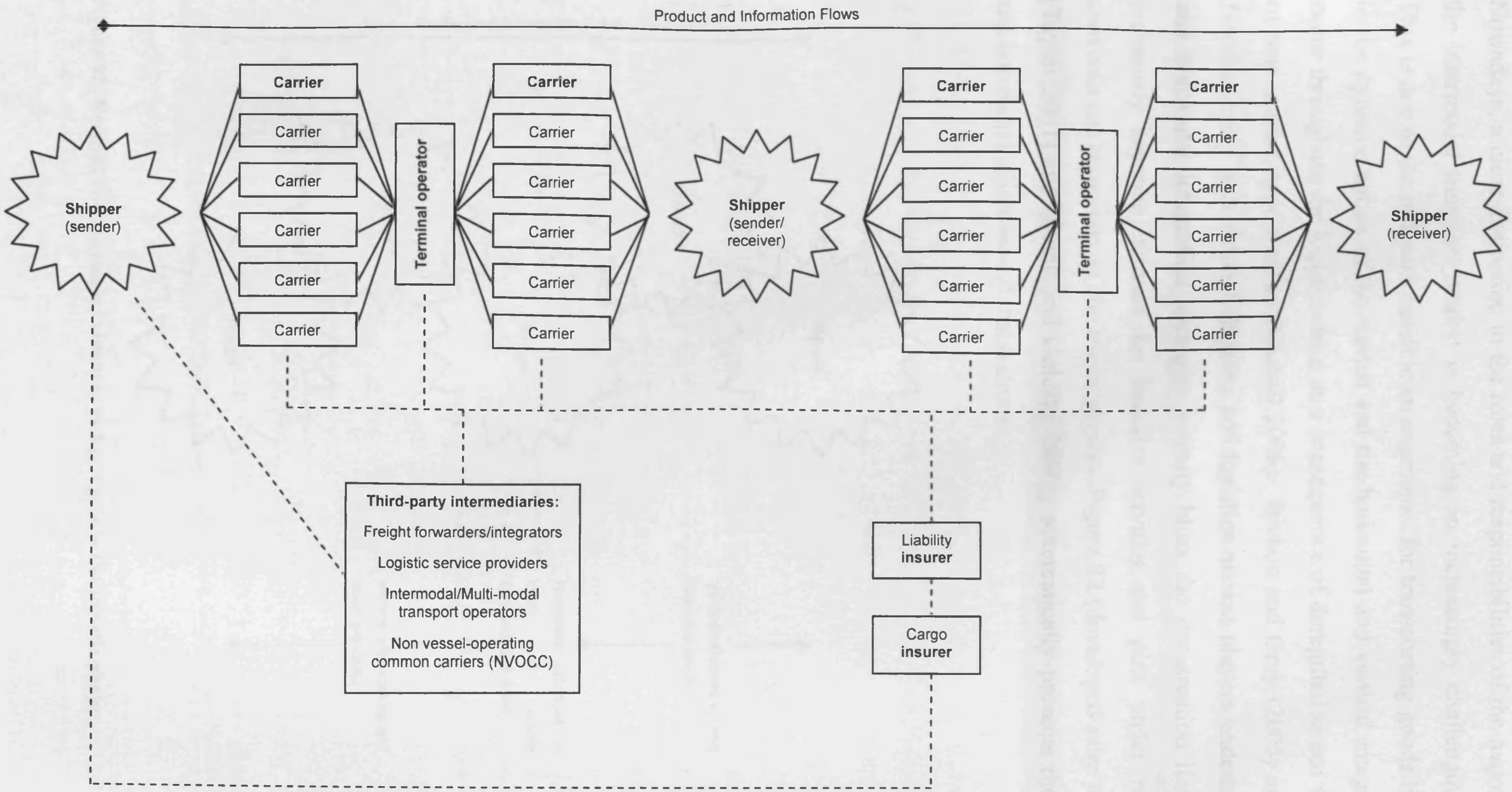


Figure 21: Main players in the logistic chain

Sources: (Taylor 1997; Frankel 1999; Stank and Goldsby 2000; Lambert 2001; Slack 2001; Taylor 2001; European Commission 2001 b; Delfmann, Albers et al. 2002; European Commission 2003 a; European Commission 2003 b; Eye for Transport 2004; FreightForward International 2004; Karamitsos 2004; Lai 2004)

Nowadays, a clear distinction in the roles and responsibilities of the major players in the intermodal transport market is becoming an increasingly challenging exercise. This is due to the different possible arrangements for transporting goods but also due to the dynamic nature of the market and the horizontal and vertical integrations that occur throughout the logistic chain as a consequence of deregulation and the opening of new market opportunities (Michail 2006). Bichou and Gray (2005) note that the fact that many international shipping and logistics market players undertake vertical and horizontal integration strategies actually blurs the demarcation lines between previously separate markets for logistics services and puts under revision the conventional taxonomy of the major players. Figure 22 (developed after the work by (Taylor 2001) and (Stank and Goldsby 2000)) schematically presents those vertical and horizontal alliances and integrations.

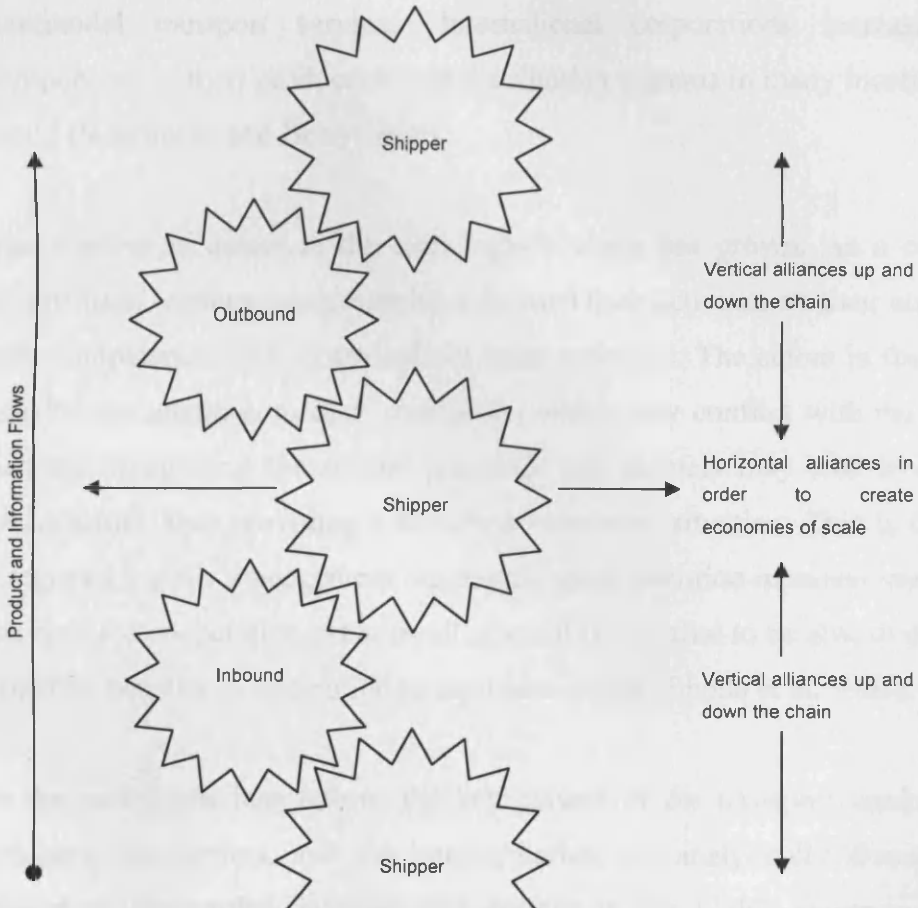


Figure 22: Vertical and horizontal alliances and mergers in the logistic chain

Strategies of vertical integration include ocean carriers and other multimodal providers (e.g. rail operators) engaging in terminal leasing and ownership. Shippers are also sometimes perceived as port owners, such as through dedicated oil or car terminals. Horizontal merging occurs between port operators and between shippers in order to create economies of scale and bargaining capability. Horizontal integration strategies were less common in the past but are gaining more support in recent years, such as through port co-operation and mergers (e.g. Copenhagen and Malmo Ports - CMP) and, more particularly, the expansion of certain ports beyond their initial spatial bases (e.g. the Port of Singapore Authority shortening its name to PSA and owning and managing ports and terminals in other countries) (Bichou and Gray 2005; Levitt 2006). Rondinelli and Berry (2000) argue that the formation of corporate strategic alliances and global manufacturing networks are among the most important responses to global competition and among the strongest forces driving the expansion of intermodal transport services. International corporations increasingly connect components of their production and distribution systems in many locations around the world (Rondinelli and Berry 2000).

The number of actors in the total logistic chain has grown. As a consequence of competition, various enterprises have focused their activities on their core business (or core competence) and contracted out other activities. The actors in the logistic chain usually pay attention to their own goals, which may conflict with the goals of other partners. Integrating the several processes and partners may lead to advantages for each partner, thus providing a so-called "win-win" situation. This is the reason why integrated logistic management has gained much attention in recent years. To achieve the required cooperation between all actors it is essential to be able to demonstrate the potential benefits of integration to each actor (Slats, Bhoda et al. 1995).

In the paragraphs that follow, the key players of the transport market, namely the shippers, the carriers, and the intermediaries, are analytically discussed. Focus is placed on their roles, interests and options in the highly dynamic and changing transport market.

3.3.1.1 Shippers

A shipper may be defined as the person or company who is usually the supplier or owner of commodities shipped (European Commission 2003 b). Shippers do not operate transport but they generate and guide the transport demand from point A to point B. A shipper may also be defined as the merchant (person) by whom, in whose name or on whose behalf a contract of carriage of goods has been concluded with a carrier or any party by whom, in whose name or on whose behalf the goods are actually delivered to the carrier in relation to the contract of carriage (Eye for Transport 2004). Synonyms that are commonly encountered in the literature are consignors, senders and receivers.

Shippers do not normally favour any particular mode; their interest is to find suitable transport solutions at the right price, coupled with quality. They focus on reducing their total logistics costs, of which transport is only a part. They are prepared to accept increases in transport costs if there are compensating reductions of other costs (e.g. warehousing costs, insurance, and packaging). Shippers are often looking for long-term relationships with logistics companies that understand their supply chains and have a wide geographical coverage. They are prepared to co-operate, even with their competitors, on certain logistics issues because this is not their core business (European Commission 2003 b).

The shippers are key market players as they set the market requirements and they influence the cargo flows (ECOPORTS project 2005 e). Strategic decisions made at a corporate level within the business affect freight transport operations. These decisions impact upon different parameters of the logistic chain. Table 5 (McKinnon 2001) illustrates the interrelationship between a set of six freight transport parameters and areas of shipper's strategic decision-making. The table demonstrates that freight transport operations are influenced by a complex multi-decision making process reflecting many areas of a shipper's business strategy.

Table 5: Impact of shippers' strategic decisions on freight transport

			Transport Parameters					
			Freight Quantity	Mode choice	Vehicle type	Vehicle utilisation	Routing	Scheduling
Strategic Decision Making Areas	Product development	Product design	√	√	√	√		
		Packaging	√	√	√	√		
		Product range	√	√	√	√		
	Marketing planning / sales acquisition	Market area	√	√	√		√	
		Marketing channels	√	√	√	√	√	
		Sales strategy promotion	√	√	√			√
	Order fulfilment	Location of production and distribution facilities	√	√			√	
		Sourcing of supplies	√	√			√	
		Production system	√		√	√		√
		Inventory management	√	√	√	√		√
		Materials handling	√	√	√	√		
		After sales service	√		√	√		√
		Recycling / reverse logistics	√	√	√	√	√	

It can be observed from the table that decisions related to the characteristics of a given product (its design, packaging, range) may influence the selection of the suitable transport mode or type of vehicle for its conveyance. It can also be noticed that, strategic shippers' decision making with regard to the location of production and distribution facilities influences or even determines the transport mode selection and the route to be followed.

In deciding how to move freight a shipper has to make 3 inter-linked decisions (European Commission 2001 b): (1) should the services of a third-party intermediary (logistic service provider, freight forwarder) be used?, (2) what mode(s) should be used (this decision may be left in the hands of the third-party intermediary)?, and (3) should the goods be moved with the protection of "all risk" cargo insurance? Shippers often appoint multiple logistic service providers and have different arrangements in place for different products, routes and services (European Commission 2003 b; Lai 2004). Some shippers rely entirely on the carrier's liability to cover any loss/damage. Others insure the cargoes moved with "all risk" cargo insurance. Cargo insurance allows the shippers to insure the value of the goods above the base level(s) provided by the carrier(s) and, because the insurer is responsible for pursuing claims, to reduce their administrative burden in the event of a claim. Compared to liability insurers, cargo insurers tend to be quicker at paying claims thus helping the cash flow of the shipper. However cargo insurance comes at a price, i.e. the premium (European Commission 2001 b).

"The time when shippers used an array of freight forwarders, truckers, clearance agents, shipping companies, railway services, etc. and various financial, freight insurance and other institutions are gone. Today major customers demand and get one-window integrated just-in-time and efficient all exclusive door-to-door service at a predetermined price. This is what the market demands now" (Frankel 1999). Shippers, customers, consignees and other stakeholders are spending more time qualifying carriers who must conform to more stringent criteria related to service performance and evaluation (Brooks 1999; Brooks 2000).

3.3.1.2 Carriers

The carriers are the owners of the means of transportation (trucks, locomotives, vessels, barges, aircrafts and pipelines). They are the parties that physically perform the transportation of cargo. A carrier is the party undertaking transport of goods from one point to another (Eye for Transport 2004). Carriers are essentially concerned with the supply of transport services. Some operators offer integrated intermodal services but these are normally offered as complementary services to support their main mode.

Their high investment in physical assets means that they are focussed on asset utilisation rather than reducing supply chain costs. For the carriers, increase in transport demand is translated to an increase for their business (European Commission 2003 b).

Many transport markets today witness intense competition that is largely focussed on price. This is due to the structure of some markets which are characterised by many small enterprises. Many of them may not be in a position, on their own, to offer more value-added services besides the pure physical transport operation, so they compete on price. Some markets suffer from over-capacity, but for various reasons, market exit of companies does not happen at the rate which would allow a more healthy relationship between supply and demand. Consolidation and concentration processes are often far more advanced on the side of transport users than on the side of transport suppliers. This puts transport users in a powerful position vis-à-vis their suppliers. All this exacerbates the competitive behaviour of transport operators. They are hence often reluctant to explore possibilities for co-operation (e.g. combining loads, sharing spare capacity) which are possible under current competition rules, even when there are savings to be made. Transport operators tend to overemphasise their competitive position versus other transport operators. Their interest is to improve the quality and competitiveness of their mode but they are not well placed to construct complex intermodal transport chains if they do not control, or have an interest in, the whole chain (European Commission 2003 b).

In recent years traditional carriers have sometimes extended their activities to other links in a multimodal chain. A sea carrier may offer door-to-door carriage, either by subcontracting to a land carrier or developing his own facilities. In such cases the operator is referred to as a multimodal transport operator (MTO) or combined transport operator (CTO). In the United States another intermediary (between the shipper and the operator of a ship) is the non-vessel-operating common carrier (NVOCC). It may occur that the MTO or CTO still contracts with a freight forwarder rather than the shipper (European Commission 2001 b).

Intermodal freight transportation industry providers are facing the challenge of who they are and what they provide in terms of transportation services. Greater customer demands in terms of service and price have forced providers to rethink what business they are in: Are they in the pure modal business or are they part of the larger business of logistics management services? This has forced carriers to form partnerships and alliances with one or more of their closest competitors to offer a greater range of services including geographical coverage. Sometimes these relationships lead to mergers and buyouts. The result is not only the formation of a new cast of players, but also a reduction in its number on some of the larger trade routes (Muller 1998).

Carriers have nowadays been transformed from product dispensers and distributors to a critical element in supply chain service performance, hence expanding the scope of their operations. In recent years there has been ample evidence to suggest a significant interest of ocean carriers in inland transportation and the provision of a total door-to-door logistics package to their clients (Panayides 2002). There are three broad roles an ocean carrier can play in the logistic chain (Brooks and Fraser 2001): (1) supplier of ocean carriage (including contracting of terminal handling arrangements) to a logistic chain managed by another company, usually a shipper, (2) supplier of more than one link in the distribution network (ocean carriage plus inland carriage, or ocean carriage plus value added services) used by a logistic chain manager, and (3) supplier of any of the above services and manager of the logistic chain on behalf of client companies. In the third case the ocean carriers undertake the role of the manager and leader of the logistic chain. This is the case of today's mega-ocean carriers. Their functions are not restricted to sea-leg transport, but are widely extended across logistics and supply channels, including as port operators and multimodal transport providers (Bichou and Gray 2005).

3.3.1.3 Third party intermediaries

The third-party intermediaries are the link between shippers, buyers, carriers of all modes, authorities and financial institutions. They are working on behalf of the shippers to organise the carriage of goods and associated logistics, including connected services and/or associated formalities. Intermediaries can be; logistic service providers, freight forwarders, intermodal and multimodal transport operators.

The distinction is based on the range of provided services and some legal implications that are explained below.

Logistics service providers are those companies that perform logistics activities on behalf of their clients (Coyle, Bardi et al. 1996; Delfmann, Albers et al. 2002). This requires a close understanding and collaboration with shippers in order to understand their business and assist them in improving their logistic chain processes. It is the dominant trend towards the outsourcing of the logistics activities that has given prominence to the concept of third-party logistics service providers (Panayides and So 2005). Due to their experience in providing transport and logistics services across numerous continents and in many different vertical market sectors, they are considered in market terms a valuable commodity (Cuthbert 2007). The provided services consist of at least the managing and operating of the transportation and warehousing functions. The logistic service providers can be classified into four main categories according to their service capability: traditional freight forwarders, transformers, full service providers and nichers (Lai 2004).

Freight Forwarders, often referred to as the architects of the transport chain (Karamitsos 2004), are the expert organisers of the transport of goods in national and international trade. They advise clients on the best way to transport goods in the most cost-effective, timely and safe fashion to or from any area in the world and they coordinate the arrangements (FreightForward International 2004). Freight forwarders communicate with carriers of all modes and confirm the transport arrangements. The also liaise with clients, advising them of the costs of transporting goods and the arrangements that have been made. When working on behalf of an importer, it may be necessary to clear goods through customs, arrange the payment of duties and taxes, and organise the delivery of goods to the importer's premises. Other duties of freight forwarders include: selecting safe routes and carriers (road, rail, sea and air), booking transport cargo space, dealing with transport rates, insurance and schedules, making calculations by weight, volume and cost, preparing quotations and invoices, preparing contracts such as Bills of Lading and Letters of Credit, and communicating with carriers and clients.

Freight forwarders do not own any vehicle of conveyance for the cargo and deal with people who do not take orders. The manner in which goods are transported (air, ocean, rail, road) depends primarily on the type, weight and size of the cargo, required speed of delivery, destination and cost. The forwarding industry is a specialised service industry that undertakes a vital neutral role in the economy as intermediary between shippers, buyers, carriers of all modes, authorities and financial institutions, thereby integrating and optimising transport and trade flows. The large international mega-freight forwarders, in other words the full logistic service providers, are able to effectively organise and coordinate the transport of goods and to provide clients with a wide range of transport and logistics through a world-wide service chain (FreightForward International 2004).

From a liability point of view, it is important to differentiate between those freight forwarders who act as a principal and those who act as agents. Freight forwarders who act as principals providing the shipper with a single contract are referred to as intermodal or multimodal transport operators in legal terms. Intermodal or multimodal transport operators are defined as the parties on whose behalf the transport document or any document evidencing a contract of multimodal carriage of goods is issued and who is responsible for the carriage of goods pursuant to the contract of carriage (Eye for Transport 2004). In that case the legal implication is that the freight forwarder assumes the rights and duties of a carrier. In theory these freight forwarders will decide on the mode(s) to be used. However, in practice some shippers also specify the mode(s) to be used or not used when using the service of a freight forwarder who acts as principal. Some freight forwarders act as agents, effectively providing an out-sourcing service to the shipper to choose the best combination of modes to move the freight. In this case for a multi-leg journey the shipper would end up with a series of contracts (European Commission 2001 b).

3.3.2 Leadership in the logistic chain

Having examined separately the roles, interests and options of shippers, carriers and intermediaries in the highly dynamic transport market, this section aims to give an answer to the challenging question of who is managing the logistic chain. Defining the potential chain manager or leader is of significance. It can be argued that a chain leader, the actor with most power in the intermodal chain, can generate overall chain steering. From a management perspective such a steering facilitates the coordination and organisation of the chain's operation. In management systems there is a need for clear objectives and targets and clear documented responsibilities. In a given organisation, it is the top management that sets those objectives and divides the responsibilities. The question while placing the focus on the logistic chain system is which party undertakes the role of the chain leader.

The challenging nature of the question is demonstrated by the outcomes of research in the field. Researchers (Woxenius 1994; Taylor and Jackson 2000) examined the role and market power of each actor in the intermodal system trying to give an answer to the question. Both of the mentioned studies concluded that in the international chain, ocean carriers have taken a leadership role. As discussed in section 3.3.1.2 today's mega-ocean carriers extent their functions across logistics and supply channels and can act as managers of the logistic chain on behalf of their clients (shippers). This is the case of a limited number of very powerful companies that dominate the international shipping market (e.g. Maersk Sealand and P&O Nedloyd). With regard to the domestic chain though, the studies of Woxenius and Taylor and Jackson concluded that such leadership is lacking. In addition, an extensive literature review by Bontekonig and Macharis (2004) also revealed that no single-actor fulfils the role of chain leader. The leadership issue has then to be dealt per individual case or per group of cases and it is associated with the market power and the service capabilities of the players involved in a specific logistic chain.

Large shippers have the market power and ability to manage and control their logistic chains. Companies such as IKEA or Stora Enso for example, are in position to demand specific and tailor made transport services and to really influence the performance of their transport chains. In that case those companies undertake the chain leader role. They can use their influence as customers to ensure that desired performance targets are met. The model of large shippers influencing and controlling their transport chains is analytically discussed in chapter 6 of the thesis. In certain cases large shippers even invest in transport modes extending their activities and also their control in the logistic chain and its performance. Such an example is the IKEA rail service (Ivarsson 2003). The picture with regard to the most common case of smaller shippers though is different. Without having such a significant influence over their contracted transport services smaller shippers cannot be seen as logistic chain leaders.

Concerning, therefore, the ability of the different parties to play a leading role in the chain, the following observations can be made:

- Shippers are the decisive factor being the buyers of transport services and at large the drivers of the freight transport demand. As seen in section 3.3.1.1 shippers' strategic decisions made at a corporate level within the business affect freight transport operations as they influence and occasionally determine several transportation parameters. Large shippers have the market power and interest to lead and manage their logistic chains.
- Carriers and especially ocean carriers are playing and increasingly important role. Aiming to get in direct contact with shippers and to extend their control throughout the transport chain, they can subcontract or buyoff land carriers, offering intermodal door-to-door services. The mega-ocean carriers have undertaken the leadership in the international chain.
- The growth in size of carrier groups, and their interest in entering in direct sales with shippers, puts in pressure the role of the neutral intermediaries in the logistic chain (Short sea shipping promotion centre Flanders 2001; Slack 2001). The European Commission (DG TREN), considering the role of neutral intermediaries as vital for a sustainable transportation system, launched in 2003 the "freight integrator action plan" (European Commission 2003 a; European Commission 2003 b; Karamitsos 2004). The aim of the action plan is to support the freight forwarders as the neutral organisers of the intermodal freight transport under the newly introduced term freight integrators. It seems that the warnings about the imminent demise of the third-party intermediaries are premature (Short sea shipping promotion centre Flanders 2001; Slack 2001).
- Overall it can be said that the leadership in the logistic chain depends on the influence and market power of the involved players. The answer therefore to the question of who is managing the logistic chain is case sensitive.

Nevertheless, the shippers as the clients of transport services do play an influential role in the chain but the degree of such influence varies significantly.

3.4 Conclusion

In this chapter a generic model has been presented and an understanding has been provided with regard to the format, function and organisation of the logistic chain. The concept of the logistic chain, its components, and the major players were studied in sections 3.1, 3.2, and 3.3 respectively. The study demonstrated that the chain is a highly dynamic, interrelated, multi-actor and complex system, already in what concerns its primary function which is to efficiently respond to the freight mobility needs. In the following chapters of the thesis the environmental and sustainability parameters of the logistic chain are discussed. It can be reasonably implied that the development of a realistic model for an environmental management framework addressing such a complex system will be equally, if not more complex and challenging. The identified organisational challenges and the leadership and liability issues are some of the main areas that need to be addressed.

4 The Logistic chain and the environment: interaction, challenge and response

The previous chapter discussed the concept of the logistic chain, its format, function and organisation, and demonstrated the complexity of coordinating and managing the multiple operations. This chapter examines the interaction between the logistic chain and the environment. It starts by conceptualising the environmental impact of the chain as the sum-total of all its embraced functions and operations. The major environmental problems, to which freight transport systems make a significant contribution, are explained and discussed. The focus is then placed on the relative environmental performance of the various freight transport modes and selected comparative studies and examples are highlighted in this context. The environmental considerations and implications arising from current practice and recent trends in logistics strategies are also examined in order to assess the degree of sustainability of modern transport systems. In this context, the chapter formulates the sustainability challenge with regard to the operation and the management of freight transport systems and the logistic chain. There is evidence demonstrating that current transport systems cannot be considered sustainable. With regard to the response of the regulation and policy framework to the challenge of sustainability, a European perspective is taken mainly in order to reveal and discuss the applicable policies, control mechanisms and their impact in the European Union. The thesis, theoretically at this stage, argues that an environmental management system or framework for the logistic chain could be a positive response option to the sustainability challenge. Assessing the feasibility and practicability of, and setting the principles for such a framework are main aims of the thesis and are examined in following chapters.

4.1 Conceptualising the environmental impact of the logistic chain

The quality of the environment reflects the sum-total impact of all natural processes and human activities. Equally, the environmental impact of the logistic chain represents the sum-total impact of all the embraced functions, activities and operations in the process of moving goods from their point of origin to their final destination. In other words the impact of the logistic chain is an amalgam of the impacts of all its elements (as analysed in chapter 3) and includes all transport modes, systems, logistic nodes and related operations (figure 23).

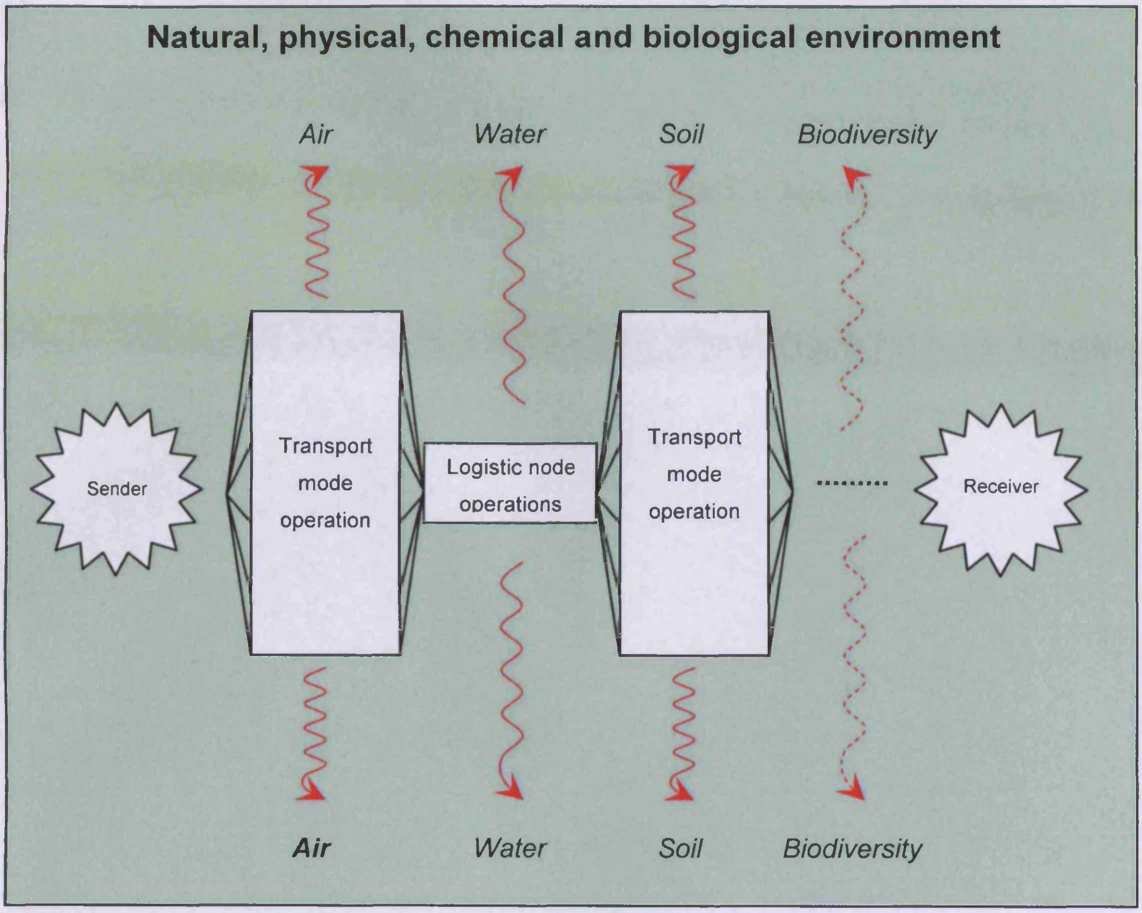


Figure 23: Environmental impact of the logistic chain (sum-total impact of embraced operations)

As such, the environmental impact of the logistic chain depends on factors such as (1) the environmental performance of each transport mode operated throughout the chain (e.g. fleets' environmental characteristics, infrastructure, technologies in use), (2) the environmental performance of the logistic nodes operations (e.g. cargo handling, warehousing, area environmental management), (3) the actual structure of the transport chain (modal shares, intermodal and multimodal structures) and (4) the total quantity of transported cargo and the distance covered. Seen from a life cycle perspective, the chain's impact also embraces the production of transport infrastructure, mobile and other supporting equipment, and the after use process of managing infrastructure and equipment withdrawn from service.

In defining the "Environmental Impact" of freight transportation the Organisation for Economic Co-operation and Development (OECD 1997) made the following remarks:

- Environmental stressors such as pollutants, noise, or exotic species are released in natural ecosystems. Each tonne of goods transported places additional stress on the environment; many stressors may therefore be measured in units per tonne of goods transported;
- The total amount of stress placed on the environment depends on the quantity of goods and the distance they are transported; in the simplest form (e.g. exhaust emissions), total stress is the quantity of goods times the distance carried multiplied by the stress per tonne. The second component of stress involves the spatial pattern of goods transported, including the transport mode used;
- Some environmental stressors, notably air and water pollutant emissions, are easily quantified, and clearly rise with increases in freight. Others, such as airport noise or the introduction of exotic species from ballast water discharges, may increase with the number of trips made, but not with distance travelled or quantity of goods carried. Moreover, the ecological harm caused by such stressors may not be quantifiable or directly related to quantity of freight.
- The environmental impact of the total stress is determined by the nature of the receiving environment. Ambient characteristics such as physical ecosystem characteristics, density of the human population affected, and whether the receiving ecosystem is considered critical or includes endangered species will determine both the physical impact of the stress and willingness to pay to prevent it.

The demand for freight transport is largely a derived demand and mainly reflects the level of economic activity. It is closely linked to the economic growth and international trade, to the overall development of the various sectors of the economy, and to land-use planning and infrastructure (OECD Environment Directorate 2002).

Figure 24 (adapted from (OECD 1988)) schematically represents the interrelationships between the general socio-economic conditions and some important transport parameters. It can be observed that the socio-economic realities critically influence transport policy aspects and the general structure of the transport sector. Both transport policy and sector's structure are the determining factors of the actual transport practices that at the end are the sources of the environmental impacts.

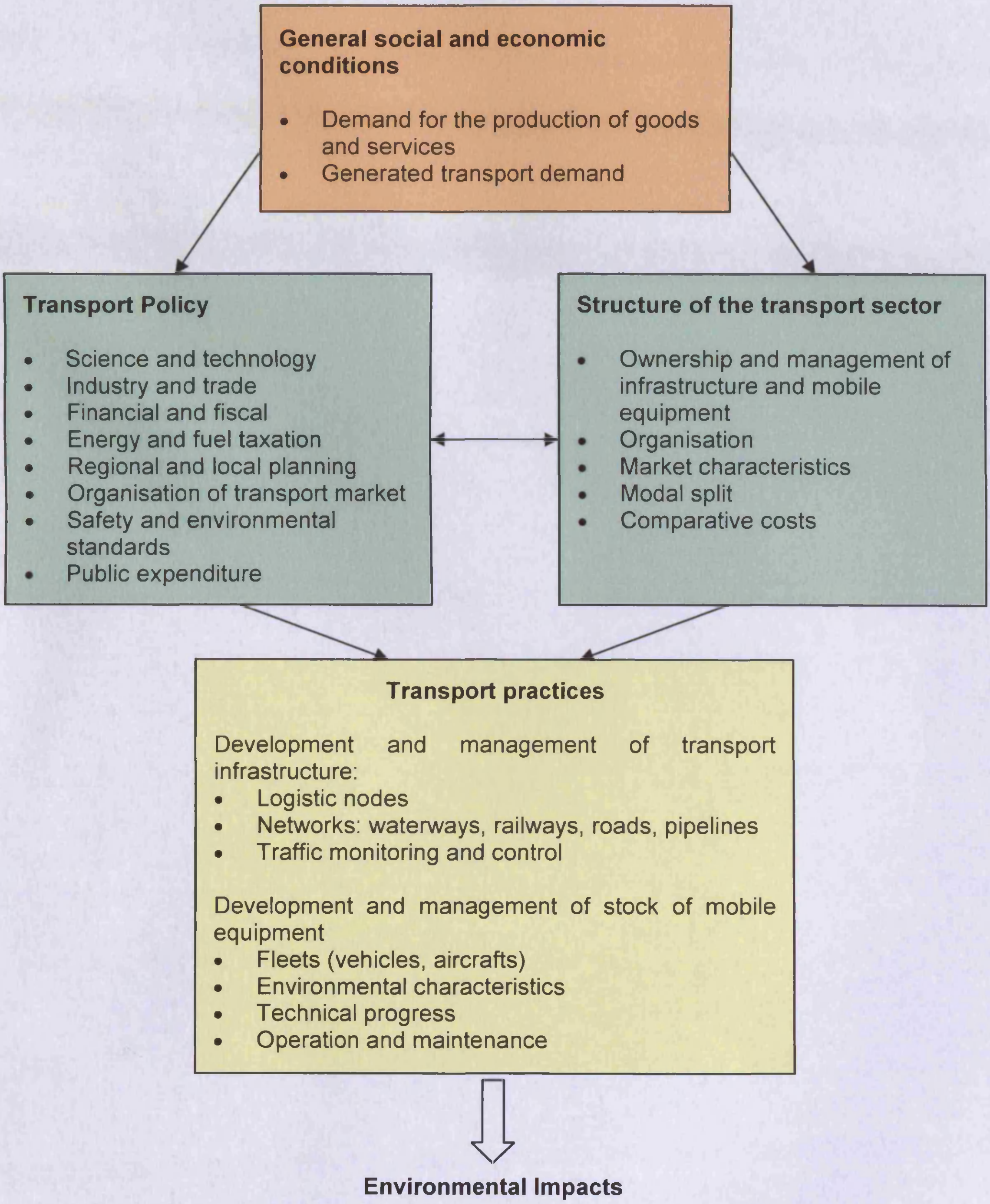


Figure 24: Transport: Policies, structure of the sector, practices and environmental impacts

The assessment of the overall environmental impact of the logistic chain, especially in quantitative terms, is a challenging exercise. A commonly raised question towards this direction concerns the way of addressing stressors which cannot easily be quantified. Three approaches are generally suggested by relevant literature (OECD 1997): (1) limiting the analysis to those stressors which can be easily quantified in comparable terms, (2) including all kinds of impacts but be descriptive when quantification is not possible, and (3) using valuation techniques which convert all environmental impacts to the costs they impose, the costs of avoiding them, or willingness to pay to avoid them. The thesis does not select a specific approach, but provides information that could be used in any of them. It describes the major environmental impacts of freight in qualitative terms. When emission factors per unit of freight are meaningful and available, it provides them.

4.2 Environmental impact of freight transport systems

Having conceptualised the overall environmental impact of the logistic chain, this section focuses on some of the major environmental considerations upon which freight transport systems are acknowledged to have a significant contribution. Then, and due to the varying degree of environmental impact of the different transport modes, their relative environmental performance is discussed. This is done by making use of some key performance indicators and available comparative studies.

4.2.1 Major freight transport environmental considerations

Transport systems play a major role in the economic life of industrialised countries and in the daily life of their citizens. An efficient transport system is a crucial precondition for economic development and an asset in international competition. Apart from its economic and social benefits, transport is a major contributor to various environmental problems. "The dramatic increase in transport demand, and in particular for road transport and aviation, has made the sector a major contributor to several health and environmental problems in Europe (European Environmental Agency 2003)."

In considering the relationship between transport and the environment, Hunter and Farrington (1998) note that a potential paradox emerges: on the one hand, modern industrial societies pursue economic growth through the open exchange of people, raw materials, energy, goods and services in an increasingly global marketplace, and on the other, the transport systems required to allow such exchanges may be exerting pressures on the environment that degrade the functional integrity and quality of natural ecosystems to the extent that the prospect of maintaining or achieving a high quality of life in many human societies is threatened.

Transport operations have a significant impact on the natural environment and are main contributors to local and global environmental problems. Emissions of air pollutants such as CO, NO_x, SO_2, hydrocarbons (HCs), volatile organic compounds (VOCs), lead and particulates contribute to local air pollution endangering human health. Carbon dioxide (CO_2) emissions from transport are a major contributor (29% of man made CO_2 is emitted by transport (EC DG-TREN 2003)) to the greenhouse effect and the global warming. The construction of transport infrastructure can result in the modification of water systems and the disruption of hydrological processes. Furthermore, transport infrastructure covers an increasing amount of land to the virtual exclusion of other uses, cuts through ecosystems and spoils the view of nature scenery and historic monuments. Run-off from roads leads to surface and groundwater pollution while routine and accidental releases of oil by tankers contribute further to the pollution of the seas. Additionally, accidents are a heavy social cost and nuisances from traffic noise, congestion and the consumption of non renewable natural resources also represent considerable environmental liabilities.

In the paragraphs to follow specific attention is given to air quality, climate change, acidification, noise, water pollution, effects on landscape and biodiversity and transport accidents. The presented issues range in scale from local to regional and global effects and are high in the environmental agenda and in the centre of the whole debate of sustainable development.

Local air quality

Air pollution has probably been the first major transport related environmental concern that has been recognised and has received more attention over time than any other environmental effect. Fuel combustion is identified as the largest single contributor to air pollutant emissions. In this category, stationary (industry, agriculture, energy) and mobile sources (internal combustion engines, transport activities) are responsible for approximately equal overall shares, varying significantly however for individual pollutants (Linster 1990). The most significant air pollutants include: lead (Pb), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NO_X), volatile organic compounds and hydrocarbons, petrochemical oxidants with ozone (O_3) being the dominant one, and particulate matter (soot, dust). Their emissions and concentrations determine the level of air pollution and influence the potential impacts that they might have on human health and the environment (Rothengatter 2003).

The impacts of air pollutants vary in scale and range from locally based to regional and global effects. This section focuses on the local effects of air pollution while the following sections on acidification and climate change provide the regional and global dimensions respectively. The impact of air pollutants on human health and the environment can be further categorised to direct and indirect (Linster 1990). Direct impacts refer to short or long term effects that are caused by the responsible pollutant before it undergoes chemical transformation (if any) in the atmosphere. Indirect impacts refer to short or long term effects which are caused by a mix of pollutants after they have undergone chemical transformation in the atmosphere.

Air pollution from the operation of the logistic chain has a consistently high profile in public concern and it is often the target of regulatory control. The following table 6 summarises the major potential effects of transport related exhaust pollutants on human health and the environment. It distinguishes between direct and indirect impacts where applied.

Table 6: Potential effects of main air pollutants on human health and the environment

Pollutant	Effects on human health and the environment
Carbon monoxide (CO)	• Direct: Reduced oxygen-carrying capacity of red blood cells. Can exacerbate cardiovascular disease symptoms, particularly angina. Can also affect the central nervous system, impairing physical coordination, vision and judgement, creating nausea and headaches. Can be linked to loss of worker productivity and general discomfort. Sustained exposure to high concentrations can result in death. • Indirect: Through the role it plays in some atmospheric reactions can also contribute to the increase of greenhouse gases in the atmosphere, thus contributing to the climate change
Sulphur dioxide (SO_2)	• Direct: Can affect lung function • Indirect: Reacting with nitrogen oxides can form atmospheric acids and acid salts, thus contributing to acid deposition and the related effects
Nitrogen oxides (NO_X)	Direct: • Nitrogen dioxide can be an irritant and exacerbate respiratory diseases such as oedema and emphysema. It can increase susceptibility to viruses. It is further responsible for a portion of the brownish coloration of air, contributes to pollutant haze, and reducing visibility Indirect: • In the lower atmosphere, light unsaturated HCs and NO_X undergo photochemical reactions together with oxygen and other organic compounds, and thus are responsible for the production of photochemical oxidants and smog. Ozone is the most prevalent photochemical oxidant and it can have significant impact on the human respiratory system • Reacting with sulphur oxides can form atmospheric acids and acid salts, thus contributing to acid deposition
Particulates	• Fine particulates may be toxic, or may carry toxic and carcinogenic organic and inorganic substances. May also penetrate deep into the respiratory system irritating lung tissue. Episodes of high atmospheric concentration often correlate highly with asthma attacks and deaths from respiratory illnesses. There is evidence that the presence of particulates in the air may cause cancer. Particulates can reduce visibility and damage buildings (due to soiling). They are also contributing to the greenhouse effect

Hydrocarbons (HCs,) and volatile organic compounds (VOCs)	• Direct: Depending on the type of compound the potential effects on human health vary from eye irritation, coughing and sneezing drowsiness and symptoms akin to drunkenness (low molecular weight HCs) to more serious effects (heavy molecular weight HCs). Both benzene and benzidine may be carcinogenic. Carbon tetrachloride is a potential teratogen • Indirect: In the lower atmosphere, light unsaturated HCs and NO_X undergo photochemical reactions together with oxygen and other organic compounds, and thus are responsible for the production of photochemical oxidants and smog. Ozone is the most prevalent photochemical oxidant and it can have significant impact on the human respiratory system
Ozone (O_3) and other photochemical oxidants (secondary pollutants – formed by reactions of primary pollutants in the atmosphere)	• Ozone can be an eye and throat irritant, cause coughs and headaches, and can have significant impact on the human respiratory system. It can damage vegetation, agricultural crops and forest resources (by attacking the cell walls of plants and inhibiting their growth). Ozone can accelerate the deterioration process of materials, especially rubber. It produces photochemical smog that reduces visibility. In the lower atmosphere, ozone also contributes to the greenhouse effect and climate change
Ethylene dibromide and ethylene dichloride	• Carcinogenic in animals, potential human carcinogens
Formaldehyde and other aldehydes	• Carcinogenic in animals, potential human carcinogens
Lead	• Lead damages the kidneys, liver, reproductive system, blood formation, basic cellular processes, and brain function. It can impair the synthesis of haem, adversely affecting oxygen transport in the blood. Can also impair neurotransmitter functions, affecting behaviour and learning performance in children. Lead is a potential human carcinogen.

Compiled using data from (Linster 1990; Houghton 1996; OECD 1996; Black 1998; Hunter, Farrington et al. 1998; Faulks 1999; Holmen and Niemeier 2003; McCubbin and Delucchi 2003; Rothengatter 2003; European Environment Agency 2007)

Table 7 highlights the contribution of the transport sector to the total anthropogenic emissions of selected pollutants in the United States.

Table 7: Transport sector's contribution to total emissions of air pollutants (United States)

Pollutant	Transport sector contribution %
NO_X	41
Sulphur oxides	5
Hydrocarbons	38
Particulate matter	23
CO	67
CO_2	30

Source: (Gordon 1991)

The operation of all transport modes is based in the burning of fossil fuels and therefore emits pollutants in the atmosphere. Road traffic though is by far the dominant source of air pollutants emissions. Table 8 shows the contribution of transport in total and road transport in specific to the man-made emissions of selected harmful substances in the European Union.

Table 8: Transport contribution to the total emissions of selected pollutants (EU)

Pollutant	Total emissions EU-15 (1000 tonnes)	Transport Emissions (1000 tonnes)	Transport %	Road Transport (1000 tonnes)	Road Transport %
NO_X (1990)	13284	8121	61%	6303	47%
NO_X (1999)	9936	6415	65%	4607	46%
NO_X 1990-1999	-25%	-21%		-27%	
CO (1990)	50104	34192	68%	31707	63%
CO (1999)	34065	21941	64%	19552	57%
CO 1990-1999	-32%	-36%		-38%	
VOC (1990)	15173	6461	43%	5862	39%
VOC (1999)	10872	4003	37%	3373	31%

VOC 1990-1999	-28%	-38%		-42%	
SO_2 (1990)	16362	828	5%	535	3%
SO_2 (1999)	6 734	470	7%	177	3%
SO_2 1990-1999	-59%	-43%		-67%	

Source: (EC DG-TREN 2003)

Climate change

The most often cited global environmental concern associated with transport is global warming and climate change. It is placed at the very centre of the debate on sustainable development and it receives the most attention by the media, general public, governmental and non-governmental organisations. The natural "greenhouse effect" is scientifically known for centuries. The Earth is surrounded by a layer of gases that is transparent to incoming solar radiation allowing this to reach and heat the surface. The heat so generated would escape the planet if it were not for the same layer of gases, which absorbs or reflects this heat back to the surface. It is this layer of "greenhouse gases" that results in this planet being warm enough for human life (Black 1998). More recently though, it has been argued that anthropogeneous emissions impact on the composition and quantity of greenhouse gases in the atmosphere resulting in a "forcing" of the greenhouse effect and a rise in global temperature.

After a period of scientific debate and a certain level of controversy, climate change is considered nowadays a fact and it threatens the sustainability of planet Earth. The earlier "soft" statements from the Intergovernmental Panel on Climate Change (IPCC) have been replaced by much stronger ones during the last decade. In 1995 IPCC was acknowledging that "the balance of evidence suggests a discernible human influence on the global climate" stating though that "the weather changes have not been proved in absolute terms" (IPCC 1995). In its third assessment report (IPCC 2001), the summarising statements are stronger – "the warming over the last 100 years is very unlikely to be due to internal variability alone", "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations". In 2007, the statements become definite – "Even if global warming is to some extent the result of natural factors, the latest scientific insight shows that over recent decades much of it can be attributed to greenhouse gas emissions from human activities (IPPC 2007)". New scientific insight and research have confirmed that global climate change is taking place and is projected to continue. Impacts of climate change on society and natural resources are already occurring worldwide and are projected to become even more pronounced (European Environment Agency 2007).

Greenhouse gases (GHGs) consist of carbon dioxide (CO_2), methane, tropospheric ozone, halocarbons, N_2O. Particulates also contribute to the greenhouse effect. Carbon dioxide is the best-known GHG and the largest contributor accounting for about 50% globally and 80 % in Europe of total GHGs emissions (Rothengatter 2003; European Environment Agency 2007). Substantial reductions in GHGs emissions are needed if the impacts of climate change are to be kept at manageable levels (European Environment Agency 2007). IPCC suggests that the continuance of current trends and policies is likely to result in increased global emissions of carbon dioxide (CO_2), with resulting overall temperature increases of 1.8 to 4.0 °C during the 21st century. Some studies suggest an even wider possible range of 1.1 to 6.4 °C (IPCC 2001; IPCC 2007). The rise in the planet's temperature is predicted to have short and long term effects, including the melting of glaciers in the Antarctic and in the North pole , sea-level rise, expansion of desserts and widespread destruction of plants, animals, and ecosystems unable to adapt to changes in temperature and other aspects of climate (OECD Environment Directorate 2002). In addition, it can be said that climate change is experienced most intensively through the impacts of extremes, rather than gradual changes. Impacts include extreme weather conditions, river floods, droughts, forest fires, and human health problems due to heat waves. Even areas that benefit from changes in average climate are still likely to suffer from more intense and more frequent climate extremes. For example, agriculture in northern Europe is projected to benefit from increasing temperatures and atmospheric CO_2 levels, but the gain could be nullified by more frequent heavy rainfall events (European Environment Agency 2007; IPPC 2007).

As one of the single largest sources of human-generated carbon emissions, the transport sector is in large part responsible for the problem of global warming (Black

1998). Transport contribution to man-made CO_2 is at the level of 25 to 30% (European Environment Agency 2003; Rothengatter 2003). Apart from the CO_2 emissions, transportation contributes to global climate change through emissions of methane and other hydrocarbons, nitrous oxide, and water vapour discharged by aircrafts (OECD 1997). The constant increase of transport demand results in increased consumption of fossil fuels by all transport modes and increased emissions of carbon dioxide (Somerville 2003). Greenhouse gas emissions from the transport sector are almost entirely dependent on the amount of energy used and directly proportional to gasoline and diesel fuel consumption (OECD Environment Directorate 2002; European Environmental Agency 2003). With regard to the contribution of the different modes to total transport CO_2 emissions the following key figures are of interest (Faulks 1999; EC DG-TREN 2003; Vidal 2007): Road transport accounts for about the 80%, with about the one third of this being from road haulage. 4-5% of the world's CO_2 emissions come from marine transport, while aviation and rail account for around 2% each. Inland waterways and pipelines contribute for less that 1%.

Estimating long-term impacts has the dual source of uncertainty of, first, the prediction of the levels and types of emissions, and, secondly, the response of the global climate to these emissions. Despite this uncertainty, to give an introduction to the importance of climate change it is worth considering that physical models of the climate system suggest that a stabilisation of atmospheric carbon dioxide concentrations at today's level requires a reduction in net emissions of approximately 50% within the next 40 years, and further reductions thereafter (Lenzen, Dey et al. 2003). Studies (Azar and Rodhe 1997; Azar 1998) concluded that in order to prevent dangerous anthropogenic interference with the climate a global reduction of absolute carbon dioxide emissions by at least 50% in comparison with the 1990 levels will be required in the next 50 years. A reduction level of 80% has been put forward in Britain by the Royal Commission on Environmental Pollution (Royal Commission on Environmental Pollution 1994) for surface transport to be achieved by the year 2020.

Acidification

Another major environmental concern that transport contributes significantly to is acidification. Acidic gases (including sulphur dioxide, nitrogen dioxide and carbon dioxide) are released in the air through the burning of fossil fuels. Those gases rise in the atmosphere, and mix with water vapour (clouds). The resultant rain is then tainted with acid which in turn finds its way into the soil, rivers and lakes (Faulks 1999). The problem of acid deposition impacts primarily fresh water marine life and plant life. Acid deposition can provoke adverse effects on vegetation, forest growth and agricultural crops. Acidic water can also pass through the soils and into ponds and lakes affecting sensitive aquatic ecosystems (Black 1998). Other impacts of acidification include affecting soil nutrients, defacing buildings and damaging constructions and materials (Faulks 1999).

With regards to the sources of acidification, it should be noticed that sulphur dioxide is produced when coal or oil containing sulphur is burnt, and oxides of nitrogen are produced whenever air is heated to high temperatures. All types of vehicles produce oxides of nitrogen in their exhausts. Additionally, ships and diesel vehicles are significant sources of sulphur dioxide emissions. In the past sulphuric acid has contributed more to acid rain than has nitric acid. As emissions of sulphuric dioxide from heavy industries reduce, contributions from nitric acid are becoming more important (Gwilliam 1991). It is important to note that the transport sector is not the primary culprit in the case of sulphuric acids deposition as it contributes for around 5% of the sulphur oxides emissions. Nevertheless, transport is a primary contributor in the case of nitrogen oxides emissions and nitric acid deposition consequently (Black 1998). In the OECD countries transport produces 30-80% of NO_X emissions (Gwilliam 1991).

<u>Noise</u>

Noise pollution, the excessive or annoying degree of unwanted sound in a particular area, is the nuisance most often cited in connection with transport and the logistic chain. Noise is produced by the operation of all transport modes and it is a top priority environmental concern in logistic nodes' operations. In addition to being unpleasant, noise contributes to such health problems as stress disturbances, cardio vascular disease, and hearing loss. It can also disturb sleep and work (Silverleaf and Turgel 1991). People feel more directly affected by noise than by any other form of pollution (OECD Environment Directorate 2002). Vibration, particularly by heavy vehicles on uneven surfaces, may in addition cause damage to transport infrastructure, buildings, underground pipes and drains (Nijkamp, Ubbels et al. 2003).

Transport is a major source of noise annoyance in most societies, partly due to its concentration in denser areas. It is the dominant source of external noise heard by people in their homes. Noise from road traffic is by far the most frequently heard external noise and also the most frequent cause of nuisance (Cerwenka 1990; Mitchell and Hickman 1990; Gwilliam 1991). Road freight is a major contributor as heavy goods vehicles are the noisiest road vehicles, in terms of both their permitted noise levels and their actual noise in service (Mitchell and Hickman 1990). From a logistic chain perspective the issue of noise in logistic nodes is also of significance. Noise in logistic nodes is produced by freight and non-freight traffic, transport related operations such as cargo handling and warehousing, and by purely industrial activities (e.g. industrial areas located in seaports).

Transport noise and vibration are, unlike most forms of air pollution, specific in space and especially in time. Noise causes nuisance only at the time and place it is emitted although the effects may be longer lasted. Measuring the magnitude of noise pollution is complex. Volume is measured in A weighted decibels dB(A). A level above 65 dB(A) is considered unacceptable and incompatible with certain land uses in OECD countries. However, a number of different parameters must be factored into an indicator of noise: volume, pitch, frequency, duration, and variability. Noise indicators are typically an average of volume and duration over a fixed period of time. In the EU it is estimated that more than 30% of citizens are exposed to road noise levels, and around 10% to rail noise levels, above 55 L_{DEN} dB(A). A 10% of the total EU population may be highly disturbed by air transport noise (European Environment Agency 2003).

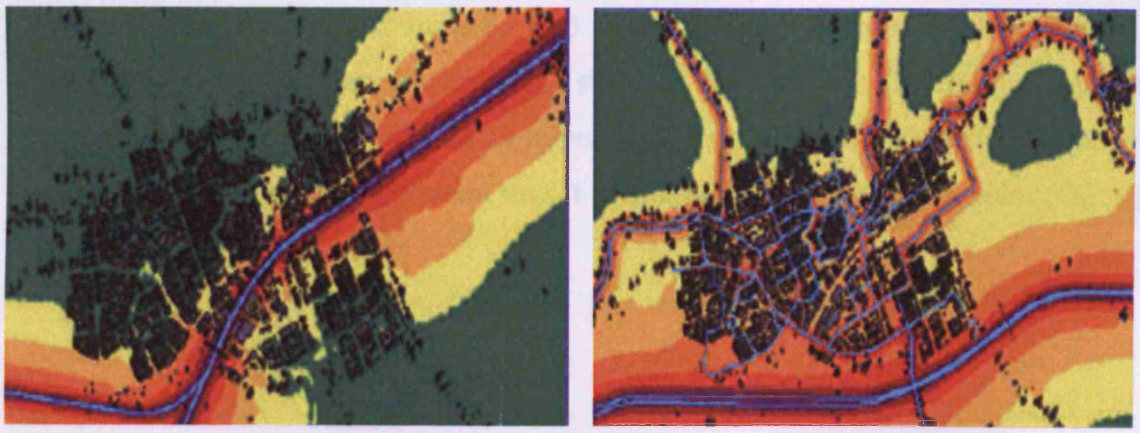


Figure 25: Road traffic noise maps produced with the Predictor software (Brüel & Kjær)

Noise can be measured accurately at its source by using advanced sound level monitoring equipment. The distribution of noise in space can be modelled by using digital space models that can simulate the dampening of echoing effects of buildings and vegetation as well as the effects of wind. Modern noise impact models combine the transport network and noise simulation in such way that the contribution from transport can be visible and identifiable (figure 25[4]). Noise monitoring and noise modelling using digital space models are analytically demonstrated in a series of case studies in chapter 8 of the thesis.

Water pollution

Transportation has both direct and indirect impacts on water quality. Shipping activity, in particular, directly affects the environment in a number of ways. The routine discharge of ballast water from marine vessels, if ballast is not segregated from cargo, introduces oil pollution at sea and in coastal waters, and can lead to introduction of nuisance species transported from the ship's origin to its destination. Shipping is a source of oil and chemical spills both routine and accidental at port, in coastal waters, and more rarely at sea. The routine maintenance dredging of ports and inland waterways stirs up toxic sediment and frequently leads to the disposal of dredged material in the open ocean. These problems increase with growth in shipping, although they are less directly linked to ton-kilometres of freight than is air pollution (OECD 1997).

The water-quality effects of land transportation are less direct. Road accidents and vehicle exhaust are both sources of oil and hazardous chemicals which run off the road into surface and ground water. The roads themselves, as well as parking lots, driveways, and other paved surfaces lead to an increase in impermeable surfaces, particularly in urban areas. Impermeable surfaces interrupt the filtration of rainfall into the ground water. An increase in impermeable surfaces will therefore aggravate flood risk and lead to more pollutant runoff into surface waters in heavy rains (OECD 1997).

[4] Source: Brüel & Kjær website www.bksv.com/pdf/Bp1602.pdf

Effects on landscape and biodiversity

The effects on nature, landscape, and biodiversity predominantly arise from the provision of transport infrastructure rather than from traffic itself. Transport infrastructure covers an increasing amount of land to the virtual exclusion of other uses, cuts through ecosystems and spoils the view of nature scenery. An estimation of the severity of this type of environmental impact depends significantly on the individuals' or society's perception and are thus usually difficult to quantify (Rothengatter 2003). Effects which are caused by the provision of infrastructure (roads, rail tracks, dams, bridges, airports) include:

- Severance, spatial separation and barrier effect
- Reduction in the quality of landscapes, loss of amenity
- Loss of natural land area (loss of biotypes, endangering rare species)

Accidents

Transport accidents and security incidents have direct adverse environmental impacts. Those include spillages of toxic, flammable and other hazardous materials, primarily from ships and road vehicles, that can have widespread and lasting effects on the natural environment (Silverleaf and Turgel 1991). In addition, most transport activities expose both users and non-users to the danger of injury or death from accidents, and also from deliberate attacks. These safety and security threats are part of the environmental sustainability issue, extracting a heavy and continuous social cost (Greene and Wegener 1997).

4.2.2 Relative environmental performance of transport modes

After having demonstrated the main environmental concerns of freight transport systems in the preceding sections, this section now focuses on the individual and relative environmental performance of the different transport modes. Although all transport modes impact on the environment, the magnitude, range and scale of the impact varies. Thus, mode selection itself influences the environmental performance of the logistic chain. For example, some transport modes such as rail and inland waterway transport use less energy or use energy more efficiently than other modes like road and air transport. A typical transport mode decision determines which transport option to use and often affects traffic congestion and air pollution both directly and indirectly (Wu and Dunn 1995). The following table 9 (Shortsea Promotion Centre Finland 2003) presents some key figures with regard to the environmental performance of the different transport modes in selected areas. It can be seen that, in terms of energy efficiency, emissions of greenhouse gases and other air pollutants, road and air transport can be considered less environmental friendly modes than shipping and rail transport.

Table 9: Key environmental performance indicators of freight transport modes

- Energy efficiency: In terms of ton-kilometres, shipping consumes 0.12-0.25 MJ, rail transport 0.60 MJ and road transport 0.70-1.20 MJ. Concerning the efficiency of energy consumption one kilogram of oil for one kilometre can transport 50 tons by truck, 97 tons by rail and 127 tons by water.
- Air pollution: Carbon dioxide emissions in the European Union area are 30g per ton-kilometre in shortsea shipping, 41g in rail transport and 207g in road transport. Of the total amount of nitrogen oxide emissions 51% originates from road transport vehicles and 12% from other traffic. The majority of sulphur dioxide emissions from transportation originate from shipping.
- External costs: The concept of external costs indicates the costs that traffic causes society, such as expenses connected with air emissions, climate change, infrastructure, noise, accidents and congestion. The total amount of external costs incurred in EU countries, Norway and Switzerland is 134.3 million euros per year. Of these expenses 92% are caused by road transport, 2% by rail transport and 0.5% by shipping.

Source: Shortsea Promotion Centre Finland

With regard to the environmental performance of the six main freight transport modes the following remarks could be made:

- Road transport: Although being the dominant inland freight transport mode it raises serious environmental concerns mainly in the areas of GHGs emissions, safety records, provision of infrastructure related issues (e.g. land take, loss of amenity, severance), and in the grounds of noise and congestion. It should be noticed that in terms of unit emissions of air pollutants road transport has been improving its performance significantly over time. The increase though in transport demand clearly offsets those unit improvements.

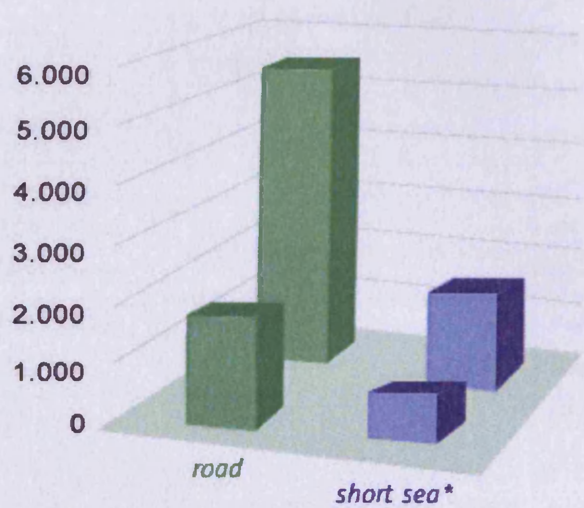
use the available techniques for exhaust emission abatement and also to use better quality fuel.

- *Inland waterway transport:* Inland waterway transport presents significant advantages in terms of its environmental performance. It is particularly effective and energy-efficient; its energy consumption per ton-kilometre of transported goods corresponds to 1/6 of the consumption on the road and to half of that of rail transport. Its noise and gaseous emissions are modest. According to recent studies, the total external costs of inland navigation (in terms of accidents, congestion, noise emissions, air pollution and other environmental impacts) are 7 times lower in than those of road transport. Inland waterway transport ensures a high degree of safety, in particular when it comes to the transport of dangerous goods. Finally, it can be seen as contributing to the decongestion of the overloaded road network in densely populated regions (EC DG-TREN 2007 c). Either alone or in various combinations with other modes of transport, inland waterways can offer an energy-efficient and relatively pollution-free mode of transport (Whitelegg 1988)
- *Air transport:* Air transport raises environmental concerns especially in the grounds of energy use, emissions of CO_2 and NO_X, and noise (Dings and Dijkstra 1997; Bonnafous and Raux 2003). The impact of aircraft exhaust in the atmosphere is multiple and complex. Conflicting effects need consideration; for example, an increase in engine pressure ratio may lessen fuel burn, but make the reduction of NO_X more difficult (Armstrong 2001). Reducing NO_X emissions by lowering thrust levels at take off can make it more difficult to comply with noise requirements (Somerville 2003). Designing aircrafts to cruise in lower altitudes may reduce adverse effects of injecting effluents in to the stratosphere, but possibly at the cost of airspace congestion requiring more lateral spread of flight tracks on busy routes, entailing higher total fuel burn. Radical innovations such as extensive laminar flow control could offer potentially major improvements to environmental characteristics but require much research and demonstration before commitment to projects can be contemplated (Armstrong 2001). The greatest potential for emissions reduction over the long term is through advances in

aircraft and engine technology but improvements in air traffic operations may also make a significant contribution (Dewes, Cottington et al. 2000).

- *Pipelines:* Pipelines are considered an environmentally favourable option for the transport of oil and gas over long distances (Knoepfel 1996).

After presenting key environmental performance indicators of the different freight transport modes, some selected comparative studies are highlighted below. The following figure 26 presents a comparative example of road transport and Short-sea shipping in terms of energy efficiency and CO_2 emissions (Shortsea Promotion Centre Germany 2005). The comparison is based on the fuel consumption and the emitted CO_2 of a full load by truck in a journey from Dortmund to Lisbon. The figures for short-sea shipping take into consideration the road pre-carriage to the port of Rotterdam and on-carriage from the port of Lisbon. The fuel consumption and the emissions of carbon dioxide appear to be more than three and a half times higher in the case of the uni-modal road transport chain.



	road	short sea
fuel kg	1.729	474
CO2 issues in kg	5.426	1.500

* The figures for short-sea shipping include the road pre-carriage to the port of Rotterdam and on-carriage from the port of Lisbon. All indications are based on average figures.

Source: Short sea shipping promotion centre Germany

Figure 26: Road and shortsea shipping performance in a journey from Dortmund to Lisbon

Table 10 presents some further selected comparative studies. It provides a description of each study and highlights the main outcomes.

Table 10: Selected comparative studies on the environmental performance of transport modes

Researcher - Year	Description	Outcome
(Lamure 1990)	Study on the environmental impact of road and rail transport	In terms of land take, energy consumption and air pollution rail is an environmentally favourable option
(Knoepfel 1996)	A set of environmental performance indicators (air emissions, energy consumption, noise, land use and visual impacts) was used in order to assess options for the transport of oil and gas over long distances	The study demonstrated that pipelines are the environmentally most favourable option
(Bonnafous and Raux 2003)	Study on the environmental impact of road and rail transport	Modal shift from road to rail may be justified in the grounds of sustainable development, but it is necessary to consider actual situations in order to assess the energy and pollution implications of such a shift
(Shortsea Promotion Centre Germany 2005)	Comparative study between road and sea transportation	The fuel consumption and the emissions of carbon dioxide appear to be more than three and a half times higher in the case of the uni-modal road transport chains
(Fridell 2006)	Comparative study between road and sea transportation	Shipping has the potential of being an environmentally friendly alternative to road transport. However, there is a need to use better quality fuel and the available techniques for exhaust emissions abatement

It can be observed that the results from comparative studies with regard to the environmental performance of the different transport modes and the potential impact of modal shift from one mode to another often present significant differences. Occasionally, they are even contradictory. An explanation might be that the studies are usually commissioned by bodies having a specific interest in the whole debate of the modal shift as a tool for the environmental management of transport.

4.3 Recent trends in logistic chain strategies

The preceding section provided an overview of the main environmental considerations of freight transport systems. In this section the dominant trends in logistic chain strategies and their environmental implications are discussed. As stated by Mr. Karamitsos on behalf of the Directorate-General for Energy and Transport (DG TREN) in his presentation in Helsinki in 2004, "... we have to understand those logistics trends and enter into a debate with the industry, on how those trends and the performance of the alternative modes can meet in order to provide viable and client-oriented transport solutions". Davies (1995) estimates that with environmental policies increasingly targeting the transport industry, the relationship between industrial logistics strategies and environmental pollution is coming under intense scrutiny.

Freight transport has decoupled from the GDP in some countries in an environmentally undesired direction. In particular the tonne and vehicle kilometres of road transport are growing much faster from the GDP. Recent developments in logistics strategies are supporting this trend. As shippers tend to prefer high flexibility and perfect control of transport to integrate freight movements into the supply chains the freight modal shift in many countries is changing in favour of the road (Rothengatter 2003). Structural changes in the economy and the expansion and improvement of road infrastructure have been accompanied by changes in the nature of goods transport: more powerful trucks can carry manufactured goods efficiently, while lighter trucks can ensure expeditious, timely and door to door delivery of high value added goods. Improved reliability and availability of relatively cheap road freight transport is both a cause and effect in the trend towards 'just in time' (JIT) production and enables manufacturers to reduce warehousing facilities (OECD Environment Directorate 2002). There are a series of factors such as JIT delivery, centralised warehousing and dispersed points of production, all favoured by the relatively low cost of road transport and the freedom of access for Heavy Goods

Vehicles (HGVs). At the same time the road freight industry has benefit from transport policies which favoured road traffic growth (CPRE 1992).

The development of sophisticated distribution centres resulted in "just in time" delivery systems. Just in time (JIT) logistics involves precise planning of deliveries to match production or sales needs. By reducing the need for stockholding it has assisted in cutting industrial costs. However, with JIT many more deliveries are made than in a system that depends on higher stockholding. JIT delivery systems turn roads into moving warehouses because it is cheaper to deliver goods as and when required than to store them (CPRE 1992). JIT is often blamed for increasing the level of transport demand and environmental pollution (OECD 1996) although there is some controversy between researchers in the field. Houghton (1996) concludes that energy consumption can be twice as high in the case of JIT as with conventional logistics. Cooper and Peters (1995) acknowledge that the move towards centralised warehouses might increase overall transport demand, but they consider that JIT driven transport operations could have many of the characteristics of bulk delivery such as the use of efficient large vehicles, offsetting this way most of the additional environmental pressure. They conclude that the environmental impact of JIT strategies might only be marginal and that it is difficult to generalise.

Other important logistic trends and factors that influence transport demand and consequently transport environmental impact include:

- Customers' demand for more frequent deliveries: More frequent delivery strategies might raise transport requirements and lead to further environmental pollution (Houghton 1996). For example, two smaller vehicles, and often not filled to capacity, might replace a single large one and their aggregate fuel consumption could exceed that of the larger vehicle. Generally though increases in customer service would, overall, have modest impact on transport demand (Davies 1995).
- Focused production: Focused production as practised by international companies tends to distance production sites from many markets which may have once been served by a local production plant. A growth in focused production across manufacturing suggests an accompanied growth in transport

demand and a resultant increase in environmental pollution, subject to critical assumptions on mode choice and similar issues. In addition, focused production often leads to a heavy concentration of flows along certain routes. This gives the manufacturer (shipper) considerable scope for negotiating price discounts with competing carriers. In that case focused factories might result in a level of environmental impact from transport which is disproportionate to the increase in transport price paid by the shipper (Cooper, Peters et al. 1995; Davies 1995).

- International and intercontinental sourcing: Decisions are based on quality and costs. Location and distances are secondary considerations since transport costs often represent a small element of total supply chain costs (Davies 1995). Supermarket chains, for example, source fresh produce from around the world to offer more variety to even more demanding customers. There are now demands for out-of-season fruits and for fruits from other places that are not available locally (OECD 1996). Clearly, the extra transport costs are more than balanced by the increased price shoppers are prepared to pay for out-of-season produce (Cooper, Peters et al. 1995; Davies 1995). Of course those practices lead to increased transport demands and greater environmental impact as the inevitable result.
- The dispersion and inter-linkage of production facilities: An example is the automobile industry itself, which assembles vehicles from components produced at plants in several countries or even continents, resulting in more movement of goods (or at least more movement of manufactured goods) (OECD 1996).
- Growth of extended organisations – in particular integrated logistics assets management: Integrated logistics assets management in which buyers and suppliers jointly examine the possibility for the deployment of assets to meet supply chain requirements may have an impact in reducing transport activity and associated environmental pollution. For example, the reduction of empty running by backloading one another's vehicles was a possibility being explored by grocery retailers such as Sainsbury in association with their suppliers (Davies 1995).

- Spatial changes: Shifts in economic activity to suburban areas have led many firms to move to edge of town and out of town sites where they are no longer connected to existing rail and port terminals (OECD Environment Directorate 2002). Unless further intermodal development takes place this spatial shift of economic activity acts in favour of road transport and adds to the overall environmental impact. In addition, there has also been much location and relocation of retail activities to urban peripheries, driven in part by retailers' desires to shift responsibility for some freight movement to customers, thereby increasing the amounts of freight activity, even if this might be recorded as customer/passenger transport (OECD 1996).
- Reverse logistics: Regulations increasingly require companies to take responsibility for their packaging and products and to arrange for their recycling or refurbishment. This inevitably implies a new use of transport. Despite the best of intentions, reverse logistics, could add measurably to transport demand, particularly when the nature of materials for recycling is not suitable for backloading (Davies 1995).

From the above it can be derived that with few exceptions the trends in logistic strategies tend to lead to increases in transport demand and to act in favour of road transport. The logistics trends though cannot be seen in isolation. In practice they reflect the transport market's response to factors such as transport policy, pricing, and general socio-economic structure of the market. While transportation often represents a small element in total supply chain costs, strategic decision making cannot be significantly influenced by the criterion of transport reductions. In any case though, the exact relationship between logistics strategies and transport related environmental impact is highly complex and it is challenging to generalise as it depends upon factors such as: industry sector, component of strategy, scale of application of strategy component, and modal choices in transport (Davies 1995). Careful consideration is required in any evaluation of how supply and logistic chain reconfigurations relate to the environmental impact.

Rothengatter (2003) predicts that the future will likely see the dynamics of growth being driven more by countries in transitions, meaning Central and East European countries (CEECs), developing countries, and countries which are the threshold of industrial development, such as China and Russia. He mentions the example of railway freight transport, which had about 70% of the market of land-borne freight transport in CEECs before the political changes at the end of the 1980s', and is expected to drop to below 25% by 2015, assuming a high economic growth combined with low transport regulation scenario.

4.4 The challenge of sustainability

This section examines the degree of sustainability of modern freight transport systems. Definitions and principles are established that aid and guide the assessment of the current structures and trends.

The concept of sustainability embraces environmental, social and economic considerations. The beneficial effects of transport are essentially social and economic. Improvements in transport have facilitated, and often stimulated or even provoked, radical changes in living standards and in patterns of behaviour which are generally regarded as "positive". Improved access and ease of movements for goods have made it possible and easy to develop sources of raw materials and agricultural products, to manufacture and assemble finished products and to distribute them to consumers, all on a worldwide scale. Improvements in transport in all modes have been a major factor in enabling the present population of the world to have higher average standards of living than those a hundred years ago, when the population was less than one billion (Silverleaf and Turgel 1991).

Transport responds to human desires and therefore a certain level of environmental impact arising from transport is inevitable. It has been suggested that sustainable transport cannot be precisely defined or achieved, but rather should be something humanity try to move towards (Gordon 1995). Sustainable transport can be seen as "satisfying current transport and mobility needs without compromising the ability of the future generations to meet these needs" (Black 1996). Adapting Daly's (Daly 1990) benchmark definition of sustainable development, Black (1998) suggests that transport is sustainable if it satisfies three conditions: (1) its rates of use of renewable resources do not exceed their rates of regeneration, (2) its rates of use of non-renewable resources do not exceed the rates at which sustainable renewable substitutes are developed, and (3) its rates of pollution emission do not exceed the assimilative capacity of the environment. Those conditions are also in accordance with the approach of OECD. Qualitatively, environmentally sustainable transport can be defined as following: Transport that does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources below their rates of regeneration, and (b) use of non renewable resources below the rates of development of renewable substitutes (OECD Environment Directorate 2002).

In line with the given definitions, the arising threats to sustainability encompass (Greene and Wegener 1997): (1) the degradation of the local and global environment (excessive rates of consumption of renewable resources); (2) consumption of non-renewable resources that appear to be essential to the quality of life of future generations; (3) other institutional failures that exacerbate the previous two problems (e.g. excessive traffic congestion which not only increases pollution and fuel consumption but also generates demand for more infrastructure and all its consequences, such as further urbanization of land and still more vehicle travel).

In assessing the sustainability of current transport systems in line with the criteria established above it is interesting to note that:

- All the main freight transport modes consume fuel derived from petroleum (non-renewable resource) and therefore cannot be considered as sustainable. Efforts to increase fuel efficiency have the potential of increasing the life of petroleum by insignificant amounts. Therefore vehicle fuel efficiency has little impact on transport's sustainability (Black 1998).
- The degradation of the local and global environment caused by transport operations, that has been extensively discussed in this chapter, indicates that the use of renewable resources exceed their rates of regeneration by natural processes.
- The fact that transport operations contribute significantly to global environmental concerns that threaten the ecological balance of the planet,

clearly shows that the rates of pollution emission exceed the assimilative capacity of ecosystems and the environment.

From the above it can be observed that none of the suggested conditions for sustainable transport is satisfied. The naturally derived conclusion is that current freight transport systems are not sustainable. The statement is supported by the remarks of major institutions and the outcomes of research in the field. Some selected examples are presented in table 11.

Table 11: Selected remarks on transport's sustainability

Institution/Researcher	Remarks on transport's sustainability
(OECD Environment Directorate 2002)	" given current trends, the impact of continued growth in transport services is not sustainable in the long term"
(European Environment Agency 2007)	"transport in Europe as we know it today is not sustainable"
(Greene and Wegener 1997)	There is now broad agreement that present trends in world transport are not sustainable
(Black 1998)	The non-sustainability of the current dominant transport modes has been recognised

It is of significance here to discuss some main principles that could be the drivers towards sustainable transportation and that are highlighted by researchers in the field. Those refer to the broad areas of renewable resources, relationship between environmental and economic considerations, and environmental liabilities and responsibilities in the logistic chain.

- *Renewable resources*: The idea that all resources must become renewable may seem impossible, but perhaps it is not. Resources are defined by human systems, especially by technology. Thus it is possible to conceive a balance between technological advancement and changes in institutions on the one hand and consumption of resources on the other. Resources that are exhaustible if technology and institutions are held constant may become renewable if the necessary changes are made at the appropriate rates (Greene and Wegener 1997).
- *Environment and economics*: Nature cannot be regarded purely as a means of production or as a source of raw materials, as in the neoclassical theory. More than that, it is necessary precondition for the continued survival of mankind in

the long run. As such, nature can never be traded off against economic wealth. A natural environment with functioning recycling processes, compatible with economic growth and social harmony, is the basis of long term sustainability (Rothengatter 2003).

- *Environmental liabilities and responsibilities*: The principle must be that any environmental pollution above the level that can be achieved by the use of the latest tried and tested technical measures, legally binding standards and responsible operation, should not be treated as a trivial offence but should be regarded as the misappropriation or destruction of natural resources and damage to the community, for which appropriate compensation, determined by the community, is to be paid. Cerwenka (1990) states: "Arguing over the details, for example how large a share of the responsibility for environmental pollution can be attributed to a particular source group, is simply a waste of time. Each segment of pollution sources can claim that it contributes only a negligible amount to environmental pollution; ultimately such reasoning leads to the conclusion that there can be practically no reduction of pollution. In fact, however, every single polluter group without exception must make the greatest efforts within its own area of activity and influence to conserve and protect natural resources. The best model is nature itself, where there are no wastes or residues, but only closed circles".
- *Tools towards sustainable transport*: Fundamental changes in technology, operation, design, and financing are needed. Half of the effort towards achieving sustainable transport would come from technological advancements for cars and lorries, fuels and infrastructure; the other half from making transport 'smarter' through mobility management, innovative mobility services and freight logistics (OECD Environment Directorate 2002).
- *Transport demand*: Economic growth continues to result in an increase in transport demand, which in turn causes further pressure on the environment (European Environment Agency 2007). The problem is not with any single mode, but rather with the excessive numbers of vehicles necessary to satisfy the demand for transport (Black 1998). Environmentally sustainable transport does not necessarily imply less transport than existing, but it certainly implies a different transport. A significant difference is the balance of use of more

rather than less environmentally friendly modes (OECD Environment Directorate 2002).

In launching Part D (Transport and the environment) of Transportation Research in 1996, the editor-in-chief stated in the preface that: "The environment is one of those topics which refuse to go away. Meanwhile there is mounting concern that with the current rapid expansion of traffic, sustainable development will not be possible without major changes in transport policy and technology." In this context the challenge for transport policy is to strike a balance between the economic and social benefits of transport and its negative impacts on society and the environment (European Environment Agency 2003; European Environment Agency 2007). From an operational perspective the challenge could be rephrased as to add the environmental component into the decision-making and the management of the logistic chain.

The challenge of sustainability:

Humanity is faced with the challenge of reducing transport's irreversible damage to the environment and health, without losing the benefits to society and economies

Responding to the challenge of sustainability requires coordinated efforts of all parties involved in the logistic chain; regulators, operators and other stakeholders. In the following section the response of the regulators is discussed. This is done taking mainly a European perspective. Then, the concept of environmental management of the logistic chain is introduced, and the potential for establishing a holistic environmental management framework or system is discussed, as being a promising response option to the challenge of sustainability. Examining the feasibility and practicability of such a framework that could deliver continual environmental improvement is one of the main aims of the thesis as established in chapters 1 and 2.

4.5 Transport policy and regulation framework

This section investigates the response of the regulative and legislative bodies as they face the challenge of selecting the appropriate policies that would enable the operation of more sustainable logistic chains. Such a study is of significance as the regulators are important stakeholders in the logistic chain. There are the bodies that set the rules that the transport industry would adapt to. As discussed, adequate transport facilities are essential to economic development, the life of the community and the nations generally. It is the responsibility of governments to ensure that proper provision is made and suitable steps are taken to achieve an appropriate and acceptable transport system.

The section starts by giving an overview of the main policy instruments and range of tools that are available in the hands of the regulative bodies. It should be noticed that political doctrines vary and are likely to differ between nations and between different governments (Faulks 1999). The plethora of international legislation and regulation concerning transport and the environment provides a complex challenge in identifying principles of the instruments involved in control and management. However, a study of the European perspective demonstrates the significance of policy during the last decade and the impact of such policies to the organisation, structure, and practice of the transport sector.

4.5.1 Transport policy instruments

Policy instruments can be categorised according to their focus or target and according to their nature. According to their focus there are three main groups of policies that can be identified (Greene and Wegener 1997; OECD Environment Directorate 2002). Each of them addresses a particular factor by which either the volume or the quality of movements or both are affected:

1. Transport technology: The environmental impacts of transport are not immutable, but are highly dependent on the technologies used to produce transport and the technologies used to mitigate its impacts. Technologies that

are now visible on the horizon, such as the hydrogen-powered fuel cell vehicle, suggest that technology may be able to reduce pollution even close to zero. The challenge is on the way of bringing the necessary technological changes required to restrain the environmental impacts of transport to sustainable levels. Desired technological changes include cleaner and fuel efficient motor vehicles, vessels, crafts and trains, emission control technologies, use of alternative fuels (e.g. biofuels, natural gas, electricity and hydrogen), and sophisticated IT systems for logistics and communication between players.

2. Transport supply: Like the demand for any good, transport demand is closely linked to transport supply. Transport supply in the form of infrastructure networks or levels of service offered by private carriers is subject to government control and therefore potentially an ideal policy instrument to influence transport demand. In the past, however, governments have seen their main responsibility in the provision of transport infrastructure to satisfy or even to stimulate demand, since the free movement of people and goods has been seen as a prerequisite for economic prosperity. The result has been the enormous growth in freight transport observed in the last fifty years. Better road networks, in turn, have further boosted road transport. Only recently the potential of transport supply management for controlling the growth in mobility and its dispersion between the different modes has been recognised. For example, infrastructure investments that are directed towards the provision, facilitation, and operation of an intermodal transport network, have the potential of re-balancing the modal shift in favour of more environmental friendly modes, such as rail. This is the case for instance of the investments for the multi-modal trans-European transport network, which constitutes a major pillar of the European common transport policy, and that are aimed to have a dominant rail share (European Commission 2001 a; European Environment Agency 2003).

3. Transport demand: Another group of policies tries to reduce the demand for transport. Growth in transport is often linked to economic growth and political openness, and to the price and quality of transport. Growth in incomes, opening of borders and better technology (resulting in lower prices and higher speeds) have all contributed to growth in transport demand. Policies in this

category are targeting transport demand at its origin, the spatial organization of cities, regions, and areas of economic activities. Transport demand results from the physical separation of human activities which, in turn, is made possible by transport supply. Policies influencing the demand for transport include land use and transport planning, traffic management, and pricing mechanisms (OECD Environment Directorate 2002).

According to the nature of their enforcement, policy instruments can be further categorised in regulations (prohibitions), fiscal instruments (financing and pricing), and voluntary agreements (Cerwenka 1990; Faulks 1999; OECD Environment Directorate 2002). This distinction can be further applied to all of the above mentioned categories.

The regulatory policy instruments refer to the prohibitions imposed and enforced by governments and regulative bodies. They can be further divided into quality or quantity control aimed. Quantity control regulations ensure that transport operations and services are in accordance with certain set values. An example here is the exhaust emissions regulations. Quality control instruments ensure that operators meet certain imposed quality standards (e.g. safety, environmental) (Faulks 1999). An example of a quality control instrument is the Strategic Environmental Assessment (SEA) in Europe. According to the SEA directive (Directive 2001/42/EC) transport plans and programmes should be subject to environmental assessment prior to their adoption (European Environment Agency 2003).

Fiscal instruments intervene on the financing and pricing of transport operations and could have a significant influence in transport practices and the logistic chain. Examples of fiscal instruments include fuel taxes, internalisation of external costs, but also recent schemes such as the Emissions Trading Scheme (ETS) in Europe. Fuel taxation is an important policy tool that provides a direct incentive to improve the energy efficiency of transport and thereby reduce greenhouse gases and other exhaust emissions. Fuel tax can also serve as a tool for payment of the external costs of infrastructure such as congestion, accident risks, air pollution and noise. Every transport user poses a burden of unpaid costs on other people, including the costs of accidents, pollution, noise and congestion. In the EU, these costs are estimated at 8 % of GDP. At the same time, many transport taxes are poorly targeted and unequal.

They do not differentiate between users and their different impacts on infrastructure, contributions to pollution, accidents and bottlenecks. Shipping and aviation fuels are not taxed at all. This distorts competition between transport modes and the untaxed sectors face no extra incentives to reduce their greenhouse gas emissions. A restructuring (and in many cases increase) of transport taxes and charges could contribute to making individual users pay the true costs imposed on society. Some western European countries pave the way for internalisation by restructuring transport taxes and charges. For example, a heavy goods vehicle (HGV) charge is dependent on distance driven in Switzerland, size of truck and the environmental class of the engine (European Environment Agency 2003).

There are also voluntary forms of control through internationally agreed standards of operational conduct which are established through international bodies. Table 12 summarises the major international bodies and trade organisations representing different freight transport industry sectors. Those organisations, whilst not exercising control in the literal sense, are involved in the development of standards and codes of practice with regard to the health, safety, environmental and security management of freight transport. Those standards and codes of practice often have a broad recognition by authorities, governments and the general public and therefore the most reputable transport operators set themselves out to comply.

Table 12: Major international bodies and trade organisations

Organisation	Freight Transport Industry
International Road Transport Union (IRU)	Road transport
International Road Federation (IRF)	Road transport
International Union of Railways (UIC)	Rail transport
International Maritime Organisation (IMO)	Maritime transport
International Chamber of Shipping (ICS)	Maritime transport
Lloyd's Register (LR)	Maritime transport
International Civil Aviation Organisation (ICAO)	Air transport
International Air Transport Association (IATA)	Air transport
European Sea-Ports Organisation (ESPO)	Seaports
International Union of combined Road-Rail transport companies (UIRR)	Combined Road-Rail transport
Inland Navigation Europe (INE)	Inland waterway transport

In assessing the effectiveness and potential of the different policy instruments the following remarks could be made:

- Sound and well-enforced regulations have brought substantial progress in reducing air and water pollution and toxic hazards in the United States, Europe, and other countries. But the piecemeal, complex, and ever-changing regulatory system has made enforcement of controls increasingly more expensive and marginally less effective for both business and governments (Rondinelli and Berry 1997).
- Research often argues in favour of fiscal instruments that in cases are considered more effective than regulations.
- The industry seems to be in favour of voluntary self regulation. The example of the port industry is characteristic here and it is analytically discussed in chapter 7 of the thesis. It has been argued that instead of introducing more legislation the governmental efforts should focus on the enforcement of the existing provisions.
- Transport policies cannot be viewed in isolation from land use changes and economic changes. There is a fundamental relationship of mutual dependence which has to be reflected in policy making at any level, and also one with the creation and alleviation of environment dereliction (Whitelegg 1988).

4.5.2 The European perspective

Having presented the range and scope of transport policy instruments that are available in the hands of regulative bodies worldwide, this section focuses on the European example. The section provides an insight on current practices and trends of the European transport system, it provides an overview of EU transport policies and initiatives during the last decade, and it finally discusses the impact of those policies. The aim is to demonstrate the applied regulative framework and how this can respond to the challenge of operating more sustainable transport systems and logistic chains.

4.5.2.1 The European transport system: modal share and growth trends

The general picture with regard to the European transport system and the actual performance of the different transport modes are described by the figures that follow. Table 13 gives an overview of the modal split in European freight transport from 1970 to 2002 (EC DG-TREN 2003). Figure 27 compares the tonne-kilometre growth of each transport mode in Europe for the period from 1995 to 2004 (Vanderhaegen 2006).

Table 13: Overview of the modal split in European freight transport (1970-2002)

	Road (%)	Rail (%)	Inland Waterways (%)	Pipelines (%)	Sea (%)
1970	34.7	20.0	7.3	4.5	33.5
1980	36.3	14.6	5.3	4.3	39.4
1990	41.9	10.9	4.6	3.0	39.6
1991	42.3	9.8	4.5	3.3	40.0
1995	43.0	8.5	4.4	3.1	41.0
2000	43.2	8.2	4.2	2.8	41.6
2001	44.0	7.9	4.1	2.8	41.1
2002	44.7	7.7	4.1	2.8	40.8

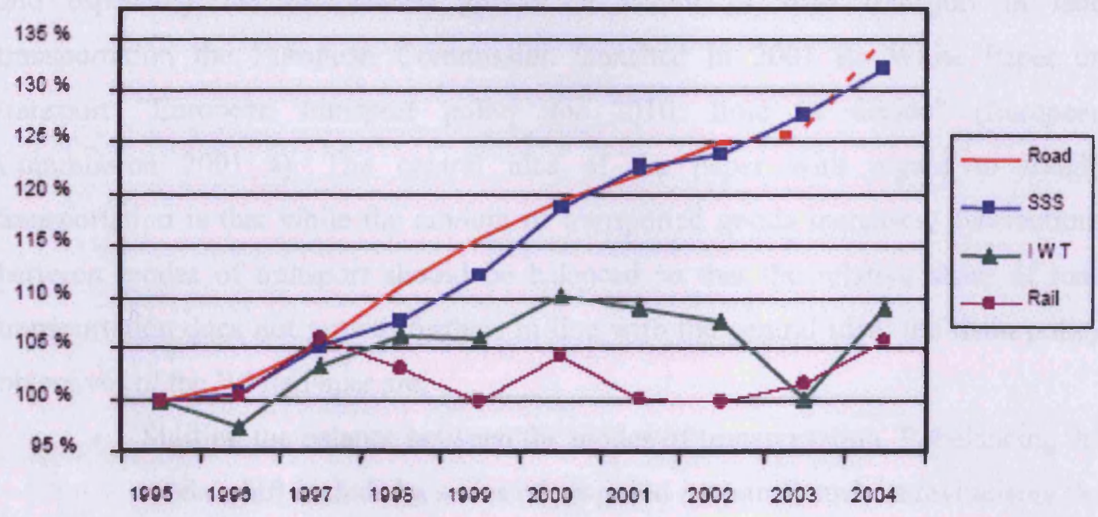


Figure 27: Tonne-kilometre growth per transport mode in Europe (1995-2004)

It can be observed that road transport and short sea shipping are by far the most commonly used modes for freight transportation in Europe. Additionally road transport and shipping are the modes that present the highest annual growth rates. Rail transport and inland water transport appear not to fulfil their potential. An example of unexplored potential of inland waterway transport is provided by the Danube corridor area. Although the enormous fluvial transport potential of the Danube River, the largest trade by far in the Danube corridor is conducted via road vehicles (Radojcic 2006).

In Western Europe (WE) freight volumes have more than doubled since 1970. The increases in WE in the 1990s were primarily in road and air transport. Total European Union (EU) freight transport increased by 33 % over the 1991-99 period (including road, rail, inland waterways and air transport) explained mainly by a 44 % increase in road transport. The share of road in inland freight transport is dominant (74%) and is still growing, while that of the alternative modes (rail, inland waterways) continues to decline. Short sea shipping in Western Europe is also quite successful, carrying almost the same amount of tonne-km as road (European Environment Agency 2003).

4.5.2.2 Main EU policies and programmes

Taking into account the realities and trends in the European freight transport system and especially the imbalanced growth in favour of road transport in land transportation the European Commission launched in 2001 its White Paper on transport "European transport policy for 2010: time to decide" (European Commission 2001 a). The central idea of the paper with regard to freight transportation is that while the amount of transported goods increases, distributions between modes of transport should be balanced so that the relative share of road transportation does not growth further. In line with the central idea, the main policy objectives of the White Paper are:

- Shifting the balance between the modes of transportation. Rebalancing the modal shift included a series of proposed measures such as revitalising the railways, promoting short sea shipping and intermodal transportation and improving services in road transport and aviation.
- Eliminating bottlenecks in the transport system. The proposed measures included infrastructural and procedural interventions in the European

transport network but also promoting research in technical and conceptual areas in order to tackle inefficiencies in uni-modal and intermodal transport operations.

The modal shift from road transport to cleaner transport modes such as short sea shipping, inland shipping and rail transport is one of the main aims of the European transport policy. Intermodality is of fundamental importance for developing competitive alternatives to road transport (European Commission 2004) and therefore rebalancing the modal split in the European transport system could be achievable through the development of door-to-door integrated and intermodal transport chains. Intermodal transport chains are characterised by a much higher degree of complexity than single transport mode solutions in terms of procedures, administration and technology in use as shown in figure 28. Those complexities have an impact in economic and efficiency terms and consecutively in the restriction of the growth of intermodal transportation. In a few important European corridors, intermodal transport has the potential to reach a market share of 30% while currently still represents a small part of freight transport between 2 and 4% (European Commission 2001). New logistics concepts, innovative technologies, and holistic chain management tools are needed for intermodal transport to really fulfil its potential offering cost and quality competing alternatives to road transport in an integrated door-to-door basis.

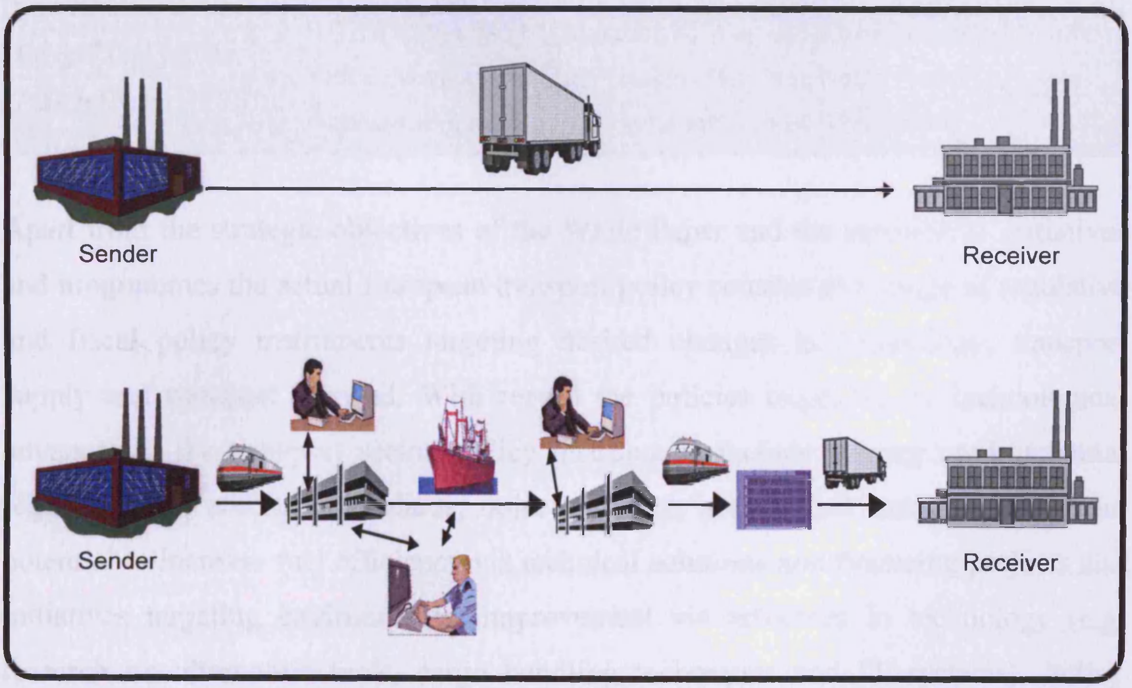


Figure 28: Uni-modal versus intermodal transport

In line with the policy objectives of its White Paper on transport the European Commission launched a series of policy initiatives and programmes during the last 5 years aiming towards the rebalancing of the modal split and the growth of intermodal transportation. Selected initiatives and programmes are presented in table 14.

Table 14: Major EU Policy initiatives

EU Policy initiatives	Description
White Paper	Modal shift from road and air transport to cleaner transport modes. "The growth in road and air traffic must therefore be brought under control, and rail and other environmentally friendly modes given the means to become competitive alternatives."
Marco Polo programme	To help shift the expected increase of international road freight to short sea shipping, rail and inland waterway.
Short-sea shipping promotion	Establishment of a network of national short-sea shipping promotion centres in all EU countries
Motorways of the Sea	To offer real competitive alternative to land transport. The "motorways of the sea" concept aims at introducing new intermodal maritime-based logistics chains in Europe.
Standardisation and harmonisation of intermodal loading units	To reduce inefficiencies in intermodal transport resulting from various sizes of containers circulating in Europe. Furthermore, the measure will help to better integrate short sea shipping into the intermodal transport chain.
Freight Integration Action Plan	To improve the organisation of intermodal freight transport. With this initiative, the Commission intends to help improving freight forwarding practices to boost intermodal transport.

Apart from the strategic objectives of the White Paper and the associative initiatives and programmes the actual European transport policy consists of a range of regulative and fiscal policy instruments targeting desired changes in technology, transport supply and transport demand. With regard the policies targeting the technological advances in the transport sector, policy instruments include: setting environmental regulations on emission standards, noise and dust, setting fuel taxes that have the potential to increase fuel efficiency via technical solutions and financing projects and initiatives targeting environmental improvement via advances in technology (e.g. research on alternative fuels, cargo handling techniques and IT systems). Policy instruments targeting the transport supply include selected investments in infrastructure networks, such as the multi-modal trans-European transport network and the Motorways of the Sea, and other initiatives that aim to shift the balance between the modes of transportation. In order to combat the environmental, safety and congestion problems resulting from the continuing growth in transport demand, the EU's sustainable development strategy, adopted at the Gothenburg Council in 2001, contains policy objectives to break the link between economic growth and the growth of transport demand (European Environment Agency 2003).

4.5.3 Policy discussion

The environmental impact of freight transport has its source both on the environmental performance of all its components (different modes), the modal share and the way that those components are linked into a system or chain, and on the total amount of freight transport demand. Efforts to control and manage the environmental impact could therefore focus on the three areas mentioned above.

EU experience shows that vehicle technology and fuel improvements can, through environmental regulation, help to reduce certain impacts per unit of transport significantly, particularly air pollution. However, such gains in eco-efficiency seem not to have been sufficient to mitigate the impacts of the rapid growth of transport and infrastructure volumes on greenhouse gas emissions, noise and habitat fragmentation. In addition to technological solutions, better integrated transport and environmental strategies are needed to restrain traffic growth and promote the use of more environmentally friendly modes (European Environmental Agency 2003).

The balance between the different transport modes has a significant impact on the environmental performance of the transport system. The current balance in Europe and the trends in transport growth constitute a serious threat for the sustainable operation of the European transport system. The policies of the European Commission are towards the desired direction focusing both in rebalancing the modal split in Europe and in improving the environmental performance of transport by promoting the implementation of technical, procedural and managerial solutions throughout the logistic chain. The trends though concerning the envisaged modal shift from road transport to cleaner transport modes do not appear to be optimistic. Road transport is still gaining modal share and is presenting the highest growth rate between the different modes of transportation. Despite regular increases in taxes, fuel for road transport remains cheaper in real terms than it was 20 years ago. Research (Rothengatter 2003), and the EU itself (European Environment Agency 2003) recognise the need to internalise the external costs of transport on society in transport policies.

There is an ongoing debate on the EU policies tackling the environmental impacts of transport with many parties involved, such as industry representing organisations, non-governmental organisations, researchers and general public.

The European Commission has been facing criticism by industry associations, mainly related to the road transport industry, with regard to some main policy elements of its White Paper on transport policy, such as the modal shift and the decoupling of transport from economic growth. Industry associations, including the European professional association of tolled motorways companies (ASECAP), the European Union Road Federation (ERF) and the International Road Transport Union (IRU), agree that the Commission's Transport Directorate has faced up some serious misconceptions in its policy framework. The concepts of forced modal shift from road to rail and the decoupling of transport from economic growth remain theories without practical application. The associations argue that those central pillars of the White Paper have been tested against the socio-economic realities of the last five years (2001-2006) and their credibility has been seriously undermined. Therefore, those associations were calling for the replacement of those concepts by strategies that do not discriminate against, or prefer any single mode of transport over another in the Commission's mid-term review of the 2001 Transport White Paper (Croner Transport News 2006).

Several parties call for a better communication between the EU policy makers and the transport industry. In many cases gaps can be observed between the industry's practice and the objectives of the European transport policy. An example is the envisaged harmonisation of container sizes in Europe. The European Commission has been considering since 2001 to introduce the European Intermodal Loading Unit, a container unit of 44ft long to replace current containers and to cope with inefficiencies occurring due to the presence of different container sizes throughout Europe. The practice though is currently oriented towards the use of 45ft containers that are increasingly introduced to the market as a result of the competition between Ro-Ro and Lo-Lo carriers. The International Union of combined Road-Rail transport companies (UIRR), commenting on the proposal by the European Commission on a standard European Intermodal Loading Unit (EILU), argues that any attempt to force interoperability will only harm combined transport. What is the use of interoperability with a universal container which can theoretically travel on all modes and be transported by all cranes if it is not accepted in practice and traffic is shifted back again to the road (UIRR 2004)?

On the positive side it should be noticed that several research and development projects, supported by the European Commission, have been undertaken during the last five years. Those projects have produced valuable tools, methodologies and innovative technical, procedural and managerial concepts contributing to the improvement of the environmental performance of the European transport system.

4.6 Environmental management framework

The previous section discussed the response of the regulators as they face the challenge to strike a balance between the positive socio-economic impacts of the logistic chain and its threatening environmental impacts. This section takes an operators', industrial perspective while examining how the same challenge could be faced. Environmental management of the chain is the key concept towards that direction. The environmental management of the logistic chain may be defined as "the functional organisation required in order to minimise the environmental impacts arising from the operation of intermodal transport systems". Such a functional organisation embraces a set of logistic chain policies adopted, actions taken, and relationships formed in response to concerns related to the natural environment with regard to the design, acquisition, distribution, use, reuse and disposal of goods and services (Zsidisin and Siferd 2001). The concept recognises the physical and economic links associated with an integrated transport system, or chain, specifically designed to transport or deliver goods in a cost-effective and sustainable manner.

It has been suggested that sustainable transport cannot be precisely defined or achieved, but rather should be something humanity tries to move towards. Continual environmental improvement would therefore be the aim of environmental management efforts. This could be delivered by the establishment of an integrated environmental management system or framework for the whole logistic chain. Assessing the feasibility and potential of such a framework is one of the main aims of the thesis. Questions to be answered include: (1) Is such a system technically feasible?, (2) is it practicable?, (3) which are the main challenges (e.g. responsibilities, leadership, and administration)?, (4) what are the benefits?, (5) which would be the catalysts for action towards this direction?, and (6) what form would such a system take? Those questions are tackled within the following chapters of the thesis (5, 6, 7, and 8) and findings and answers are summarised in chapter 9.

In this section the generic format of such a framework is introduced drawing on the principles of well established environmental management systems. A general Environmental Management Framework for the logistic chain has to be developed in such a way that environmental considerations can be made at different scales, from the international overview through to the chain component specific application or operation. The overall system should be tiered in form and structure conforming to the model advocated by the widely recognised ISO standard. The general picture (adapted from (ISO 1996) and (International Navigation Association 1999)) is presented in figure 29.

Any EMS consists of four main phased steps, namely policy, plan, act and continual improvement, and of feedback loops. The first step is to identify the governing environmental policy that will be used as a guideline for environmental practice at the desired organisational level. As part of the process the general areas of possible environmental concern in all embraced activities are identified. These concerns are then evaluated against the international and national legislation and the interests of stakeholders. Output of the policy development system is policy objectives on environmental issues relating to the operation of the logistic chain, which are attainable by working through the other components of the environmental management framework.

The Plan phase has got two ultimate aims: (1) to produce an environmental strategy in agreement with the corporate management and (2) to develop specific and prioritised and achievable environmental goals. The strategy and goals are derived from an assessment of the environmental effects of transport related activities. The output of the Plan phase is a series of prioritised goals that the management has made a commitment to achieve providing the appropriate finances and resources.

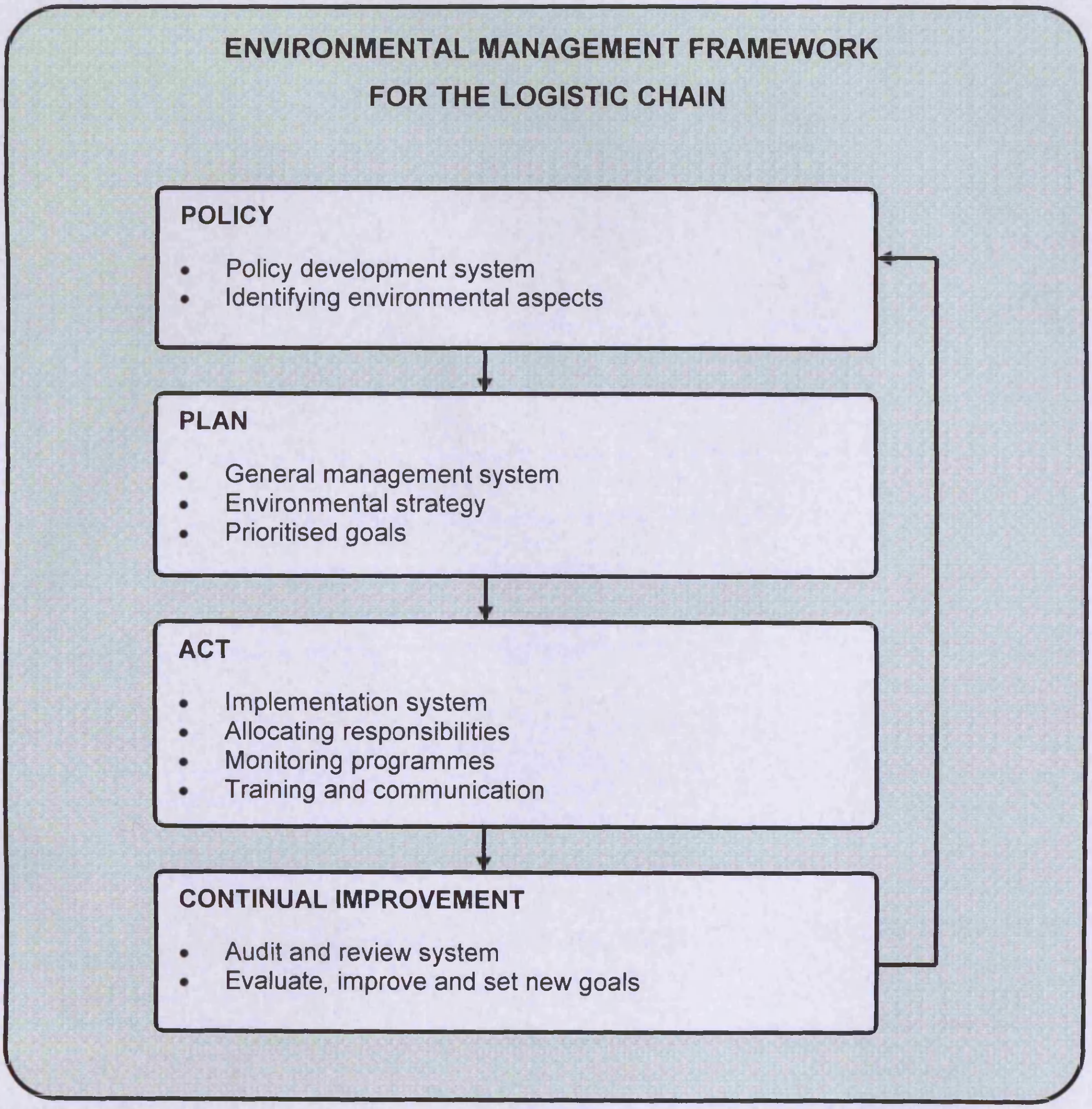


Figure 29: Generic form and structure of an EMS for the logistic chain

The Act phase of the environmental management framework is the implementation phase, where specific measures or actions are carried out with the aim of achieving the goals set during the planning phase. There are three main preconditions; (1) allocation of clear responsibilities and tasks, (2) procedures and methods for monitoring must be implemented and environmental performance indicators must be selected in order to assess progress towards a goal, (3) training and communication programmes must be established to ensure the necessary details for the implementation.

The records of the procedures for, and the results of the monitoring programmes from, the implementation phase are evaluated against the target for each goal (audit and review system). In case the results of the review indicate that the methods of implementation are not achieving the required standard for the individual goal, a feedback to the implementation system is provided within the environmental management framework. This allows the methods of implementation or operation control to be refined to improve performance to the required level. This feedback loop can continue until the environmental audit indicates that the goal has been achieved. The environmental review evaluates whether the goals have been achieved and whether the organisation's objectives are still valid. These may be changed due to new or refined legislation or to a change in emphasis by stakeholders or the general public. This implements the concept of continual improvement.

The model described in this section is an EMS on its generic form that through adaptation can be applied to several organisational structures. In the case of the logistic chain, such a model should be evaluated, modified and validated as to whether it can tackle the peculiarities and complexities of the logistic chain system. A major challenge arises from the fact that such EMS models require a functional entity, a well established organisational structure (commonly referred to as organisation). The organisational structure ensures that decisions are made, objectives are set, communicated and assessed, and that responsibilities and resources are allocated. In other words the organisation is vital for the system to function and to deliver continuous environmental improvement. As it has been demonstrated in chapter 3, the identification of clear leadership in the logistic chain is challenging since none of the parties involved (shippers, carriers, logistic service providers, and terminal operators) sees to fulfil the role of a generally acclaimed chain leader. An environmental management framework for the logistic chain should therefore respond to this challenge.

The generic model of figure 29 can then been seen as an over-arching framework that will be filtered and adapted through the findings of the following chapters of the thesis in order to fit both the administrative and operational requirements of the logistic chain. The studies in chapters 5, 6, 7 and 8 provide the necessary insight towards that direction and guide the development and the validation of the logistic chain specific model that is presented in chapter 9.

4.7 Conclusion

This chapter examined the interaction between the logistic chain and the environment. It studied the environmental impact of chain operations and concluded that current structures and trends cannot be considered sustainable. In this context, the chapter formulated the sustainability challenge, being to strike a balance between the economic and social benefits of transport and its negative impacts on society and the environment. Towards responding to the challenge, the key concept of holistic environmental management was introduced. With regard to the regulators' response, a European perspective was taken in order to demonstrate applied policies, and to discuss their impact on the structure and performance of the logistic chain.

The chapter concludes the first part of the thesis that established the main questions and considerations and set up the analysis. The following chapters of the thesis are focussing on answering the arisen questions applying a multi-method phased approach as described in chapter 2 on research approach and pathway.

5 Significant Environmental Aspects of the Logistic chain

This chapter is the first "results" chapter of the thesis and it contributes towards the concept of integrated environmental management of the logistic chain. Following a widely acknowledged management methodology, based on ISO guidelines, the environmental impacts of the logistic chain are analysed. The analysis framework reveals the causal mechanisms of those impacts via examining them in line with the activities that are likely to cause them and the associated significant environmental aspects. The exercise identifies and demonstrates the range of significant environmental aspects that need to be addressed by environmental management. This is an essential first step for the setup of any environmental management scheme or system and is therefore part of the phased development of the research pathway. The outcome of the chapter, in the form of the presented and explained analytical matrices, can be seen, as an analytical tool to identify the significant environmental aspects, and as a stand alone handbook for demonstrating and then managing the range of impacts associated with transport and the logistic chain.

5.1 Background

As established in chapter 2, and in line with the main research hypothesis, the thesis aims to contribute in the field of the environmental management of the logistic chain by examining the feasibility and practicability of a holistic management scheme or system. One of the essential first steps in any attempt to establish an environmental management system, no matter how basic or how sophisticated, is the identification of the elements that need to be managed. In other words a clear understanding is required of those activities, services or products that can interact with the environment in an undesirable manner. "Identifying major transportation activities with impacts on the environment is an essential first step in effective environmental management" (Rondinelli and Berry 2000). Figure 30 presents the generic methodological framework which was applied. The actual analysis framework is discussed and explained in section 5.2 that follows.

Input

- Literature review on environmental science and transportation
- Researcher's experience in environmental management
- Consultation with a panel of experts for advice

⇩

Process

- Environmental management methodology, based on ISO and EMAS systems , for analysing the transport related environmental considerations revealing their causal mechanisms in the form of activities – environmental aspects – environmental impacts

⇩

Output

Analytical matrixes for each transport mode which serve as:

- Phased development towards integrated environmental management of the logistic chain
- Analytical tools for identifying the significant environmental aspects of the chain
- Stand-alone handbook for demonstrating the range of impacts of freight transport operations

Figure 30: Methodological framework

The body of knowledge with regard to the environmental considerations of the logistic chain was studied by reviewing relevant literature. Then this knowledge was filtered through, structured and analysed according to environmental management system guidelines. The exercise required a certain level of experience in environmental management and an understanding of the terms in use. Additional input assisting the process was the consultation with experts in the field. The output is an analytical tool assisting in the identification of the significant environmental aspects of the logistic chain.

5.2 Analysis framework

The knowledge database with regard to the environmental impacts of the logistic chain is not uniformed in structure or content. It consists of disparate sources such as scientific books, journal papers, policy documents, educational books and material, industrial press, NGOs' documents and reports, research and development projects' reports, and authorities' reports. Studies in the field differ in nature and in content ranging from quite broad generic overviews of transport related environmental considerations to analytical studies of specific aspects in the transport chain. Studies are often organised on a sector by sector, transport mode basis.

Due to the differences in the nature of the provided information from the disparate sources a certain level of confusion can be observed with regard to the terminology in use. Terms such as environmental impacts, aspects, issues and considerations are commonly used generically in the various literature sources and without differentiating between their etymologies. Environmental management though requires a very clear distinction of those terms to be applied. Distinguishing and clearly documenting an organisation's activities, environmental aspects and environmental impacts is a precondition for establishing an environmental management system, such as ISO or EMAS.

It is therefore of significance to filter the body of knowledge on transport environmental considerations following a structured environmental management based approach. This process is graphically represented in figure 31. It can be observed that the process consists of restructuring the knowledge database in order to get an output consistent with environmental management guidelines. The filtering process is based on (1) developing a structure for the analysis (headings of the analytical matrices) and (2) on clearly defining the terms in use. The developed structure can be seen in figure 31 (analytical matrices) and it has been driven by the ISO 14001 standard guidelines and by consulting different studies (OECD 1988; Rothengatter 1990; EN ISO 14001 1996; Eriksson, Blinge et al. 1996; Workport Project 1999; Rondinelli and Berry 2000; Darbra, Ronza et al. 2005) that also attempted a structured classification of transport related environmental considerations either on a theoretical either on a practical level. The selected structure dictates an analysis that demonstrates the causal chain of the different environmental impacts in the form of activities – aspects – impacts.

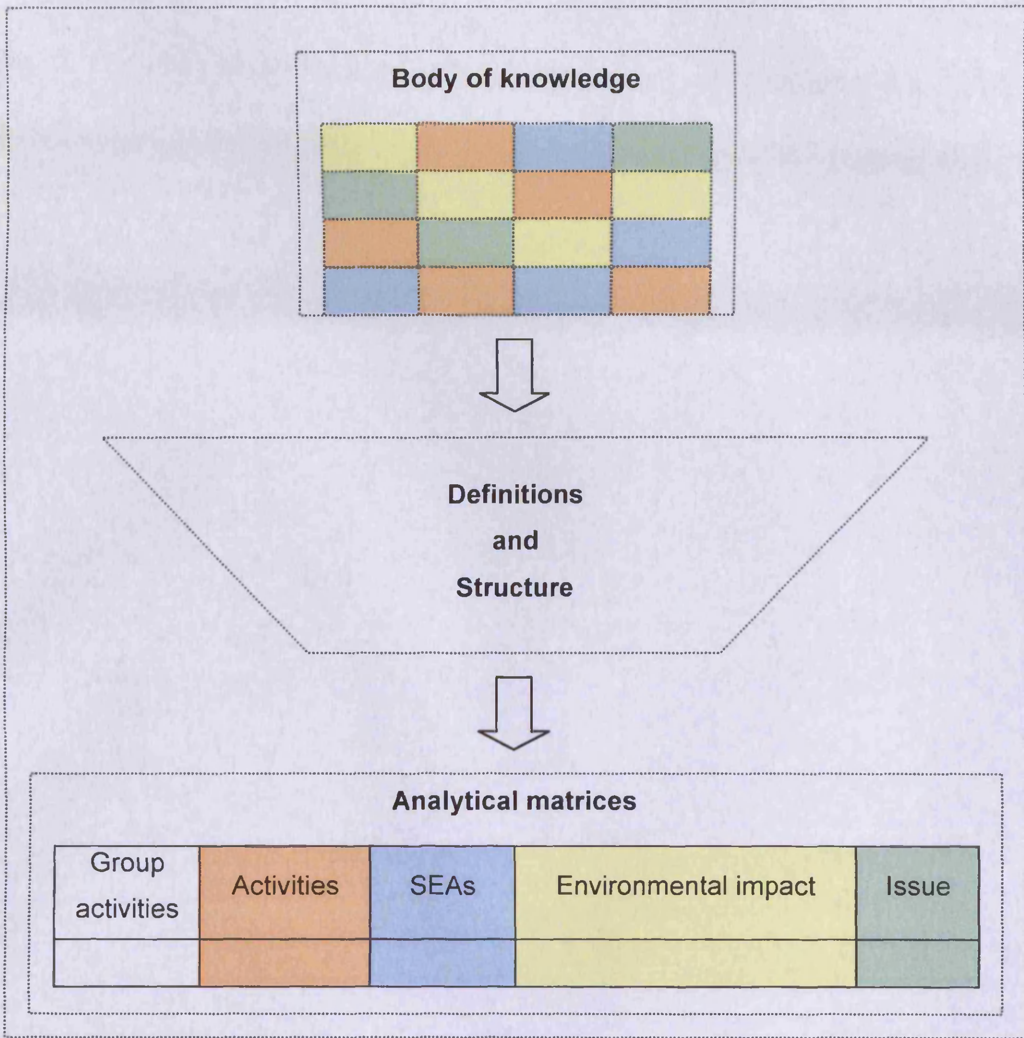


Figure 31: Analysis process of transport related environmental considerations

In order to reveal those causal chains in a consistent manner it is of significance to clearly define the terms in use. The following table 15 provides the definitions of the terms used in the analysis and throughout the thesis.

Table 15: Definition and explanation of terms

Definition and explanation of the terms (headings of the analytical matrices):
• Activity: The term "activity" on the matrices is used generically and embraces any activities, products or services related to the transport mode under question that

might have elements interacting with the environment

- Group Activity: Grouping together activities, products, or services in line with the main sources of transport related environmental impacts (see figure 32). The grouping option is selected for reasons of consistency and coherence of the matrices
- Environmental Aspect: An element of an organisation's activities, products or services that can interact with the environment (ISO 1996)
- Significant Environmental Aspect: An environmental aspect that has or can have a significant environmental impact (ISO 1996)
- Environmental Impact: The effect of an environmental aspect on the environment and its components. The environmental impacts are meant to be potential.
- Environmental Issue: Generic term, it shows interaction of the aspect - impact chain under examination with the environment via or with one of its main elements (air, water, soil and nature, landscape, biodiversity). Examples (aspects – issue): exhaust emissions – air, solid waste disposal – soil (primarily), land take of roads – landscape, discharge of ballast water - water

Those defined terms give the essence of the analysis and clarify the structure of the analytical matrices that are presented in section 5.3. The column of group activities is aimed at further classifying the activities in the logistic chain that might impact on the environment in some broad categories for reasons of consistency and coherence. Those categories include the production/construction, operation, maintenance, and disposal of both the means of transport (vehicles, vessels, aircrafts, trains, pipes) and infrastructural assets (roads, railways, seaports, airports, inland and dry ports) used as seen in figure 32.

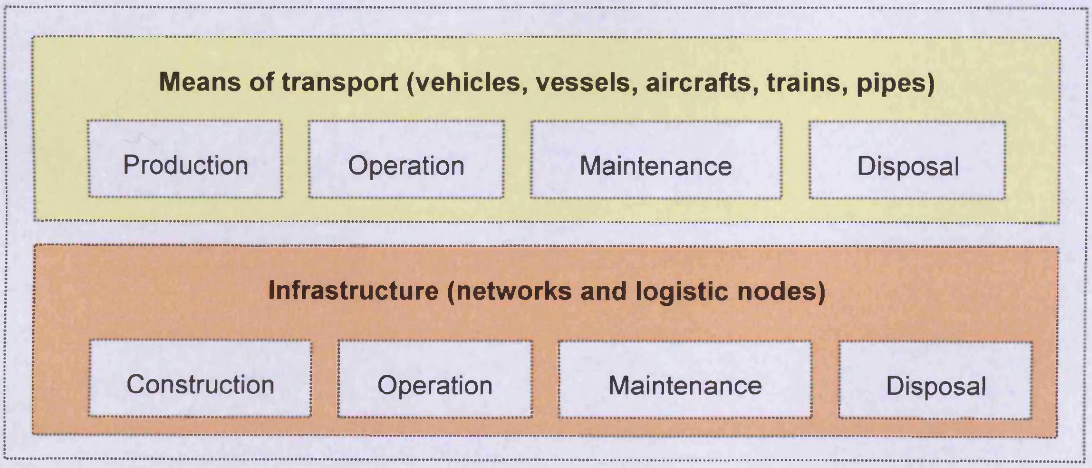


Figure 32: Group activities – source areas of environmental aspects

It should be noticed that the matrices do not prioritise between the different aspects and impacts. There are meant to be generic embracing various considerations. The ordering of aspects and impacts on the matrices is in accordance with the group activities column classification (first the means of transport and then the infrastructure related considerations are presented on the matrices) and not according to significance. According to ISO 14001 and EMAS (European Eco-Management and Audit Scheme), widely accepted as the most important international environmental management standards, an environmental aspect is defined as ''an element of an organisation's activities, products or services that can interact with the environment'' (ISO 1996). These standards define a significant aspect as ''an environmental aspect that has or can have a significant environmental impact''. Screening for significance of different aspects is case specific and it falls under the responsibility of experts with good knowledge of the system or organisation under question.

5.3 Analytical matrices

The matrices that follow in this section are the result of applying the methodological framework explained above for each of the six different freight transport modes. The division according to the mode has been dictated for reasons of clarity in the presentation and display of results. It may be suggested that six smaller and more concise matrices are more user friendly than one expanded matrix. For each transport mode the environmental aspects of operations related to infrastructural assets and terminals (logistic nodes) are also being considered and analysed. Therefore, the matrices collectively identify and demonstrate the whole range of aspects associated with the operation of the logistic chain, the network of consecutive links between transport modes and logistic nodes as established in chapter 3.

The analytical matrices are presented and discussed in the following sections. Each of the six sections, one for each freight transport mode, starts with an introduction pointing out the more significant environmental aspects of the examined mode. The mode specific environmental aspects are also highlighted. Some aspects, such as noise or certain exhaust emissions, are common up to a certain degree for all transport modes. There are though, some mode specific aspects (e.g. use of anti-fouling chemicals for vessel maintenance, aviation's nitrogen oxides and water vapour emissions at high altitudes) that are of significance and are discussed. Examples of interest are also highlighted where necessary.

5.3.1 Road transport

The significant environmental aspects associated with road freight transport include: air exhaust emissions (figure 35[5]) that contribute both to local air pollution and associated effects in human health, and to global issues such as climate change, the risk of road accidents with heavy social and environmental costs, the generation of traffic related noise one of the most commonly mentioned nuisances associated with road transport, and infrastructure related aspects such as land take, loss of amenity and severance. It should be noticed that in terms of unit emissions of air pollutants road transport has been improving its performance significantly over time. The increase though in transport demand clearly offsets those unit improvements.

Figure 33: Road haulage of containers

[5] Retrieved from http://www.cdlu.net/images/kenya-dumptruck.jpg on December 2007

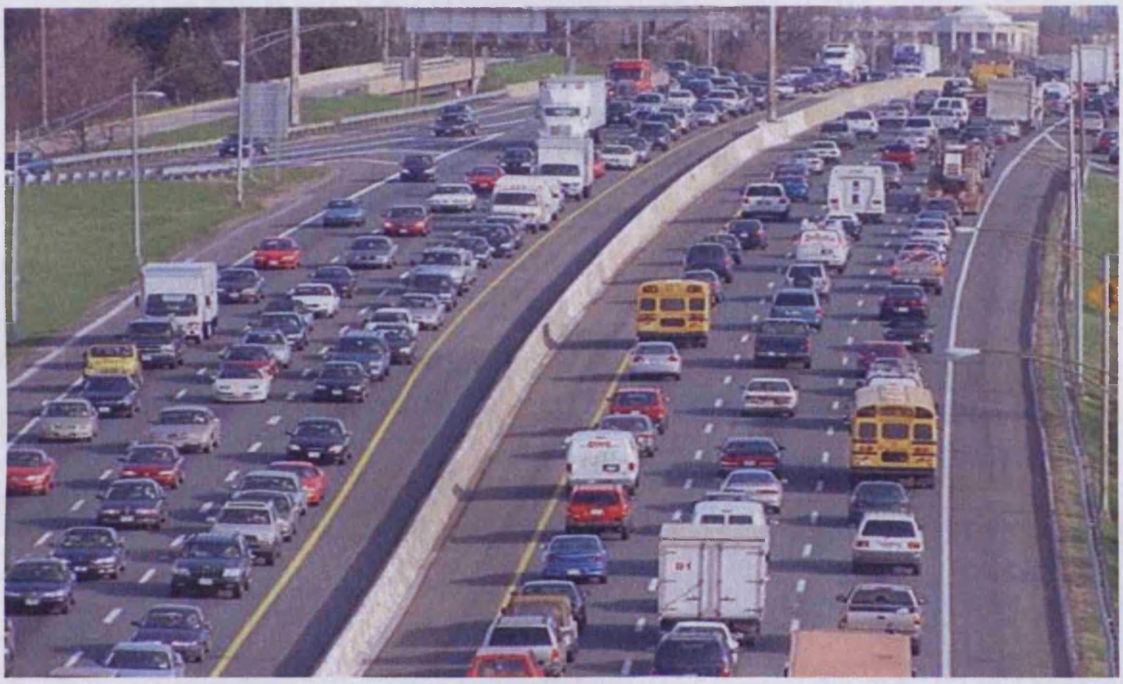


Figure 34: Congestion

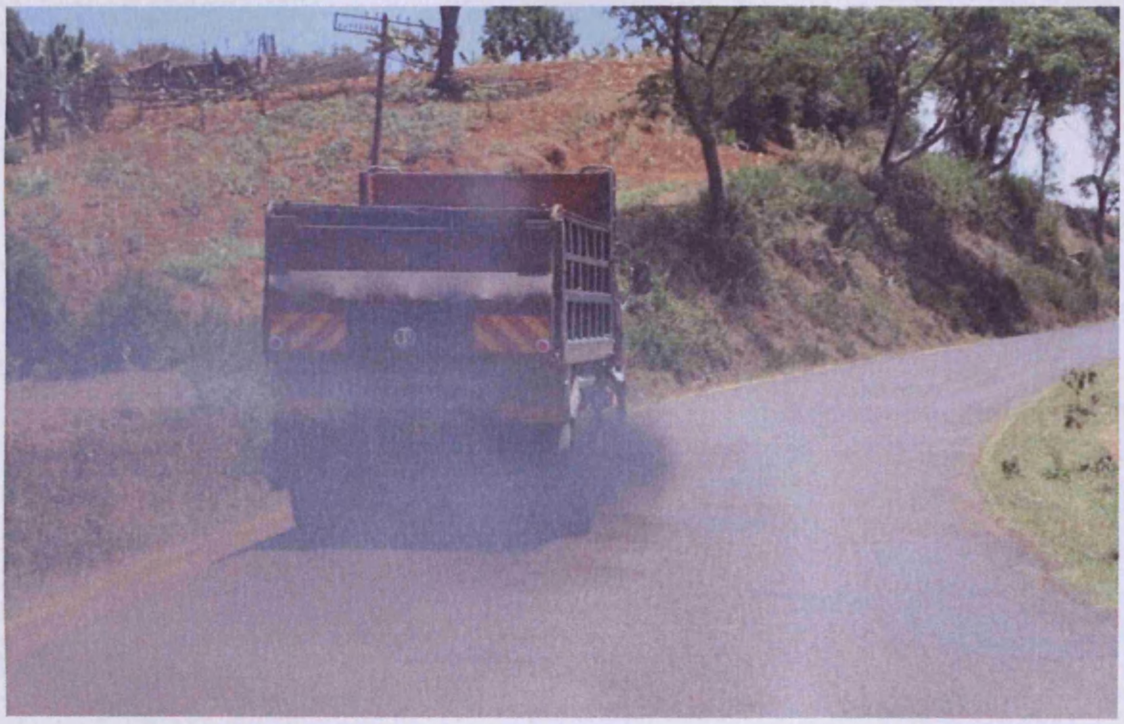


Figure 35: Truck exhaust emissions

The analytical matrix that is presented below (Table 16) occurred by following the previously described process. The matrix reveals the nature and range of environmental aspects related to road freight transport operations.

Table 16: Significant environmental aspects of road transport

Group activity	Activity	SEAs	Impacts [6] [7]	Issue
Vehicle production	Production of seating and other foamed products	Emissions of chlorofluorocarbons (CFCs)	Thinning of the stratospheric ozone layer. Contribute to the climate change when they pass through the troposphere.	Air
Vehicle production	Production of lorries and trucks	Consumption of natural resources (metals and non-fuel minerals)	Long term concerns on resource utilisation and recycling	Nature – Landscape – Biodiversity
Vehicle operation	Engine operation – Incomplete combustion of gasoline, diesel, CNG or LPG	Emissions of Carbon monoxide (CO) [8]	Effects on human health	Air
Vehicle operation	Engine operation - Combustion of gasoline, diesel, CNG or LPG	Carbon dioxide (CO_2) [9]	Climate change – global warming	Air
Vehicle operation	Engine operation - Combustion of diesel	Emission of Sulphur dioxide (SO_2)	Effects on human health and the environment	Air
Vehicle operation	Engine operation - Combustion of gasoline, diesel, CNG or LPG at high combustion temperatures	Emission of Nitrogen oxides (NO_x) [10]	Effects on human health and the environment	Air

[6] The potential effects of individual air pollutants on human health and the environment were analytically presented in table 6, section 4.2.1
[7] The potential effects of noise on human health are analytically presented in table 73, section 8.2
[8] In the case of diesel, CNG and LPG more efficient combustion leads to lower rates of carbon monoxide emissions (up to ten times lower rates in the case of diesel)
[9] In the case of diesel, CNG and LPG more efficient combustion leads to lower rates of carbon dioxide emissions
[10] In the case of diesel lower combustion temperatures lead to lower rates of nitrogen oxides' emissions

Vehicle operation	Engine operation – Incomplete combustion of gasoline, diesel, CNG or LPG	Hydrocarbons (HCs, both light and aromatic) and volatile organic compounds (VOCs)	Effects on human health and the environment	Air
Vehicle operation	Engine operation - Combustion of gasoline (Pb added to attain the desired octane rating)	Emission of Lead (Pb)	Effects on human health	Air
Vehicle operation	Engine operation - Combustion of diesel	Fine particulate matter (dust)	Effects on human health and the environment	Air
Vehicle operation	Engine operation - Combustion of gasoline	Emission of Ethylene dibromide and dichloride	Carcinogenic in animals, potential human carcinogens	Air
Vehicle operation	Engine operation - Combustion of gasoline or diesel	Emission of formaldehyde and other aldehydes	Carcinogenic in animals, potential human carcinogens	Air
Vehicle operation	Engine operation - Combustion of gasoline, diesel, CNG or LPG	Photochemical oxidants as secondary products	Photochemical smog Reduction in natural visibility Climate change	Air
Vehicle operation	Engine operation	Generation of Noise	Damage to physical and psychological health Nuisance	Air
Vehicle operation	Engine operation Heavy vehicles on uneven surfaces	Vibration	Damage to psychological health Damage on transport infrastructure, buildings, underground pipes and drains	Air

Vehicle operation	Tyres on road surface	Generation of noise	Damage to physical and psychological health Nuisance	Air
Vehicle operation	Body and suspension rattle	Generation of noise	Damage to physical and psychological health Nuisance	Air
Vehicle operation	Brake squeal	Generation of noise	Damage to physical and psychological health Nuisance	Air
Vehicle operation	Friction and turbulence	Re-suspension of particulate matter (dust)	Effects on human health and the environment	Air
Vehicle operation	Wear and tear of tyres and brakes	Particulate matter (dust)	Effects on human health and the environment	Air
Vehicle operation	Use of regenerated lubricants containing PCBs	Emissions of dioxins	Effects on human health	Air
Vehicle operation	Fuel evaporative emissions from the fuel tank and the carburettor	Evaporated unburned gasoline (HCs emissions)	Effects on human health and the environment	Air
Vehicle operation	Air conditioning systems	Emissions of chlorofluorocarbons (CFCs)	Thinning of the stratospheric ozone layer. Contribute to the climate change when they pass through the troposphere.	Air
Vehicle operation	Transport of hazardous substances	Risk of accidents	Diverse effects on air, water, soil, nature landscape and biodiversity	Air, Water, Soil, Nature – Landscape –

			Human injuries ad fatalities	Biodiversity
Vehicle disposal	Vehicles withdrawn from service	Disposal of waste oil, batteries and tyres	Soil contamination and ground water contamination	Water, Soil
Infrastructure construction	Road construction	Modification of water systems, disruption of hydrological processes	Modification of water systems, disruption of hydrological processes	Water
Infrastructure construction	Exposed soil surfaces (road construction)	Increased suspended sediments loads due to erosion of exposed soil surfaces	Ecological damage	Soil, Nature – Landscape – Biodiversity
Infrastructure construction	Covering of permeable soil surfaces with impermeable materials (concrete, tarmac)	Reduce the infiltration of rainfall	Increase risk of standing water and flooding	Soil, Nature - Landscape – Biodiversity
Infrastructure construction	Road construction	Land utilised for the extraction of the raw materials (aggregates) required for construction	Loss of natural land area Loss of biotypes, endangering rare species	Nature – Landscape – Biodiversity
Infrastructure construction	Road construction	Consumption of natural resources (metals and non-fuel minerals)	Long term concerns on resource utilisation and recycling	Nature – Landscape – Biodiversity
Infrastructure construction and operation	Roads	Severance: large areas divided into smaller ones	Reducing biodiversity Adversely affecting rare species	Nature – Landscape – Biodiversity

Infrastructure construction and operation	Roads	Effect on amenity	Reducing amenity and quality of landscapes	Nature – Landscape – Biodiversity
Infrastructure construction and operation	Roads	Spatial separation effects - barrier effect	Reducing biodiversity Adversely affecting rare species	Nature – Landscape – Biodiversity
Infrastructure construction and operation	Roads	Land take	Loss of natural land area Loss of biotypes, endangering rare species	Nature – Landscape – Biodiversity
Infrastructure construction and operation	Roads in urban areas	Loss of urban land	Scarcity of space in urban areas	Nature – Landscape – Biodiversity
Infrastructure construction and operation	Roads in urban areas	Separation/barrier effect in urban areas	Cut across existing social interrelationships (in urban areas)	Nature – Landscape – Biodiversity
Infrastructure operation	Road abrasion	Particulate matter (dust)	Effects on human health and the environment	Air
Infrastructure operation	Terminals operation (cargo handling, warehousing, auxiliary fleet and equipment)	Exhaust emissions	Air pollution Effects on human health Climate change	Air
Infrastructure operation	Terminals operation (cargo handling, warehousing, auxiliary fleet and equipment)	Generation of noise	Damage to physical and psychological health Nuisance	Air

Infrastructure operation	Terminals operation (cargo handling, warehousing, auxiliary fleet and equipment)	Emissions of particulate matter (dust)	Effects on human health and the environment	Air
Infrastructure operation	Terminals operation (cargo handling, warehousing, auxiliary fleet and equipment)	Risk of accidents	Diverse effects on air, water, soil, nature landscape and biodiversity Human injuries and fatalities	Air, Water, Soil, Nature – Landscape – Biodiversity
Infrastructure operation	Road utilisation	Run-off from roads [11]	Contamination of soil Surface and groundwater pollution Damage to aquatic plant and animal communities	Water, Soil, Nature – Landscape – Biodiversity
Infrastructure disposal	Abandoned spoil tips and rubble from road works	Loss of amenity	Landscape degradation	Nature – Landscape – Biodiversity

Sources of information on environmental considerations of road transport: (OECD 1988; Whitelegg 1988; Lamure 1990; Linster 1990; Mitchell and Hickman 1990; Gwilliam 1991; Silverleaf and Turgel 1991; CPRE 1992; Button 1993; Stanners and Bourdeau 1995; Houghton 1996; OECD 1996; Owens 1996; Greene and Wegener 1997; OECD 1997; Black 1998; Hunter, Farrington et al. 1998; Faulks 1999; Rondinelli and Berry 2000; OECD Environment Directorate 2002; Handy 2003; Nijkamp, Ubbels et al. 2003; Rothengatter 2003; D'Agosto and Ribeiro 2004)

[11] Rubber, bitumen, tyre derivatives, metals, petrochemicals, hydrocarbons, petrol, oil, aggregate, tarmac derivatives and particles, de-icing salt and grit, spills from any type of transported loads

5.3.2 Rail transport

Figure 36: Container trains (double stack)

Rail is seen as an alternative to road transport because it makes more efficient use of land, can use renewable energy sources, helps to relieve traffic congestion in urban areas, causes less pollution, and generates less noise (Rao, Grenoble et al. 1991). Rail transport appears to be twice more energy efficient than road transport (Bonnafous and Raux 2003). Nevertheless, a broad range of significant environmental aspects of rail transport operations can be identified as presented in table 17.

Figure 37: Transport of cars by rail

Table 17: Significant environmental aspects of rail transport

Group activity	Activity	SEAs	Impacts [12] [13]	Issue
Train production	Production of seating and other foamed products	Emissions of chlorofluorocarbons (CFCs)	Thinning of the stratospheric ozone layer. Contribute to the climate change when they pass through the troposphere.	Air
Train production	Production of trains	Energy use, exhaust emissions and noise generation during production	Air pollution Effects on human health Climate change	Air
Train production	Production of trains	Consumption of natural resources (metals and non-fuel minerals)	Long term concerns on resource utilisation and recycling	Nature – Landscape – Biodiversity
Train operation	Diesel trains	Exhaust emissions (CO_2, NO_X, SO_X)	Air pollution Effects on human health Climate change	Air
Train operation	Steam trains	Exhaust emissions	Air pollution Effects on human health Climate change	Air

[12] The potential effects of individual air pollutants on human health and the environment were analytically presented in table 6, section 4.2.1
[13] The potential effects of noise on human health are analytically presented in table 73, section 8.2

Train operation	Electric trains	Emissions during the generation of electricity to run the electric trains (primarily CO_2, SO_2)	Air pollution Effects on human health Climate change	Air
Train operation	Friction and turbulence	Re-suspension of particulate matter (dust)	Effects on human health and the environment	Air
Train operation	All train types	Railway noise (Around terminals and along rail lines)	Damage to physical and psychological health Nuisance	Air
Train operation	Train signalling	Generation of noise	Damage to physical and psychological health Nuisance	Air
Train operation	All train types	Vibration	Damage to psychological health Damage on transport infrastructure, buildings, underground pipes and drains	Air
Train operation	Fuelling of diesel trains	Vapours (VOCs, HCs)	Effects on human health and the environment	Air
Train operation	Operation of diesel trains	Run-offs	Soil contamination Surface and ground water pollution	Water, Soil

Train operation	Break systems	Use of PCB	Soil contamination Groundwater pollution	Water, Soil
Train operation	Transport of hazardous substances	Risk of accidents	Diverse effects on air, water, soil, nature landscape and biodiversity Human injuries and fatalities	Air, Water, Soil, Nature – Landscape – Biodiversity
Train operation	Derailment, collision	Accidents	Human injuries and fatalities	Nature – Landscape – Biodiversity
Train maintenance	Railcar refurbishing and maintenance operations	Use of degreasers, solvents, acids, paint thinners, paints, and epoxies	Soil contamination Groundwater pollution	Water, Soil
Train maintenance	Locomotive maintenance	Sludge, waste solvents, and cleaners	Soil contamination Groundwater pollution	Water, Soil
Train disposal	Wagons, locomotives and equipment withdrawn from service	Disposal of hazardous substances	Soil contamination Groundwater pollution	Water, Soil
Infrastructure construction	Terminal and railway construction	Generation of noise	Damage to physical and psychological health Nuisance	Air
Infrastructure construction	Terminal and railway construction	Emissions of particulate matter (dust)	Effects on human health and the environment	Air
Infrastructure construction	Terminal and railway construction	Modification of hydrological systems	Modification of hydrological systems	Water

Infrastructure construction	Terminal and railway construction	Disposal of spoil	Soil contamination	Soil
Infrastructure construction	Terminal and railway construction	Land take	Loss of natural land area Loss of biotypes, endangering rare species	Nature – Landscape – Biodiversity
Infrastructure construction	Railway construction	Tunnels, cuttings and viaducts	Loss of amenity Environmental damage	Nature – Landscape – Biodiversity
Infrastructure construction and operation	Railways	Severance effect	Partition of wildlife corridors and communities	Nature – Landscape – Biodiversity
Infrastructure construction and operation	Railways	Possible hindrance to wildlife migration	Endangering species	Nature – Landscape – Biodiversity
Infrastructure construction and operation	Railways	Obstruction and intrusion	Visual impacts	Nature – Landscape – Biodiversity
Infrastructure operation	Terminal operations (cargo handling, warehousing, auxiliary fleet and equipment)	Exhaust emissions	Air pollution Effects on human health Climate change	Air
Infrastructure operation	Terminal operations (cargo handling, warehousing, auxiliary fleet and equipment)	Generation of noise	Damage to physical and psychological health Nuisance	Air

Infrastructure operation	Terminal operations (cargo handling, warehousing, auxiliary fleet and equipment)	Emissions of particulate matter (dust)	Effects on human health and the environment	Air
Infrastructure operation	Terminal operations (cargo handling, warehousing, auxiliary fleet and equipment)	Risk of accidents	Diverse effects on air, water, soil, nature landscape and biodiversity Human injuries and fatalities	Air, Water, Soil, Nature – Landscape – Biodiversity
Infrastructure maintenance	Railway maintenance	Use of creosol to preserve wood	Soil contamination	Soil
Infrastructure disposal	Equipment withdrawn from service	Disposal of hazardous substances	Soil contamination Groundwater pollution	Water, Soil
Infrastructure disposal	Abandoned lines, equipment and rolling stock	Dereliction of obsolete facilities	Landscape degradation	Nature – Landscape – Biodiversity

Sources of information on environmental considerations of rail transport: (OECD 1988; Lamure 1990; Linster 1990; Carpenter 1994; Stanners and Bourdeau 1995; Houghton 1996; Reid 1996; Greene and Wegener 1997; OECD 1997; Black 1998; Hunter, Farrington et al. 1998; Faulks 1999; Rondinelli and Berry 2000; Bonnafous and Raux 2003; Rothengatter 2003)

5.3.3 Marine transport

In comparison to land transport, shipping is more energy efficient, emits less CO_2, produces less disturbing noise, uses less land and has got better safety records. The more significant environmental aspects of marine transportation are the exhaust emissions (figure 38) of especially NO_X and SO_2 (Paixao and Marlow 2002). Vessel engines are the dirtiest combustion sources per ton of fuel consumed, producing 14% of the world's nitrogen emissions from fossil fuels and 16% of all sulphur emissions of petroleum (Spice 1999). These problems can be attributed to the lack of regulations and to the common practise to use low-quality fuel.

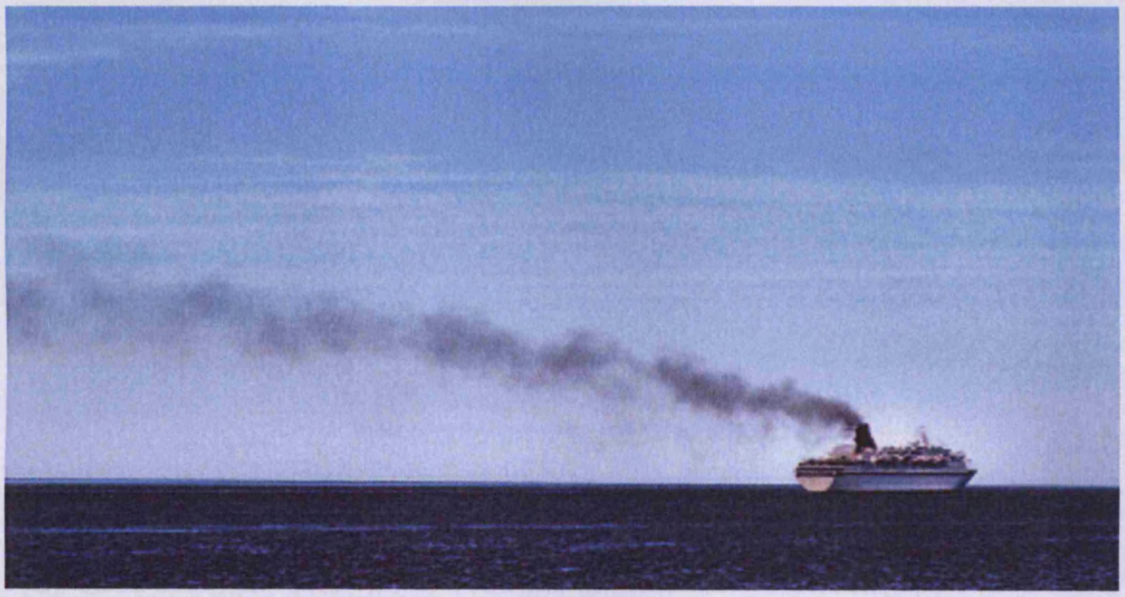


Figure 38: Ship exhaust emissions

Shipping specific significant environmental aspects include discharge of ballast water, accidental and operational spillages, dredging and dredging disposal, and using of antifouling chemicals for vessel maintenance.

- Vessel ballast water acquired in one region may contain indigenous aquatic life that will be harmful to the indigenous aquatic life of the region where the water is discharged (Talley 2003). The routine discharge of ballast water from marine vessels, if ballast is not segregated from cargo, introduces oil pollution at sea and in coastal waters (Rondinelli and Berry 2000).

- Ships may accidentally, operationally or intentionally release substances into the environment. When tanker vessels accidents spill large quantities of oil, they receive the attention of the world's media, politicians, and the general public. The damage to plants, fisheries, birds, and mammals can be considerable.
- Sea life may also be affected when waterways are dredged to deepen or maintain depths. The disposal of dredged sediments that are biologically and chemically active and hazardous material from scrapped vessels can contaminate disposal sites (Rondinelli and Berry 2000; Talley 2003).
- Anti-fouling chemicals to remove unwanted growth of biological material on the water-immersed surface of the vessel may not only be effective in killing those organisms attached to the vessel hull but other sea life as well (OECD 1997; Talley 2003)

In addition, operations and activities in seaport areas (figure 39 – Port of Amsterdam) embrace significant environmental considerations. Table 18 occurred by applying the analysis framework of section 5.2 and presents the significant environmental aspects of maritime transport related operations.

Figure 39: Seaport area activities and operations embrace significant environmental aspects

Table 18: Significant environmental aspects of maritime transport

Group activity	Activity	SEAs	Impacts [14 15]	Issue
Vessels production	Production of seating and other foamed products	Emissions of chlorofluorocarbons (CFCs)	Thinning of the stratospheric ozone layer. Contribute to the climate change when they pass through the troposphere.	Air
Vessels production	Production of vessels	Consumption of natural resources (metals and non-fuel minerals)	Long term concerns on resource utilisation and recycling	Nature – Landscape – Biodiversity
Vessels operation	Engine operation Combustion of diesel	Emissions of $C0_2$	Climate change – global warming	Air
Vessels operation	Engine operation Combustion of diesel	Emissions of Sulphur dioxide $S0_2$	Effects on human health and the environment	Air
Vessels operation	Engine operation Combustion of diesel	Emissions of Nitrogen oxides $N0_X$	Effects on human health and the environment	Air
Vessels operation	Engine operation Combustion of diesel	Emissions of particulate matter (dust)	Effects on human health and the environment	Air
Vessels operation	Bunkering and fuelling	Emissions of VOCs and HCs	Effects on human health and the environment	Air

[14] The potential effects of individual air pollutants on human health and the environment were analytically presented in table 6, section 4.2.1
[15] The potential effects of noise on human health are analytically presented in table 73, section 8.2

Vessels operation	Tankers	Methane escapes from tankers	Climate change – global warming	Air
Vessel operation	Ship manoeuvring in ports	Generation of noise	Damage to physical and psychological health Nuisance	Air
Vessel operation	Engine operation in ports (for electricity generation)	Generation of noise	Damage to physical and psychological health Nuisance	Air
Vessel operation	Vessel signalling	Generation of noise	Damage to physical and psychological health Nuisance	Air
Vessels operation	Operational discharges of oil: Ballast water in oil cargo tanks	Discharge of ballast water-in-oil mixture	Water pollution	Water
Vessels operation	Waste disposal at sea	Sewage and waste water from ships	Water pollution	Water
Vessels operation	Waste disposal at sea	Garbage dumped from vessels	Water pollution	Water
Vessel operation	Vessel engine	Underwater noise	Disturbance to marine mammals and fish	Water, Nature – Landscape – Biodiversity
Vessel operation	Vessel wash	Changes in physical regime (waves and sediment transport)	Changes to hydrodynamic regime resulting in erosion of inter-tidal and swallow sub-tidal habitats	Water, Nature – Landscape – Biodiversity

Vessels operation	Ballast water	Discharge of ballast water	Introduction of non indigenous species – disruption of local ecosystems	Water, Nature – Landscape – Biodiversity
Vessels operation	Run-offs from ships	Operational spills of oil products	Water pollution and effects on habitats	Water, Nature – Landscape – Biodiversity
Vessels operation	Risk of accidents	Accidental spills of oil products from fuel tanks	Water pollution and effects on habitats	Water, Nature – Landscape – Biodiversity
Vessels operation	Bulk transport of fuels and hazardous substances	Risk of accidents – Accidental spills of hazardous cargo	Petroleum spills Water pollution and effects on habitats	Water, Nature – Landscape – Biodiversity
Vessels maintenance	Vessels painting	Use of antifouling paints containing tributyltin (TBT)	Water pollution Endangering aquatic species	Water, Nature – Landscape – Biodiversity
Vessels disposal	Vessels withdrawn from service	Disposal of hazardous substances	Soil contamination	Soil
Vessels disposal	Vessel scrapping	Disposal of scrapped vessel materials	Soil contamination	Soil
Infrastructure construction	Port construction	Canal cutting	Modification of water systems Effects on habitats	Water, Nature – Landscape – Biodiversity
Infrastructure construction	Port construction	Dredging	Modification of water systems Effects on habitats	Water, Nature – Landscape – Biodiversity
Infrastructure construction	Port construction	Dredging disposal	Soil contamination Ground water pollution Loss of wetlands	Water, Soil, Nature – Landscape – Biodiversity

Infrastructure construction	Port construction	Land take	Loss of natural land area Loss of biotypes	Nature – Landscape – Biodiversity
Infrastructure operation	Port fleet and equipment operation	Exhaust emissions	Effects on local air quality Effects on human health	Air
Infrastructure operation	Port access (roads, railways, pipelines)	Exhaust emissions	Effects on local air quality Effects on human health	Air
Infrastructure operation	Port operations (cargo, handling, warehousing, port generated traffic)	Generation of noise	Damage to physical and psychological health Nuisance	Air
Infrastructure operation	Port operations (cargo, handling, warehousing, port generated traffic)	Emissions of particulate matter (dust)	Effects on human health and the environment	Air
Infrastructure operation	Port operations (cargo, handling, warehousing, port generated traffic)	Risk of accidents	Diverse effects on air, water, soil, nature landscape and biodiversity Human injuries ad fatalities	Air, Water, Soil, Nature – Landscape – Biodiversity
Infrastructure operation	Handling of hazardous cargo	Risk of accidents	Diverse effects on air, water, soil, nature landscape and biodiversity Human injuries ad fatalities	Air, Water, Soil, Nature – Landscape – Biodiversity
Infrastructure operation	Port area operations	Run offs from port areas (petroleum products, paints, lubricants)	Water pollution at port	Water

Infrastructure operation	Port waste management	Disposal of waste and hazardous materials	Soil contamination Surface and ground water pollution	Water, Soil
Infrastructure maintenance	Maintenance of safe navigation	Dredging disposal	Soil contamination Ground water pollution Loss of wetlands	Water, Soil, Nature – Landscape – Biodiversity
Infrastructure maintenance	Maintenance of safe navigation	Maintenance Dredging	Disruption of ecosystems and habitats Turbidity	Nature – Landscape – Biodiversity
Infrastructure disposal	Port fleet and equipment withdrawn from service	Disposal of hazardous substances	Soil contamination Ground water pollution	Water, Soil

Sources of information on environmental considerations of maritime transport: (OECD 1988; Linster 1990; Stanners and Bourdeau 1995; OECD 1996; Greene and Wegener 1997; OECD 1997; Black 1998; ABP Research 1999; Rondinelli and Berry 2000; Walker 2000; Talley, Jin et al. 2001; Paixao and Marlow 2002; Michail, De Leffe et al. 2003; Talley 2003; Fridell 2006)

5.3.4 Inland waterway transport

Inland waterway transport (figure 40) presents significant advantages in terms of its environmental performance. It is particularly effective and energy-efficient, its noise and gaseous emissions are modest and it ensures a high degree of safety, in particular when it comes to the transport of dangerous goods. Dredging and dredging disposal are considered to be of the most significant environmental aspects of inland waterway transport.

Figure 40: Inland waterway transport

Table 19 presents selected environmental aspects of inland waterway transport related operations.

Table 19: Significant environmental aspects of inland waterway transport

Group activity	Activity	SEAs	Impacts [16] [17]	Issue
Barge production	Production of barges	Exhaust emissions during production phase	Effects on local air quality and climate change	Air
Barge production	Production of barges	Consumption of natural resources (metals and non-fuel minerals)	Long term concerns on resource utilisation and recycling	Nature – Landscape – Biodiversity
Barge operation	Engine operation Combustion of diesel	Emissions of carbon dioxide CO_2	Climate change – global warming	Air
Barge operation	Engine operation Combustion of diesel	Emissions of Sulphur dioxide $S0_2$	Effects on human health and the environment	Air
Barge operation	Engine operation Combustion of diesel	Emissions of Nitrogen oxides $N0_X$	Effects on human health and the environment	Air
Barge operation	Engine operation Combustion of diesel	Emissions of particulate matter (PM)	Effects on human health and the environment	Air
Barge operation	Fuelling	Emissions of VOCs and HCs	Effects on human health and the environment	Air
Barge operation	Barge engine	Generation of noise	Damage to physical and psychological health Nuisance	Air

[16] The potential effects of individual air pollutants on human health and the environment were analytically presented in table 6, section 4.2.1

[17] The potential effects of noise on human health are analytically presented in table 73, section 8.2

Barge operation	Bulk transport of fuels and hazardous substances	Risk of accidents	Potential adverse effects on water quality, ecosystems, habitats. Potential human injuries and fatalities	Air, Water, Nature – landscape - biodiversity
Barge operation	Run-offs from barges	Operational discharges of oil products	Water pollution and effects on habitats	Water, Nature – Landscape – Biodiversity
Barge disposal	Barges withdrawn from service	Disposal of hazardous substances	Soil contamination Groundwater pollution	Water, Soil
Infrastructure construction	Inland port construction	Dredging disposal	Soil contamination Ground water pollution Loss of wetlands	Water, Soil, Nature – Landscape – Biodiversity
Infrastructure construction	Inland port construction	River and canal engineering	Modification of water systems Effects on habitats	Water, Nature – Landscape – Biodiversity
Infrastructure construction	Inland port construction	Dredging	Modification of water systems Effects on habitats	Water, Nature – Landscape – Biodiversity
Infrastructure construction	Inland port construction	Land take	Loss of natural land area Loss of biotypes, endangering rare species	Nature – Landscape – Biodiversity
Infrastructure operation	Inland port fleet and equipment operation	Exhaust emissions	Effects on local air quality Effects on human health	Air
Infrastructure operation	Inland port access (roads, railways, pipelines)	Exhaust emissions	Effects on local air quality Effects on human health	Air

Infrastructure operation	Inland port operations (cargo, handling, warehousing, port generated traffic)	Generation of noise	Damage to physical and psychological health Nuisance	Air
Infrastructure operation	Inland port operations (cargo handling, warehousing, port traffic)	Emissions of particulate matter (dust)	Effects on local air quality Effects on human health	Air
Infrastructure operation	Inland port operations (cargo, handling, warehousing, port generated traffic)	Risk of accidents	Diverse effects on air, water, soil, nature landscape and biodiversity Human injuries ad fatalities	Air, Water, Soil, Nature – Landscape – Biodiversity
Infrastructure operation	Handling of hazardous cargo	Risk of accidents	Diverse effects on air, water, soil, nature landscape and biodiversity Human injuries ad fatalities	Air, Water, Soil, Nature – Landscape – Biodiversity
Infrastructure operation	Inland port area operations	Run offs from inland port areas (petroleum products, paints, lubricants)	Water pollution at port	Water
Infrastructure operation	Inland port waste management	Disposal of waste and hazardous materials	Soil contamination Water pollution	Water, Soil
Infrastructure maintenance	Maintaining safe navigation depths	Dredging	Modification of water systems, affecting ecosystems and habitats	Water, Nature – Landscape – Biodiversity

Sources of information on environmental considerations of inland waterway transport: (OECD 1988; Linster 1990; Roeleven, Kok et al. 1995; OECD 1997; ABP Research 1999; Rondinelli and Berry 2000; Pinter, Miller et al. 2004)

5.3.5 Air transport

Air transport raises environmental concerns especially in the grounds of energy use, emissions of CO_2 and NO_X, and generation of noise (Dings and Dijkstra 1997; Bonnafous and Raux 2003). Noise has been traditionally a significant environmental aspect related to air transport. In mid 1960s it was considered as the main recognised environmental consideration associated with air transport was noise (Price and Probert 1995). Aircraft noise and noise around airports raise concerns regarding air transport's environmental performance.

Figure 41: Aero-engine exhaust emissions

The most globally significant, environmentally damaging impact of flying is that arising from aero-engine exhaust emissions (figure 41[18]), which contain CO_2, H_2O, CO, C, NO_X, SO_X and unburned hydrocarbons. The negative environmental effects of aircraft emissions vary with altitude, latitude and temperature (Archer 1993; Price and Probert 1995). Total aviation emissions have increased, because increased demand for air transport has outpaced the reductions in specific emissions from the continuing improvements in technology and operational procedures (IPCC 1999). Today, the major long term issue is the total effect of aviation as a contributor to the global climate change (Armstrong 2001). Emissions from aircraft are rising 3 times faster

---

[18] Photos retrieved from www.amc.af.mil/photos (left) and www.martin-wagner.org/flugzeuge.htm (right) in January 2008

than previously thought threatening the reduction targets in greenhouse gases emissions that developed nations agreed in Kyoto in 1997 (Noble 1999). With regard to the emission of greenhouse gases and their effect to global warming, aviation requires special attention. It is the fastest growing energy user in the transport sector, and the impact on the climate of all aviation emissions is estimated at two to four times higher than of the CO_2 alone, mainly because of nitrogen oxides emissions and condensation trails at higher altitudes (IPCC 1999; European Environmental Agency 2003).

Aero-engines are the only anthropogenic source of NO_X emitted directly into the stratosphere. In addition, the environmental effects of airborne NO_X emissions are greater than those from surface sources, being up to 50 times more effective as a greenhouse gas per unit emitted when compared with ground-level emissions (Hamer 1992; Archer 1993; Price and Probert 1995). The NO_X which is emitted into the atmosphere close to ground level gets removed by rainfall within days. However high-altitude NO_X is resident for much longer. At altitudes exceeding 20 km, NO_X emissions contribute to the breakdown of stratospheric ozone. In addition, NO_X released from aircraft at cruise altitudes causes ozone depletion and clouds to form, thus altering the Earth's radiative heat-balance (Price and Probert 1995).

Water vapour is the most important atmospheric 'greenhouse gas' and is also a product of the combustion of kerosene. When emitted from aero-engines at relatively high altitudes, H_2O, in the form of steam, rapidly freezes to form clouds and plays an important part in the greenhouse effect. The condensation trails (i.e. contrails) left in the wake of some aircraft can remain in the sky for several hours if the atmospheric conditions are humid and can be several kilometres wide and hundreds of kilometres long (Archer 1993). At altitudes between 9 and 22 km, the artificial cirrus clouds created by H_2O emissions from aircraft indirectly can cause changes in temperature via the reflection of thermal radiation emitted from the Earth's surface (Price and Probert 1995). It should be noticed that for aviation, the mix of gases that can contribute to global warming is different from those for ground-based sources, with only carbon dioxide being common (Somerville 2003).

Many of the environmental effects of aviation emissions are as yet insufficiently quantifiable. The US Panel on Atmospheric Effects of Aviation recognised recently "that research on aviation's atmospheric impacts is by no means complete, and that this issue will become all the more important in the coming decades as demand for air travel continues to increase" (Dewes, Cottington et al. 2000). Studies are ongoing to determine the environmental effects of aviation emissions. Consensus is, however, that there is an impact of aviation on both climate and local air quality and that this impact is growing due to the substantial growth in aviation itself (Vlek and Vogels 2000).

Airport activities and operations also raise significant environmental concerns. Figure 42 (source: Google Earth) is an aerial photo of Schiphol airport in the Netherlands. The conflict between neighbouring areas (e.g. farmlands, residential areas) and environmental aspects such as noise and exhaust emissions can be demonstrated.

Figure 42: Aerial view of Schiphol Airport

Table 20 presents the significant environmental aspects of air transport related operations.

Table 20: Significant environmental aspects of air transport

Group activity	Activity	SEAs	Impacts [19] [20]	Issue
Aircraft production	Production of seating and other foamed products	Emissions of chlorofluorocarbons (CFCs)	Thinning of the stratospheric ozone layer. Contribute to the climate change when they pass through the troposphere.	Air
Aircraft production	Production of aircrafts	Consumption of natural resources (metals and non-fuel minerals)	Long term concerns on resource utilisation and recycling	Nature – Landscape – Biodiversity
Aircraft operation	Engine operation. Combustion of kerosene	Emissions of Carbon monoxide (CO)	Effects on human health and the environment	Air
Aircraft operation	Engine operation. Combustion of kerosene	Emissions of Carbon dioxide (CO_2)	Climate change – global warming	Air
Aircraft operation	Engine operation. Combustion of kerosene	Emission of Sulphur dioxide (SO_2) and SO_X	Effects on human health and the environment	Air
Aircraft operation	Engine operation. Combustion of kerosene	Emission of Nitrogen oxides (NO_x) in the troposphere	Effects on human health and the environment	Air
Aircraft operation	Engine operation. Combustion of kerosene	Emissions of NO_X in the stratosphere	Depletion of ozone layer	Air

[19] The potential effects of individual air pollutants on human health and the environment were analytically presented in table 6, section 4.2.1
[20] The potential effects of noise on human health are analytically presented in table 73, section 8.2

Aircraft operation	Engine operation. Combustion of kerosene	Hydrocarbons (HCs, both light and aromatic) and volatile organic compounds (VOCs)	Effects on human health and the environment	Air
Aircraft operation	Engine operation. Combustion of kerosene	Smoke and particulates	Visibility reduction, soiling, plumes, possible carriers of toxic material, nucleation sites for water, possible weather modification	Air
Aircraft operation	Engine operation. Combustion of kerosene	Emissions of water vapour H_2O at high altitudes	Production of ice and fog – potential weather modification Formation of condensation trails and cirrus clouds Climate change - global warming	Air
Aircraft operation	Engine operation - Combustion kerosene	Photochemical oxidants as secondary products (reactions between primary exhaust gases NO_x - HCs)	Photochemical smog Reduction in natural visibility Climate change	Air
Aircraft operation	Engine operation. Combustion of kerosene	Precious metals	Toxic gases, atmospheric reactions	Air
Aircraft operation	Engine operation. Combustion of kerosene	Emissions of halogen compounds	Toxic gases, atmospheric reactions	Air

Aircraft operation	Engine operation. Combustion of kerosene	Emissions of aldehydes	Irritants, odorants, photochemical smog precursors	Air
Aircraft operation	Engine operation.	Generation of noise	Damage to physical and psychological health Annoyance	Air
Aircraft operation	Engine testing	Generation of noise	Damage to physical and psychological health Annoyance	Air
Aircraft operation	Supersonic aircrafts	Sonic booms (noise)	Damage to physical and psychological health Annoyance	Air
Aircraft operation	Aircrafts en route	Generation of noise	Damage to physical and psychological health Annoyance	Air
Aircraft operation	Fuel loading and handling	Vapour displacement – emissions of Hydrocarbons	Effects on human health Photochemical smog precursors	Air
Aircraft operation	Fuel handling	Emissions of precious metals	Toxic gases, atmospheric reactions	Air
Aircraft operation	Fuel handling	Emissions of halogen compounds	Toxic gases, atmospheric reactions	Air

Aircraft operation	Inefficient flight routings [21]	Congestion in the air (stacking – unavailability of landing slots)	Effects associated to: Increased fuel consumption, increased emissions, and increased noise	Air
Aircraft operation	Aircraft de-icing	Glycol-based materials runoff	Soil contamination Surface and ground water pollution	Water and Soil
Aircraft operation	Fuel jettisoning [22]	Amount of fuel reaching the ground (fuel jettisoning)	Soil contamination	Soil
Aircraft operation	Flying	Risk of accidents (release of hazardous substances)	Various effects to air, water, soil, nature-landscape and biodiversity	All
Aircraft maintenance	Aircraft painting	Emissions of VOCs	Effects on human health and the environment	Air
Aircraft maintenance	Aircraft painting	Paint storage and disposal	Contamination of soil, surface and groundwater	Water and Soil
Aircraft maintenance	Aircraft lubrication and fluid changes	Storage, transfer and disposal of petroleum products	Contamination of soil, surface and groundwater	Water and Soil
Aircraft maintenance	Aircraft battery repair and replacement	Sulphuric acids	Contamination of soil, surface and groundwater	Water and Soil

[21] Military air-space restrictions, low ATC (Air traffic control) and ATM (Air traffic movements) system productivity
[22] Fuel jettisoning (at altitudes over 6000 feet and away from centres of population) is required occasionally in order to decrease to the safe landing weight. This procedure may be invoked for safety reasons if it is considered necessary to return to the airport shortly after departure

Aircraft disposal	Aircrafts withdrawn from service	Disposal	Soil contamination Water pollution	Water and Soil
Infrastructure construction	Airport construction	Modification of water tables, river courses and field drainage	Related effects	Water
Infrastructure construction	Airport construction	Extraction of building material	Soil erosion Depletion of natural resources	Soil
Infrastructure construction	Airport construction	Land take	Loss of wetlands Loss of natural land area Loss of biotypes, endangering fauna and flora	Nature – Landscape – Biodiversity
Infrastructure construction and operation	Airport construction and operation	Loss of amenity Barrier effects Severance	Reducing amenity and quality of landscapes Reducing biodiversity	Nature – Landscape – Biodiversity
Infrastructure operation	Ground vehicle fleet operation	Exhaust emissions	Air pollution near airports Effects on human health	Air
Infrastructure operation	Airport operations (cargo handling, warehousing, auxiliary fleet and equipment, airport generated traffic)	Generation of noise	Noise pollution around airports Damage to physical and psychological health Annoyance	Air
Infrastructure operation	Airport access	Congestion around airports Increased exhaust emissions	Air pollution near airports Effects on human health	Air

Infrastructure operation	Airport operation	Inadequate treatment of contaminants in airport's waste water	Water pollution	Water
Infrastructure operation	Airport operation	Run-off from airports containing oil and anti-freeze	Soil contamination Water pollution	Water and soil
Infrastructure operation	Airport operation	Leakages from storage tanks	Soil contamination Water pollution	Water and Soil
Infrastructure operation and maintenance	Airport refuse management	Disposal of environmentally damaging materials used in aircraft servicing and maintenance	Soil contamination Water pollution	Water and Soil
Infrastructure operation and maintenance	Airport refuse management	Disposal of rubbish from airport and incoming traffic	Soil contamination Water pollution	Water and Soil

Sources of information on environmental considerations of air transport: (OECD 1988; Linster 1990; Price and Probert 1995; Stanners and Bourdeau 1995; OECD 1996; Somerville 1996; Greene and Wegener 1997; OECD 1997; Black 1998; Graham 1998; Faulks 1999; IPCC 1999; Noble 1999; Rondinelli and Berry 2000; Vlek and Vogels 2000; Somerville 2003)

5.3.6 Pipelines

Goods move through pipelines because they are either pumped (for liquids) or compressed (for gases). The fuel flowing through the pipelines serves as the energy source for the pumps and compressors, which emit air pollutants as would any other machine. The only available aggregate estimates of pipeline emissions do not distinguish between oil and gas pipelines. They do suggest, however, that pipeline transport generates substantially less air pollution than the predominant alternatives (OECD 1997).

Figure 43: Alaskan pipeline

Pipelines have been established as an energy efficient, safe, environment friendly and economic transport mode for the conveyance of hydrocarbons (gas, crude oil and finished products) over long distances. Nevertheless, the cross-country petroleum pipelines are environmentally sensitive because they traverse through various terrains covering crop fields, forests, rivers, populated areas, desert, hills and offshore. Any malfunction of these pipelines may cause devastating effects on the environment (Dey 2002). While pipelines are one of the safest transport modes, with failure rates much less compared to rail/road transport, failures do occur and sometimes with catastrophic consequences. While pipeline failures rarely cause fatalities, they can result in releases of large quantities of petroleum products and lead to considerable environmental damage (Dey, Ogunlana et al. 1998).

Figure 44: Oil pipeline on central North Slope coastal plain, Alaska

Figure 45: Burgas-Alexandroupolis oil pipeline

Table 21 summarises the significant environmental aspects of the deploying and operating pipelines.

Table 21: Significant environmental aspects of pipelines

Group activity	Activity	Aspects	Impacts [23]	Issue
Pipelines construction	Excavations for pipelines deployment	Emissions of particulate matter (dust)	Effects on human health and the environment	Air
Pipelines construction	Pipes	Energy use and exhaust emissions during production	Air quality Effects on human health Climate change	Air
Pipelines construction	Pipes	Consumption of natural resources (metals and non-fuel minerals)	Long term concerns on resource utilisation and recycling	Nature – Landscape – Biodiversity
Pipelines construction	Pipelines deployment	Land take [24]	Loss of natural land area Loss of biotypes, endangering rare species	Nature – Landscape – Biodiversity
Pipelines construction	Pipelines deployment	Barriers to wild life migration	Endangering species	Nature – Landscape – Biodiversity
Pipelines operation	Pumping stations (for liquids) and compressors (for gases)	Exhaust emissions	Air quality Effects on human health Climate change	Air
Pipelines operation	Petroleum pipelines	Emissions of methane CH_4	Climate change - global warming	Air

[23] The potential effects of individual air pollutants on human health and the environment were analytically presented in table 6, section 4.2.1

[24] Zones adjacent to infrastructure developments rendered unsuitable for a wide range of activities. For example in the case of pipelines carrying volatile materials (e.g. pressurised gas) - a corridor of land must be kept undeveloped for safety reasons

Pipelines operation	Petroleum pipelines	Oil leakages	Water pollution	Water
Pipelines operation	Petroleum pipelines	Oil leakages	Soil contamination	Soil
Pipelines operation	Petroleum pipelines	Risk of accidents	Air, soil and water contamination, effects on human health	Air , Water, Soil, Nature – Landscape – Biodiversity
Pipelines disposal	Pipes and equipment disposal	Disposal of hazardous substances	Soil contamination and water pollution	Water and Soil

Sources of information on pipelines related environmental considerations: (Stanners and Bourdeau 1995; OECD 1997; Black 1998; Dey, Ogunlana et al. 1998; Hunter, Farrington et al. 1998; Dey 2002)

5.4 Conclusions

As already discussed, the end result of this chapter can be seen as a preliminary, but nevertheless essential step towards the effort to address the integrated environmental management of the logistic chain. As such, it is part of the phased development of the research pathway of the thesis. The outcome, in the form of the presented matrices, can be seen as a tool that identifies the significant environmental aspects, and demonstrates the range of environmental impacts associated with the logistic chain and the operation of intermodal freight transport systems. As such, the relevance of the chapter's outcome as a significant component of any environmental management framework for the logistic chain is highlighted.

In addition, and as is demonstrated in chapter 8 of the thesis (section 8.3.4.1), the produced matrices, through further development, can form the basis of an analytical environmental management tool. This can be achieved by complementing the matrices with the regulative concerns and the available management options for each of the identified environmental aspects. In that case the user, cannot only identify the elements that need to be addressed by environmental management, but can also prioritise actions and consider a range of solutions and available management options. Another option for using the matrices is to place the focus on a specific environmental aspect and examine it in line with all the activities, products, or services of the logistic chain operations that can have an influence upon that aspect. This is again analytically demonstrated in chapter 8 of the thesis (section 8.3.2), using the example of environmental noise. The matrices could also be adapted to a specific logistic chain. Given a known logistic chain from point A to point B via a network of successive links between transport modes and logistic nodes, the user or manager could isolate only the applicable information from the matrices and identify the significant environmental aspects of the logistic chain under examination. In that case some further research of cargo specific related considerations might also be taken into account and relevant information might need to be included. While examining a specific logistic chain it might be more relevant to focus on the operational and maintenance aspects of the transport modes and infrastructure than on aspects related to the production and construction phase of the above.

6 Major players' response to the sustainability challenge

The previous chapter focussed on the systematic identification of the significant environmental aspects of the logistic chain. This chapter discusses the contribution of the main industry players and operators of the logistic chain, namely shippers and transport providers, with regard to its environmental management. It focuses in particular on the major players' response as they face the challenge to operate a sustainable logistic chain. The chapter first examines the theoretical principles for the operation of greener logistic chains and how those could be translated in terms of responsible operational practices. The catalysts and forcing mechanisms for response, being the legislative and regulative framework, and the increasing pressure from the public and stakeholders, are discussed. A survey (Michail 2005-2006a) is then based on the policies, interests, and practises of selected firms in order to reveal the good practice trends related to the proactive environmental management of freight transportation and the logistic chain. Acknowledging the gap between good and common practices, the chapter argues that the highlighted good practice examples demonstrate trends and reveal the pathway towards the responsible firm's contribution to the operation of more sustainable logistic chains. Selected industry driven collaborative initiatives that aim to control and manage the environmental impact of freight transport systems are highlighted and discussed separately. The discussion of both the collaborative initiatives and the survey outcomes has got a double orientation; (1) their comparison with the previously established theoretical principles and (2) the parallel assessment of their potential for improving the environmental performance of the logistic chain.

6.1 Approach

The growth of the activity in the transport sector is often faster than the growth of economic indicators (e.g. GDP). As a result the need for technological development and for coordinated efforts from both regulators and operators to bring a growing transport sector in line with sustainability criteria is considered to be greater than in other industrial sectors (Roth and Kaberger 2002). After discussing the regulative framework in the previous chapter, the focus is placed here on the efforts of the main industry players and the transport operators. Specifically, their practices and interests with regard to the environmental management of the logistic chain are examined. As established in chapter 3 the players with a major role in the organisation of the logistic chain are shippers, carriers and third party logistic service providers. The aim of this chapter is to analyse how those players could respond and how they are in fact responding to the sustainability challenge as this was formulated in chapter 4. The following figure 46 presents the selected approach for the analysis.

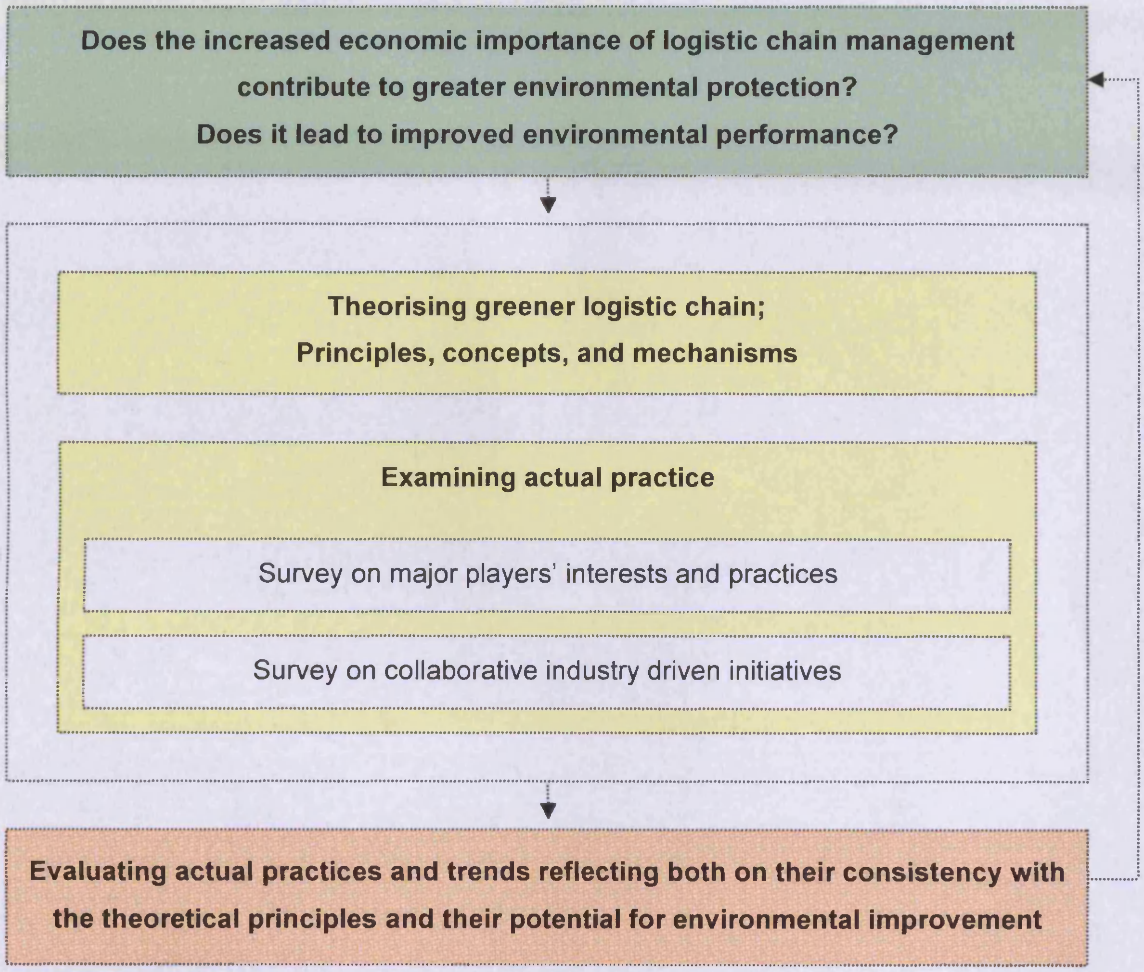


Figure 46: Approach to the research on the major players

The concepts of supply and logistic chain management are mainly driven by financial imperatives and they are of ever increasing economic importance. In this context, it is important to examine whether or not the increasing economic importance of logistic chain management is matched by a greater contribution to environmental protection, and this chapter aims to provide an answer to this question. First, the theoretical principles and possibilities for "greener" logistic chains are examined in section 6.2. Then a survey of a selected sample of firms is carried out in order to demonstrate current corporate practice and interest. The survey specifically addresses good practice and highlights collaborative initiatives between different firms in the logistic chain. The survey results are presented in section 6.3 and selected collaborative initiatives are separately discussed in section 6.4. The analysis that follows consists of comparing the theoretical perspective with both the corporate rhetoric as expressed in the firms' websites, policy documents, and available environmental reports, and the corporate actions and good practices as being reported.

6.2 Theorising greener logistic chain

This section is aimed at discussing some key concepts, principles, and mechanisms that have the potential to enable the operation of "greener" logistic chains. It is a study of environmental management trends and their theoretical implications in different levels. It starts by discussing the evolution and principles of environmental management. Then, the focus is placed on interpreting and integrating those into the transport sector's perspective and the specific logistic chain environment. Finally, a generic model is developed in order to map the interrelationships and catalysts that could lead to the operation of greener logistic chains.

6.2.1 Evolution catalysts in corporate environmental management

Rondinelli and Berry (1997 and 1998) discussed the evolution of corporate environmental management from the 60s until the end of the twentieth century (figure 47). The industry's practice during the 60s and 70s can be generally described as avoiding regulatory compliance and coping with crises as they occurred. During the 80s and due to the pressure from the environmental protection imperatives the industry has moved to what is referred to as the reactive mode. Common practice has been to react to ever growing regulatory requirements and attempting to minimise the costs of compliance. Finally, during the 1990s, proactive environmental management strategies emerge and companies begin to take control of their environmental problems and even turning them into competitive opportunities (Rondinelli and Berry 1997).

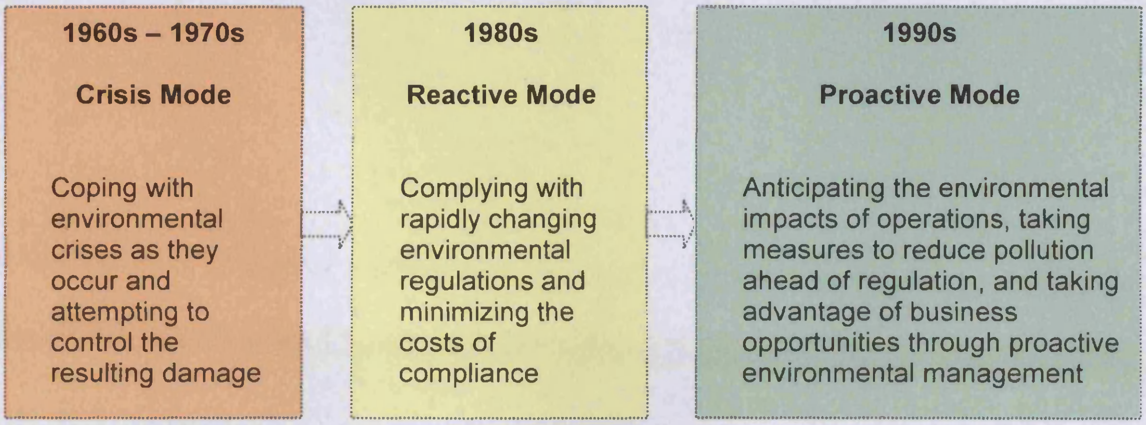


Figure 47: Evolution of environmental management strategies

Nowadays, corporations in industrialised, and in most newly industrializing nations are embracing environmental protection as part of their international competitive strategies. For many firms the shift to proactive environmental management is driven by pressures from governments, customers, employees, and competitors. Both consumers and investors are beginning to see more clearly the relationship between business performance and environmental quality. The trend towards proactive environmental management is being accelerated by public pressures on governments in order to assure a cleaner environment. Government regulations have become more stringent, legal liabilities for environmental damage have become more burdensome, and customers have become more demanding. Additionally, there is growing evidence that firms that adopt proactive environmental management strategies become more efficient and competitive. Environmental sustainability - the need to operate in line with the imperatives of environmental protection and natural resources conservation - is now a value embraced by the most competitive and successful multinational companies (Berry and Rondinelli 1998).

The expansion of the global market and the proliferation of international trade agreements are also driving the movement toward voluntary international standards for environmental management (Rondinelli and Vastag 1996). The European Community has issued a Standard Eco-Management and Audit Scheme (EMAS), which member nations are expected to implement. The ISO 14000 series is likely to become the dominant international standard for environmental management systems. Although these standards differ somewhat in their requirements and criteria, they both seek explicitly to encourage corporations to integrate environmental and corporate management systems (Berry and Rondinelli 1998).

In addition, with companies increasingly relying on their supplier's environmental performance, managers are coming to understand that environmental compliance is not sufficient; governments and consumers require better environmental stewardship. A large and increasing amount of environmental risk can be found in nearly every company's supply chain. A striking aspect of supply chain management is its recent transformation. From a routine clerical perspective concerned with little more than purchase price and continuity of supply, the function's outlook has mutated first into a commercial orientation with an emphasis on cost saving and then into a proactive strategic outlook that is fully integrated into the competitive strategy of the company (Hall and Braithwaite 2001; Preuss 2005). The strategic orientation has been accompanied by a long-term outlook on the relationship with key suppliers. In view of the argument that it is the short-termism of the competitive market economy that prevents attention to the degradation of the natural environment, such a new style of business relationship is offering new research opportunities on the interaction between private sector companies and the natural environment (Preuss 2005). Two apparently divergent business trends meet: the acceptance of supply chain strategy for competitive advantage and the role of environmental performance in competitive advantage. In addition to traditional performance dimensions of cost, quality, delivery and technology, managers must also consider the impact of their decisions on the environment (Handfield and Nichols 1999; Handfield, Sroufe et al. 2005).

Calls for responsible corporate behaviour are coming from investors, insurers, environmental interest groups, financial institutions, international trading partners, and the general public. It can be argued that corporate action in the field of proactive environmental management is triggered by the pressure received by the above referred bodies and it is dependent on the amount of this pressure. For example, the typical industrial sectors with relatively high environmental impact, thus sectors that receive the most criticism on their environmental performance, are the ones that lead in environmental and sustainability reporting (KPMG 2005).

Failure to manage the environmental impacts of their operations raises serious potential risks for firms. Potential risks include (Rondinelli and Berry 2000):

- Threats of increased regulatory control by national governments and international organisations: industries that do not manage their own environmental impacts will see stronger demands by localities and environmental groups for more stringent government regulation.
- Financial risks: Firms that ignore negative environmental impacts not only incur opportunity costs, but also potentially higher absolute costs for pollution control technologies in the future and the loss of competitive pricing advantages.
- Damages to corporate image: Environmental interest groups that uncover serious hazards or the potential for pollution and degradation can permanently harm a company's reputation. Public demands for corporate responsibility are growing in the wake of expanding international trade agreements. Shareholders and corporate directors are becoming increasingly intolerant of environmentally dangerous conditions.
- Competitive risks: Increasingly, trade agreements and treaties include requirements for complying with international environmental standards such as ISO 14000, or EMAS. Firms that fail to comply with regulatory controls and international standards risk losing competitive advantage in international markets.

Research (Berry and Rondinelli 1998) argues that "corporations that do not adopt proactive approaches to environmental management will not be competitive in the global economy of the 21st century". As the need for proactive environmental management becomes clear, the search for innovative approaches to pollution prevention is moving beyond individual firms to incorporate networks and strategic alliances. It is of significance therefore to examine the implications of proactive environmental management for the business sectors that constitute and control the logistic chain networks.

6.2.2 Logistic chain industry perspective

This section aims at examining the implications of the trends towards proactive environmental management for the major players in the logistic chain. In other words it targets the clarification on how the principles of proactive environmental management could be integrated in the practices of the major players. As established in chapter 3, the players with a major role in the organisation and operation of the logistic chain are shippers, carriers and third party logistic service providers (figure 48).

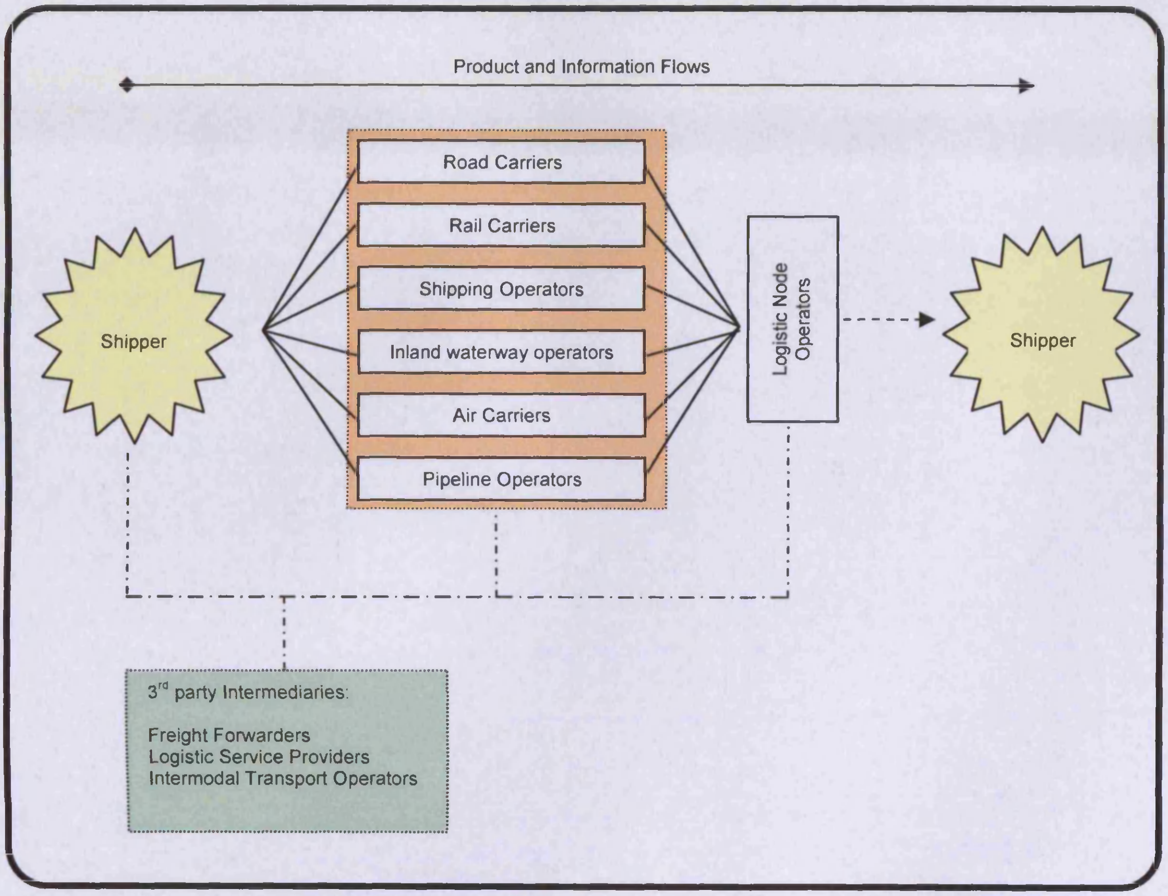


Figure 48: Major players in the logistic chain

As transportation systems (and chains) expand and become more integrated, their impacts on the physical environment become more complex. It has been argued that regulatory compliance, while necessary, may not be sufficient to manage effectively the potentially negative environmental impacts of multimodal transportation. Coping with the environmental impacts of the logistic chain, requires both the transportation industry (transport operators and providers) and its customers (shippers) to move from strategies based on regulatory compliance to those emphasizing proactive environmental management. Proactive environmental management is also essential for organizations managing multimodal transportation hubs that integrate several types of freight carriers, logistics services, and manufacturing or processing activities at a single site. According to Rondinelli and Berry (2000), proactive management of environmental issues requires corporations to identify: (1) the interactions among transportation activities that have negative environmental impacts, (2) the types of environmental impacts emanating from transportation operations and facilities, and (3) alternative means of controlling and preventing environmental pollution and natural resource degradation.

Over the last 15 years, companies have come under mounting pressure to focus on the environmental performance of their logistic chains. Much of this pressure has come from tightening government legislation. Significant triggering factors though in encouraging companies to act voluntarily and to adopt environmental best practice in their logistical operations have been the numerous campaigns by trade organisations, environmental groups and NGOs (McKinnon 2003). At the beginning of the 90s the significant aspects considered by the companies in relation to transport operations were mainly the vehicles' emissions and the packaging waste. Both aspects were driven by legislation, for example in the EU by the emission standards that were set for new trucks, and by the EC Directive on Packaging and Packaging Waste (European Parliament and Council 1994). After the mid 90s though, a turn towards more proactive environmental practices can be noticed. For example a significant rise in the number of companies establishing an environmental management system and obtaining ISO 14001 accreditation was observed (McKinnon 2003). In addition, Corporate Responsibility reporting has been steadily rising since 1993 and it has substantially increased since 2000 (KPMG 2005).

In examining the interpretation of proactive environmental management principles into responsible practices for the major players in the logistic chain, a clear distinction should be made between the shippers on the one hand and the carriers and logistic service providers on the other. The carriers and the logistic service providers are the actual transport providers and operators, the parties that own or control the means of transportation (vehicles, trains, vessels, barges, aircrafts and pipelines). As such, they have an obvious relation with the environmental impact arising from the operation of those means. A carrier's environmental footprint is almost entirely dependent on the total operated transport and its performance characteristics. The shippers on the other hand are not transport operators or at least this is not their core business. For shippers the transport related environmental impact is only a varying proportion of their total environmental footprint. Shippers' motivation in acting towards the environmental management of transportation is only rarely legislation driven and it usually falls under their voluntary commitment to the environmental management of their supply chain, part of which is transportation. This is mainly the result of multi-source (e.g. trade organisations, environmental groups, society) forcing mechanisms and demands for a cleaner transportation system. Shippers' good practices are in line with the principles of corporate environmental responsibility towards a proactive approach in controlling and minimising the firm's environmental footprint via managing their supply and logistic chain.

In accordance with the above differentiation between the major players of the logistic chain it is interesting to examine how proactive environmental management practices could lead to the operation of greener chains. In the following paragraphs the actions that the major players could commit to, demonstrating their pro-activeness to environmental management, are discussed. The discussion starts with the potential transport providers' good practices and continues with the shippers' ones.

As noted previously, the environmental impact of transport providers is dependent on the total operated transport and its performance characteristics. Transport providers have an overall limited influence over the transport demand and the total operated transport. Normally, the carriers cannot influence the transport demand as their customers make strategic decisions about the location of factories as well as patterns of sourcing and distribution. Within the limits set by the customer, the transport provider may minimise the traffic work as much as possible (Roth and Kaberger 2002). The providers' contribution to the environmental management of the logistic chain comes primarily from tackling the environmental characteristics of their operated fleet, aiming towards continuous and ahead of legislation improvement. This could be achieved by implementing technical, managerial, and procedural solutions and best practices. Such potential solutions and best practices are summarised in the following table 22.

Table 22: Transport providers' potential contribution to greener logistic chains

Transport providers potential contribution	
Technical solutions	Improving the environmental performance of the means of transport (e.g. energy use, exhaust emissions, cleaner fuels)
Managerial solutions	Establishing an EMS targeting continuous environmental improvement of operations Personnel training (e.g. drivers on eco-driving)
Procedural solutions	Monitoring and reporting environmental performance IT systems for more efficient operations Modal shift from road and air transport to cleaner modes and intermodal solutions (in the case of multimodal transport operators and service providers)

The table is not exhaustive in presenting all potential actions and solutions. Nevertheless, the highlighted examples are of significance as they form a generic theory based database of potential actions of transport providers and operators. It is expected that such actions and solutions will be encountered while researching the actual practices of transport providers in the survey to follow on section 6.3.

With regards to the shippers, and in line with the discussion above, it can be said that transport buyers' responsible practice is driven by their voluntary commitment to the environmental management of the supply chain. Any organisation is a member of some kind of supply chain or network and the numerous production, marketing or sourcing decisions made could lead to various implications for its supply chain, including implications for the natural environment (Sakris 2001). A comprehensive account of an organisation's environmental impact requires attention to its supply chain management (Preuss 2005). Environmental supply chain management may be defined as "the set of supply chain management policies held, actions taken, and relationships formed in response to concerns related to the natural environment with regard to the design, acquisition, production, distribution, use, reuse, and disposal of the firm's goods and services" (Zsidisin and Siferd 2001). Large companies usually have large shares of their environmental load from transport and distribution activities. It is that part of environmental supply chain management that focuses on transportation and distribution that can be defined as the environmental management of the logistic chain.

Environmental logistic chain management involves introducing and integrating environmental aspects into transport and distribution management processes. Handfield and Sroufe (2005) argue that by integrating environmental and logistic chain decisions a company is able to move past the ill founded belief that there is an inherent trade-off between being environmentally friendly and being profitable. Many companies nowadays plan and manage their freight transport operations as part of a broader logistical strategy. This allows them to coordinate transport more effectively with related activities such as inventory management, production scheduling, warehousing, order processing, and materials handling (McKinnon 2003).

The environmental performance of freight transport is influenced by several parameters at different levels and therefore needs to be addressed holistically. McKinnon (2003) notes that often the beneficial effects of operational decisions and applied technical solutions in order to improve performance (e.g. improvements in unit vehicle emissions) are offset by strategic decisions (e.g. centralised warehousing, global sourcing, JIT) that tend to increase the total demand for transport in terms of vehicle kilometres. In the context of shippers' responsible practices, an assessment of the impact of such strategic corporate decisions on total generated transport could therefore be expected. Transport buyers could even draw attention to a possible decrease in the total distance of transported goods, thus minimising the environmental impact of their generated transport. It should be acknowledged that the opportunity for individual companies to act unilaterally to cut freight traffic volumes is limited by the activities of customers, distributors, and suppliers with which its logistical system must interface. The rationalisation of freight transport operations often requires close cooperation by firms at different levels in the logistic and supply chain. There is a need therefore, for industry-wide initiatives and strong government support for the diffusion of sustainable logistics practices (McKinnon 2003).

In addition to considering and tackling transport demand related issues, shippers have the ability to influence the environmental performance of their transport providers and operators. Roth and Kaberger (2002) argued that there are cases when the transport buyers clearly deserve a credit for the improved environmental performance of the transport providers. This occurs for example when the shippers exercise their influence as customers by demanding cleaner transport services, or when they audit, and assess transport providers on environmental performance metrics and indicators (Handfield, Sroufe et al. 2005).

Summarising the above, some selected actions that transport buyers could consider in order to contribute to the operation of greener logistic chains are highlighted in the following table 23.

Table 23: Potential transport buyers' contribution to greener logistic chains

Shippers' practices that have the potential to contribute to the operation of greener logistic chains: • The buying company could stipulate minimum environmental standards the transport services and operations have to fulfil • May require accreditation to an environmental management standard or the introduction of an environmental policy by its transport providers and operators • Certain threshold in terms of environmental performance might be a precondition for being awarded a contract • Including environment as a parameter in transport providers' assessment • Well functioning relations in the logistic chain are a prerequisite not only for improvements in distribution practices, but also for successfully tackling environmental problems • Demanding continual improvement of transport operators' environmental performance • Demanding and acting towards the modal shift from road and air transport solutions to cleaner modes (e.g. rail and inland waterways) and to intermodal solutions • Assessing the impact of corporate strategic decision making (e.g. centralised warehousing, global sourcing, JIT) on total generated transport • Screening alternatives for decreasing the total generated transport (e.g. flat packaging, consolidating freight)

The actions highlighted on the table are of significance as they form a generic theory based database of responsible shippers' practices. It is expected that such actions and solutions will be encountered while researching the actual practices of transport buyers in the survey to follow on section 6.3.

Environmentally responsible practice tends to favour fewer shipments, less handling, shorter movements, more direct routes, and better space utilization. Environmentally responsible logistics is willing to trade time for transport savings (using a slower but more environmentally responsible carrier) and trade information systems investment for logistics costs (using advanced information systems to manage logistics systems better). Logistics managers in manufacturing companies are challenged to design optimal networks that can fit into the firm's existing structure while achieving the goals set by top management. They could reduce the use of road transport, increase the use of alternative fuels in the firms' fleets, and keep fleets more energy efficient and less polluting. They could also focus at reducing the number of trips by consolidating freight and balancing backhaul movements. Efficient information systems and innovative management ideas can also help reducing pollution and traffic congestion by allowing for more efficient loading, scheduling and routeing (Wu and Dunn 1995).

6.2.3 Generic model for greener logistic chains

This section draws on the discussed principles for greener logistic chain operation. A generic model is developed in order to map and explain the catalysts and the players' dynamic interrelationships that lead to responsible practices and overall to the contribution towards the operation of greener logistic chains. The generic theoretical model is presented in the following figure 49 and it is partly inspired and adapted from the work of Preuss (2005).

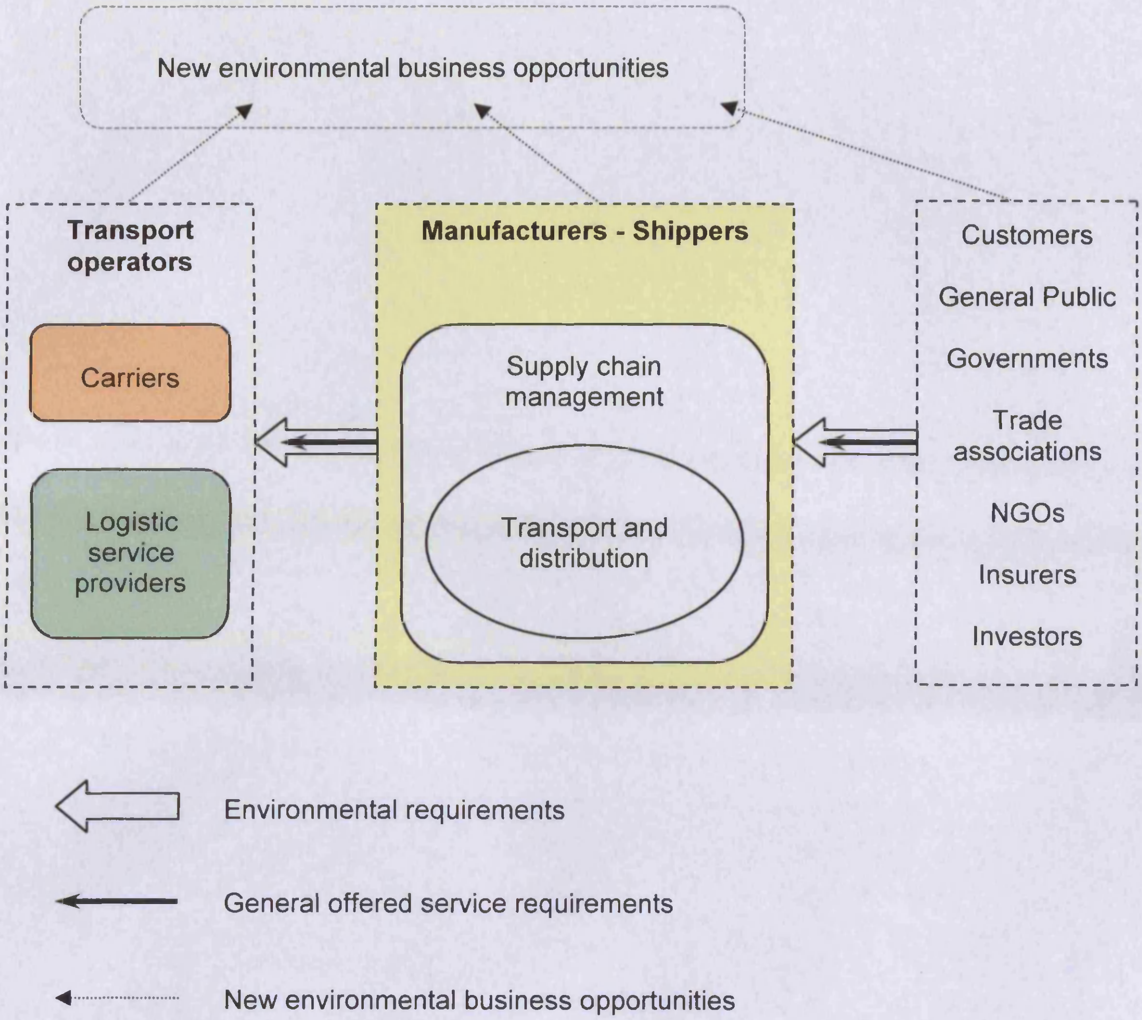


Figure 49: Forcing mechanisms and catalysts motivating action towards greener logistic chains

As can be observed on the figure, the model can be described by the following chain of forcing mechanisms, catalysts and effects:

1. The diverse environmental impacts arising from the operation of the logistic chain are widely acknowledged and current transport systems cannot be considered sustainable.
2. As a result, a diverse group of stakeholders, including trade associations, governments, environmental groups and the general public, places the pressure on the transport buyers and operators with regard to their environmental performance and that of the whole logistic chain.
3. The transport buyers (manufacturers, shippers) voluntary respond to this pressure by adopting environmental management strategies for their supply chains. Transport and distribution is a significant component of those strategies. The environmental management of a shipper's logistic chain,

targets both the total amount of generated transport and its performance characteristics. The first can be directly addressed by the shipper. The second requires the shipper to exercise its influence as costumer towards its transport providers.

4. The transport operators are facing both the primary pressure from the generic group of stakeholders and the secondary pressure by their customers, the shippers, on environmental performance grounds. Therefore, they are also driven to a proactive approach aiming for continual improvement of their performance above and ahead of legislation.
5. In that way the forcing mechanisms chain (stakeholders – shippers – providers) can lead to improved environmental performance of the logistic chain and can create new environmental business opportunities for the parties involved.

With regard to the role of shippers in this model of catalysts and relationships, Preuss (2005) makes reference to what he calls the shipper's driven "green multiplier effect". As such he refers to the ability of the shipper to exercise his influence towards its outsourced transport services and the resulting effect of such a practise. In that way the shipper can initiate a green multiplier effect, as a plethora of carriers and logistic service providers will strive to comply with the new shipper's environmental requirements in order to stay in business. Preuss (2005) considers this mechanism to be one of the most effective and thorough ways to achieve environmental performance standards in the whole logistic chain.

With reference to the model above, another challenge with regard to the environmental management of the logistic chain can also be addressed. Roth, Kaberger et al. (2002), between other researchers, pointed out the lack of an obvious answer to the question of who is liable for the environmental aspects (e.g. emissions) in a logistic chain. Is it the transport provider, the transport buyer or the end consumer of a given product? Giving a very simplistic example of a purchase of a banana by a Swedish consumer in December the liability question becomes apparent. Who is responsible for the environmental impact generated by the transport of this banana from its country of origin? Is it the transport operator who brought it - Is it the shipper who ordered the import – or is it the consumer who decided to buy the banana?

Following the ISO (EN ISO 14001 1996) recommendations, values for environmental parameters that have a significant impact and on which someone has an influence should be identified. Therefore, both the transport providers and the transport buyers are responsible for the generated environmental impact. According to the model the consumer can also be considered liable not only because of the purchasing decision, but also because of the limited pressure exercised towards the shipper in that case in transport related environmental grounds.

6.3 Survey: Major players' interests, practices and trends

After discussing the theoretical principles, mechanisms and models that could drive the operation of more sustainable logistic chains, and the potential contribution of transport buyers and transport providers towards that direction, the current section focuses on investigating the actual interests and practices of selected companies. For this purpose a survey (Michail 2005-2006a) was based on a sample of firms, consisting of both transport buyers (shippers) and operators (carriers and logistic service providers). The sample of firms was researched on the basis of approaches, policies and concrete actions targeting the environmental management of operated or generated transport, thus contributing in operating greener logistic chains. The survey, its aims, identity, methodology and results are analysed and discussed in the paragraphs that follow. The discussion opens with a short review of recent similar studies in the field that inspired the survey in terms of methodology and approach.

6.3.1 Selected previous studies in the field

Before presenting the actual survey and its results some selected recent studies in similar grounds are summarised and discussed upon in this paragraph. The presented studies influenced the methodology and the content of the survey. The following table 24 highlights those selected studies on the actors in the supply/logistic chain and their environmental practice and interest.

Table 24: Selected studies on players' interests and practices

Researcher	Title	Sample	Method
(Roth and Kaberger 2002)	Making transport systems sustainable	8 companies (4 transport buyers, 4 transport operators)	Desk study: Studying the publicly available environmental reports of the selected firms
(Preuss 2005)	Rhetoric and Reality of Corporate Greening: a View from the Supply Chain Management Function	30 manufacturers (transport buyers)	Field and desk study: Semi-structured interviews, study of internal documents, environmental reports, promotional documents, and external reports
(Handfield, Sroufe et al. 2005)	Integrating Environmental Management and Supply Chain Strategies	17 manufacturers (transport buyers)	Field and desk study: Prior research and Interviews

Roth and Kaberger (2002) examined the environmental reports of companies in the Swedish transport sector (both transport buyers and transport operators) in relation to their carbon dioxide emissions, choice of indicators, and long-term goals. The study revealed that the supply chain structure of the transport sector creates a problem with assigning environmental liability (in that case for carbon dioxide emissions) along the chain. The researchers analysed the way that the different actors in the transport sector could take on this challenge in order to contribute to the operation of greener logistic chains. They argued that the matter of liability can be handled by applying a holistic supply/logistic chain perspective, instead of narrowly focussing at single companies. In such way the interaction between the transport buyer and transport provider is of vital significance. As the supply chain perspective is customer orientated, this will stress the responsibility of the transport buyer in steering chain environmental performance. With a supply chain perspective the liability for the environmental impacts of transport would have to be regulated as part of the business agreements. With an increased explicit contractual assignment of liability for emissions, awareness would increase, improving the conditions for conscientious management of the environmental aspects of the logistic chain.

Preuss (2005) researched the contribution of the increasingly important function of supply chain management to environmental protection. Theoretical perspectives on greener supply were developed and then tested against the practices of 30 manufacturing companies from a broad range of industries in Scotland and the United Kingdom. The data collection included semi structured interviews with companies' managers and desk study. The research revealed that although the corporate rhetoric offers surface evidence for a proactive supply chain management role in environmental protection, the situation appears to be suboptimal while examining the actual corporate practices. Preuss acknowledges that there are some exemplary companies that involve their supply chains in environmental protection initiatives, stating though that in their majority those are large corporations which are furthermore concentrated in industries that are already in the public limelight over their environmental performance.

Handfield, Sroufe et al. (2005) reviewed the way that companies integrate environmental considerations in their supply chain strategies. Interviews with 17 manufacturing companies of various industry sectors in four countries (US, UK, Korea, and Japan) took place in order to develop a framework for environmental supply chain strategy decision making. The study concluded by suggesting guidelines on the way that companies could modify their current supply chain practices in order to successfully integrate environmental issues.

By examining the identity, methodology, and content of those studies some remarks can be made and some implications can be derived with regard to the characteristics of the undertaken survey. Concerning the size and composition of the research samples, those appear to be case specific and relate to the aims of the different studies. In general it can be argued that the research samples cannot be eligible for statistical analysis and cannot be broadly considered as representative due to the large total number of companies in the field. Therefore, it can be said that the qualitative characteristics of the defined research samples and how those relate to the aims of the studies are more significant than the quantitative ones. Concerning the methods used, those included desk studies and field visits. Again, the methods are case specific and depend on the aims and application.

6.3.2 Aims, identity and methodology of the survey

Building on the experience of the previous studies, both in terms of approach and content, the methodological and structure related aspects of the survey on transport buyers and operators (Michail 2005-2006a) were set. In this section the aims, methodology and identity of the survey are discussed.

The survey was specifically designed to demonstrate good environmental management practices of selected companies in the logistic chain sector. Acknowledging that common practice and performance in the field is considered to be suboptimal, as recent research demonstrated (Preuss 2005), the survey focuses on an exemplary sample of companies that tend to integrate environmental components in their supply chains, logistic chains, and operations' management. The primary aim is to reveal good practice examples and to then examine if those are in accordance with the theoretical perspectives for operating greener logistic chains and the transport policy trends. The survey is also aimed at investigating the mechanisms (tools, systems, initiatives) that are applied in order to manage transport and distribution related environmental aspects in a chain concept.

The general methodological framework of the survey is presented in figure 50 (Michail 2005-2006a). The input – preparation phase consisted of decision-making on the methods and sources of information to be used for the data collection, and of determining the research sample of companies in accordance with specifically developed selection criteria. The process of data collection was aided and guided by an information checklist, developed in accordance with the aims of the survey and the desired outcomes.

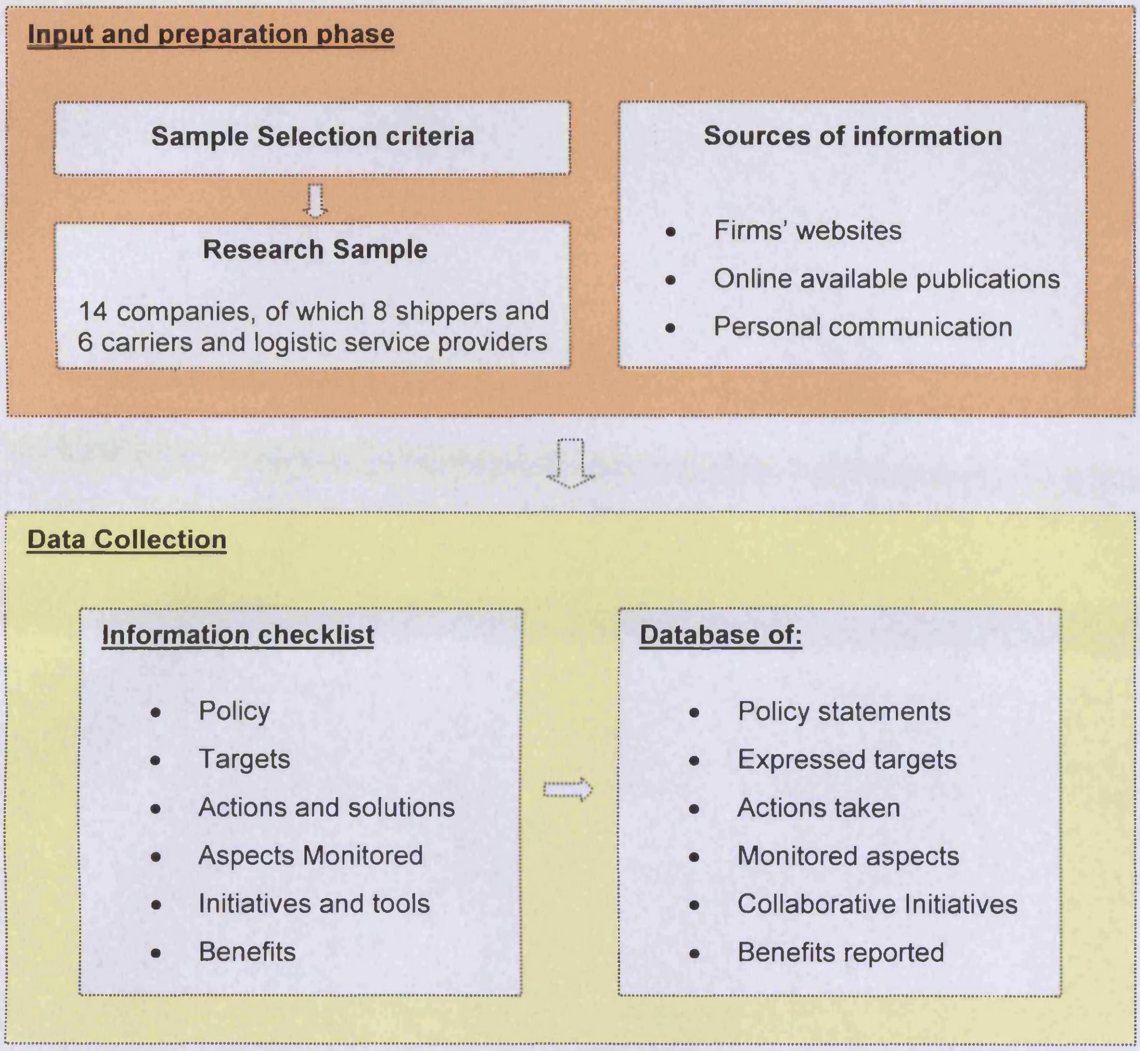


Figure 50: Survey methodological framework

With regard to the selected method, the research was primarily a desk study. The main sources of information were the websites of the selected companies and the online available publications such as newsletters and environmental reports. External reports, such as publications on industrial journals and the media reflecting practices of the selected firms, and relevant conference proceedings and presentations by firms' managers were also used. In addition in some cases (4 out of 14) personal communication with managers and field visits in firms' operational sites took place in order to improve knowledge and validate certain aspects.

The selection of the exemplary sample of companies was based on criteria specifically designed in accordance with the aims of the survey and the desired outcome. The selection criteria are presented and discussed in the following table 25.

Table 25: Research sample selection criteria

Selection criteria for the research sample: • To be representative of various manufacturing sectors (furniture, chemicals, food, electronics) that can be considered "sensitive" as being in the public limelight over their environmental performance • To be representative of both transport buyers (shippers) and transport providers (carriers and logistic service providers), the parties with the greatest influence in the logistic chain • To consist of companies that have a far reaching environmental policy (e.g. Health, Safety and Environmental management systems in place, publicly available environmental information). • To focus on medium and big size companies operating internationally

(Michail 2005-2006a)

In addition to the above mentioned criteria, the final selection of the research sample was assisted by the consultation of a panel of experts. The panel consisted of port managers (on both operational and senior level), environmental management consultants, and academics. It was formulated for the needs of the ECOPORTS project working group discussing the role of ports in the logistic chain (ECOPORTS project 2005 e). The panel was consulted by the researcher (Michail 2005-2006a) on the selection of firms with an established record of good and best practices in the field of environmental management of the logistic chain. This has been considered of significance due to the aim of the survey to demonstrate and assess best practice more than common one. After the application of the above mentioned criteria the research sample presented on table 26 (Michail 2005-2006a) emerged. It consisted of 14 companies of which 8 multinational manufacturers (shippers – transport buyers) and 6 major transport providers (freight carriers and logistic service providers).

Table 26: Survey sample characteristics

	Company	Shippers	Carriers and Distributors	Logistic Service Providers
1	Otto Versand	√	√	
2	IKEA	√		
3	Stora Enso	√		
4	Shell Chemicals	√		
5	Philips	√		
6	Cargill	√		√
7	P&O Nedlloyd		√	√
8	Hewlett-Packard	√		
9	Schenker		√	√
10	Katoen Natie		√	√
11	Maersk		√	√
12	B&Q	√		
13	Freightliner		√	√
14	Sarlis S.A.		√	√

The size of the sample is acknowledged as being too small for statistical analysis and/or for being considered generally representative. This would have even be the case if the number of companies in the sample was significantly bigger (e.g. even a hundred companies cannot be considered representative of the thousands of manufacturing and transport operating firms). Nevertheless, the selected companies may be considered representative of the large and internationally operated transport buyers and providers and it is believed that the selection process of the sample was such that enables the demonstration of good practice trends in line with the aims of the survey. It is suggested that the survey makes a qualitative contribution to understanding the rhetoric and reality of logistic chain management involvement in environmental protection.

The data collection phase of the survey was assisted and guided by a checklist of information in order to systematically filter the available data. The checklist was developed in line with the aims of the survey and it was designed to reflect both the corporate rhetoric and the actual objectives, and actions as reported by the firms on their publicly available information. The checklist is presented and explained in the following table 27.

Table 27: Survey information checklist

Checklist Items	Explanation
Policy	Main policies and policy statements with regard to the environmental management of transport
Targets	Main objectives and targets aiming to reduce the environmental impact arising from transport operations
Actions and solutions	Actions taken and solutions implemented aiming to reduce the environmental impact of transport related operations
Aspects Monitored	Environmental monitoring schemes with regard to transport related environmental aspects
Initiatives and Communication tools	Projects and initiatives that are addressing health, safety, environmental and security aspects of transport operations in a chain concept (collaboration with other parties in the logistic chain)
Benefits	Reported benefits of transport related environmental policies for both business and the environment

(Michail 2005-2006a)

The checklist proved to be a valuable tool while screening for significance and relevance of the provided environmental management data. It functioned as the filter through which the data was systematically classified and structured. The output of this exercise was a database of knowledge with regard to the policies, objectives and targets set, actions and solutions implemented, initiatives taken, aspects monitored, and resulting benefits of the selected sample of transport buyers and providers. This database of knowledge is presented, discussed and analysed on the following sections.

6.3.3 Survey Results and Analysis

This section presents the results of the survey on transport buyers', and providers' good practices. Those are presented and discussed following the structure dictated by the checklist of information as presented above in table 27.

The first step was the investigation of the firms' environmental policies. These were derived by the generic policy documents and statements that were accessible either in separate sections on the firms' websites, either on their publicly available environmental (often entitled corporate responsibility, or sustainability) reports. Selected examples of policy statements from both manufacturers and transport providers are highlighted in table 28.

Table 28: Examples of environmental policy statements

Shippers

- "We believe that our social and environmental responsibility covers the whole supply chain" – IKEA (Ivarsson 2003)
- "We leverage our communication opportunities to convince suppliers and consumers alike of the importance of environmental protection, and to strengthen the role of the environment as a factor in the supply-and-demand equation." – (Otto Versand 2003)
- "We want to ensure our standards and expectations are upheld throughout our supply chain and we use our influence as a customer to do this (Hewlett Packard 2003)".

Transport providers and operators

- "Since we are one of the leading logistics service providers in Europe, the company has to carry part of the burden to reduce environmental impacts of transport" – (Schenker 2004)

(Michail 2005-2006a)

Some significant observations can be made with regard to the corporate rhetoric as expressed on the policy statements. Concerning the manufacturers it should be noticed that although they are not physically involved in transport operations they actually generate and guide the transport demand. In line with the concept of corporate social and environmental responsibility good shippers' practice initiates by accepting the environmental responsibility for their entire supply chain and of their generated transport as part of it. The environmental policy documents and statements by the sample companies seem to offer surface evidence for a proactive supply chain management role in environmental protection. Transport buyers' supply chain policies are addressing health, safety and environmental aspects of production and distribution, risk management and labour conditions. The rhetoric employed in corporate environmental policy documents promises a proactive environmental approach that involves the supply and the logistic chain. Some of the statements go a step further in expressing the firms' commitment to use their customers' derived influence in order to ensure that the outsourced transport and logistic services meet certain environmental performance, in line with other efficiency based standards. It is often declared that compliance with the standards and expectations is an important factor in shippers' decision to enter or to remain in business relationship with transport operators.

With regard to the transport operators, the pre-survey opinion that in their case the picture would be more straight-forward as their core business is directly transport related, appears to be confirmed and validated by the study of their policy statements. Transport operators are at large expressing their commitment in carrying their part of the burden in order to reduce the environmental impacts of transport operations.

The second research item on the checklist and respectively on the presentation and discussion is the investigation of the policy objectives and targets set by the firms in line with their aspirations for improving their transport related environmental performance. It should be noticed that due to the nature of the survey (desk study) the objectives and targets were derived in a quite generic and primarily qualitative format. By examining, in the majority of cases, the publicly available information sources (websites, reports) and not the potentially more precise internal documents, this was something to be expected. Available information on quantitative targets concerned primarily carbon dioxide (CO_2) emissions, filling rate performance (-15% on CO_2 emissions, 60% filling rate by 2005 (Ivarsson 2003)) and distribution incidents (halving of the number of distribution incidents by 2010 (Anon 2003)). The following tables 29 and 30 present the analytical outcomes of the investigation on the policy objectives and targets of transport buyers (shippers) and transport operators (freight carriers and logistic service providers) respectively. The tables follow a generic classification of objectives and targets according to their orientation towards technical-operational, strategic-managerial, and procedural aspects.

Table 29: Shippers' policy objectives and targets

Shippers - Policy objectives and targets	
Technology	Outsourcing transport services that make use of state of the art technologies (Ivarsson 2003; Otto Versand 2003; Stora Enso 2003; IKEA 2004; IKEA 2005; Otto Versand 2005; Stora Enso 2005 a)
	To ensure that own fleets make use of state of the art technologies (Otto Versand 2003; Otto Versand 2005)
Strategic	To increase the use of rail / inland waterways and sea transport (Ivarsson 2003; Otto Versand 2003; Stora Enso 2003; IKEA 2004; B&Q 2005; IKEA 2005; Otto Versand 2005; Stora Enso 2005 a)
	To reduce the road and air transport shares (Otto Versand 2003; B&Q 2005; Otto Versand 2005)
	Skill promotion and training (driver training, safety training) (Otto Versand 2003; Otto Versand 2005)
	To monitor transport impacts and report performance (Ivarsson 2003; IKEA 2004; IKEA 2005)
	To increase energy efficiency (for different modes) (Ivarsson 2003; Stora Enso 2003; IKEA 2004; B&Q 2005; IKEA 2005; Stora Enso 2005 a)
	To reduce greenhouse gases emissions (Ivarsson 2003; Otto Versand 2003; Stora Enso 2003; IKEA 2004; B&Q 2005; IKEA 2005; Otto Versand 2005; Stora Enso 2005 a)
Procedural	To favourite multimodal and intermodal solutions (Ivarsson 2003; Otto Versand 2003; IKEA 2004; IKEA 2005; Otto Versand 2005)
	To research innovative concepts and transport solutions (Ivarsson 2003; Otto Versand 2003; Stora Enso 2003; IKEA 2004; IKEA 2005; Otto Versand 2005; Stora Enso 2005 a)
	To increase filling rate (Ivarsson 2003; IKEA 2004; IKEA 2005)

(Michail 2005-2006a)

In examining the targets set by the shippers it can be observed that those tend to be oriented on a strategic level. This is something that was expected due to their role in the logistic chain. Main shippers' policy objectives referred to the modal shift from road transport and aviation to more environmental friendly transport modes, to the reduction of the CO_2 emissions of their transportation, to monitoring and reporting environmental performance of their logistic chain and to cooperating with other partners in the chain undertaking common initiatives to tackle common challenges.

Table 30: Transport operators' and providers' policy objectives and targets

Transport operators - Policy objectives and targets	
Technology	To make use of state of the art technologies (Schenker 2004; Schenker 2005)
	Use new technology for vessels (P&O Nedlloyd 2004 a; P&O Nedlloyd 2004 b; Maersk Sealand 2005; P&O Nedlloyd 2005)
	To use alternative fuels (Schenker 2004; Schenker 2005)
Strategic	Modal shift from road to cleaner transport modes (P&O Nedlloyd 2004 a; P&O Nedlloyd 2004 b; P&O Nedlloyd 2005; Sarlis S.A. 2005)
	To comply with legislation (Schenker 2004; Diment, Gibbs et al. 2005; Maersk Sealand 2005; Schenker 2005)
	To be proactive above legislation (Schenker 2004; Schenker 2005)
	To monitor and report performance (Schenker 2004; Schenker 2005)
	To increase fuel efficiency (all modes) (P&O Nedlloyd 2004 a; P&O Nedlloyd 2004 b; P&O Nedlloyd 2005)
	To reduce CO_2 emissions (Schenker 2004; Schenker 2005)
	To mitigate the impact of sea transport (Maersk Sealand 2005)
Procedural	To co-operate with stakeholders (Schenker 2004; Schenker 2005)
	To constantly research new logistic concepts and solutions (Koukoumelis 2004; Schenker 2004; Schenker 2005)

(Michail 2005-2006a)

As anticipated, the transport operators tend to orient their policy objectives primarily on improving unit environmental performance of their operated means of transport (e.g. vehicles, vessels). The policy objectives of carriers and logistic service providers are oriented towards reducing air emissions and increasing the energy efficiency of transport operations.

The next step of the survey focused on identifying the actions and solutions taken and implemented by the firms in respect to their policy objectives and targets set. The following tables 31 and 32 present the actions and solutions that were reported by transport buyers and operators respectively.

Table 31: Actions and solutions implemented by transport buyers

Shippers - Actions and solutions	
Technology	Employing transport service providers with state of the art aircrafts leading to CO_2 decreases. (Otto Versand 2004)
	Employing ships with catalytic conversion, equipped for electricity supplies from shore and low sulphur oil (Stora Enso 2005 c)
	Investing in a modern fuel-efficient, low emission, low noise vehicle fleet (B&Q 2005)
	Operating vehicles with gas motors (Otto Versand 2005)
	Testing hydrogen powered vehicles (Otto Versand 2005)
Procedural / Logistic	Packing products more densely on each pallet, reducing the total number of trips. (Hewlett Packard 2003; Hewlett Packard 2005)
	Increasing filling rate and avoid empty positioning (Ivarsson 2003)
	Setting and auditing performance criteria for railway companies. (Shell Chemicals 2005)
	Setting qualifying criteria for motor carriers (Shell Chemicals 2005)
	Including waste management clauses in contracts with barge carriers (Shell Chemicals 2005)
	Clever design and flatter packaging, more products into every load carrying unit, lower emissions (IKEA 2004)
	Terminal inspections to ensure that products are stored, loaded, and delivered safely (Shell Chemicals 2005)
Managerial	Involvement in the international co-operative forum BLICC (The Business Leaders; Initiative on Climate Change) aiming in reducing CO2 emissions. (IKEA 2004)
	Developing alliances with carriers (Shell Chemicals 2005)
Modal Shift	Increasing or maintaining sea transport shares at high levels (Hewlett Packard 2003; Otto Versand 2004; Stora Enso 2004 b; Hewlett Packard 2005)
	Shifting transport to rail (Ivarsson 2003; Stora Enso 2003; Otto Versand 2004; Stora Enso 2004 a; Stora Enso 2004 b; Otto Versand 2005; Stora Enso 2005 a; Stora Enso 2005 c)
	Shifting transport to inland shipping (Otto Versand 2004; Otto Versand 2005)
	Decreasing airfreight (Hewlett Packard 2003; Otto Versand 2004; Hewlett Packard 2005)
	Shifting transport of goods to combined and intermodal solutions (Otto Versand 2004; Otto Versand 2005)

(Michail 2005-2006a)

In terms of actions and implemented solutions some major shippers are using their influence as customers while outsourcing transport and logistic services to ensure an efficient and sustainable distribution of their products. Like factoring in environmental considerations while purchasing raw materials from suppliers, some industries have begun to pay equal attention to transport purchasing. In many cases transport providers are expected to have environmental management systems in place, to aim towards continuous improvement and to share information concerning their performance. Specific tools are often used for communicating with the suppliers (and transport providers) and for ensuring compliance with the standards and expectations. Such tools are the Supplier Declaration on Sustainability (Philips 2003) and the Supplier Code of Conduct (Hewlett Packard 2003). Many companies clearly declare that compliance with the standards and expectations is an important factor in their decision to enter or to remain in business relationship. Good practice examples include applying specific criteria for the evaluation of the environmental performance of the transport operators and demanding commitment towards continuous environmental improvement. "We require that our transport service suppliers inform us about, and continuously improve their environmental performance (Stora Enso 2005 b)."

Table 32: Actions and solutions implemented by transport providers and operators

Transport operators - Actions and solutions	
Technology	Involvement in projects to cut emissions from main engines and auxiliary equipment (P&O Nedlloyd 2004 a; P&O Nedlloyd 2004 b; P&O Nedlloyd 2005)
	Investing on efficient after-treatment techniques affecting the emissions of nitric oxides, hydrocarbons and particles to the air (Schenker 2004; Schenker 2005)
	Utilising emission control technology for reduced hydrocarbons, particles and nitric oxides emissions (Schenker 2004; Schenker 2005)
	Making use of CO_2-powered cooling units for mobile sources to reduce diesel exhaust emissions (Schenker 2004; Schenker 2005)
	Making use of NO_X efficient engine technology (NO_X emissions reduction by up to 26%) (Maersk Sealand 2005)
	New cylinder lubrication systems that use less lubricating oil and reduce particulate emissions by 25% (Maersk Sealand 2005)

	Testing alternative fuels: ethanol-powered trucks, electric-hybrid trucks, trucks that run on biogas and natural gas (Schenker 2004; Schenker 2005)
	Introducing bio-fuels will dramatically reduce emissions of carbon dioxide (Schenker 2004; Schenker 2005)
	Participating in projects in cooperation with truck manufacturers in the field of alternative fuels and after-treatment equipment. (Schenker 2004; Schenker 2005)
	Waste heat recovery systems (fuel consumption reduction by up to 10%) (Maersk Sealand 2005)
	Utilizing low sulphur fuels (Maersk Sealand 2005)
	Waste oil clarification decanters (separate burnable liquids from waste oil, water and sludge mixtures) (Maersk Sealand 2005)
	The 98% of all vessel materials is recycled (Maersk Sealand 2005)
	CFC-free cooling systems in all refrigerated containers (Maersk Sealand 2005)
	Use of "protected fuel tanks" (minimises the risk of oil spills) (Maersk Sealand 2005)
	Advanced computer systems that improve our efficiency by making sure our ships can carry the maximum possible cargo, and sail the optimum route at the optimum speed (Maersk Sealand 2005)
Procedural / Logistic	Reducing unnecessary mileage by consolidating goods and co-ordinating transports (Schenker 2004; Schenker 2005)
	GPS (Global Positioning System) to improve traffic control and increase efficiency in the transport system (Schenker 2004; Schenker 2005)
	Offering environmental services to clients: optimal logistics solutions considering costs, services and environmental impacts (ecology, ecomap tools) (Schenker 2004; Schenker 2005)
	Setting environmental requirements on subcontracted carriers (Schenker 2004; Schenker 2005)
Managerial	ISO 14001 certification (Schenker 2004; Maersk Sealand 2005; Schenker 2005)
	Environmental training for employees (Schenker 2004; Schenker 2005)
	Training in Eco-driving (Schenker 2004; Schenker 2005)
	Communication, conferences and seminars (Schenker 2004; Schenker 2005)
	Cooperation with other partners in the logistic chain (Schenker 2004; Maersk Sealand 2005; Sarlis S.A. 2005; Schenker 2005)
	Subcontracted ocean carriers have to qualify by complying with environmental standards such as ISO 14001 and the International

	Convention for Prevention of Pollution from Ships (Marpol) (Schenker 2004; Schenker 2005)
	Vessels and operated facilities in compliance with the ISPS Code (Maersk Sealand 2005)
	Ballast water management (Maersk Sealand 2005)
	Garbage and Waste Management Plan on each vessel. (Maersk Sealand 2005)
Modal Shift	Investing in inland shipping (P&O Nedlloyd 2004 a; P&O Nedlloyd 2004 b; P&O Nedlloyd 2005)
	investing in rail operations (P&O Nedlloyd 2004 a; P&O Nedlloyd 2004 b; Maersk Sealand 2005; P&O Nedlloyd 2005)
	Participating in projects aiming to optimise the use of trains for the transport of containers (Marco Polo) (Koukoumelis 2004)

(Michail 2005-2006a)

It can be observed that many transport operators are investing in the implementation of state-of-the-art innovative technical solutions including exhaust emissions control and engine technology, vehicle technology and alternative fuel technology.

The next survey results area was the demonstration of the environmental components that are monitored by the selected firms. Those are presented in table 33. It is interesting to note that the desk survey did not reveal information on other issues such as water pollution, soil contamination, effect on ecosystems and noise.

Table 33: Environmental components monitored by the sample companies

The following environmental aspects of transport operations are currently monitored by the industry:

- Air emissions (CO_2, CO, HC, NO_X, SO_X, PM)
- Modal split
- Energy consumption
- Ballast water
- Energy efficiency
- "Ecological Efficiency" indicator. The higher the tonnage of goods and shipments moved per ton of CO_2, the higher the efficiency
- Risk, safety, security

(Michail 2005-2006a)

Another important area of investigation has been the collaborative initiatives aimed at environment that bring together different players in the logistic chain. It is interesting to note that many of the researched firms actively participate in such initiatives. In line with those initiatives, specific communication tools have been developed in order to ensure the exchange of relevant information between the participating parties. Collaborative initiatives and communication tools are of particular significance for the overall aim of the thesis as they demonstrate an integrated approach between different chain players. Lessons and experience derived from their study could therefore add to the effort of integrating roles and responsibilities in the form of an EMS for the logistic chain. The initiatives and communication tools are presented in table 34 and are discussed in the following paragraphs. Due to their particular significance some selected collaborative initiatives are further discussed in a separate section of this chapter (section 6.4).

Table 34: Cooperative initiatives and communication tools

Cooperative Initiatives
• 'Responsible Care' • 'Clean Cargo' working group • Sustainable Freight Transport Group • Clean Routing System • Business Leaders Initiative on Climate Change
Communication Tools
• Staircase models for continuous improvement • 'Environmental Performance Survey' • Carrier safety protocols • Ecomap, Ecolog • Responsible Care code on product distribution

(Michail 2005-2006a)

Apart from the individual transport policies and objectives of each company, the research revealed collaborative initiatives that brought together shippers, carriers and logistic services providers aiming towards a more sustainable transport system. IKEA, Hewlett Packard, Maersk and P&O Nedlloyd participate in the Business for Social

Responsibility (BSR) Clean Cargo working group aiming to promote sustainable product transportation at sea and in port (Business for Social Responsibility - BSR 2005). IKEA again, together with Stora Enso, and Maersk Sealand are part of the Business Leaders Initiative on Climate Change (BLICC) that aims to reduce CO_2 emissions arising from manufacturing and transport operations. Shell Chemicals integrates the Responsible Care management code on product distribution. The code is designed to reduce the risk that the transportation and storage of chemicals poses to the public, carriers, customers, contractors, company employees and to the environment.

In line with the outlined initiatives, various tools were developed and applied for the communication between shippers and carriers concerning the environmental performance of transport operations. The Environmental Performance Survey developed by the Business for Social Responsibility (BSR) Clean Cargo working group is assessing the environmental performance of ocean carriers. The Carrier Safety Protocols developed under the Responsible Care initiative provide companies with the mechanism to gather Health, Safety and Environmental information from carriers and distributors.

The reported benefits for both the environment and the industry from the applied policies, measures and solutions are presented in table 35.

Table 35: Reported benefits

Reported Benefits	
For the environment • Reduction in CO_2 emissions • Reduction of air emissions • Decrease in fuel consumption per ton of goods • Energy savings • Lorries off the road • Safer distribution	For the industry • Differentiation from competitors • Pro-actively alleviate negative publicity • Improvements in efficiency and processes • Increased trust • Cost savings (efficiency, insurance rates)

(Michail 2005-2006a)

The reported environmental benefits are primarily in the areas of air exhaust emissions and in particular in greenhouse gases. Those are the aspects that are given the most attention by the media and the general public. It can be argued that the reported benefits concern aspects that are in the public limelight and at the centre of interest and discussion. In examining the reported benefits for business it can be confirmed that in practice certain policies and actions towards improving environmental performance are also efficient in economic terms. In other words it appears that economics and environmental imperatives are not mutually exclusive.

6.3.4 Theoretical perspectives compared with survey results

After presenting the outcomes of the survey, especially in the area of corporate actions taken and solutions implemented, this section aims to examine them against the theoretical perspectives, principles and mechanisms that were established in section 6.2 and to assess their potential to act as "greening" drivers of the logistic chain. Good practice actions and examples from both transport buyers and operators as derived from the outcomes of the survey, appear to be generally towards the desired direction as this was formulated while theorising greener logistic chains in section 6.2. The investigated transport buyers incorporate freight transport related environmental considerations in the scope of their environmental policies and management systems. Specific targets and responding actions are reported to deliver environmental improvement. Transport operators seem at large to acknowledge their responsibility towards the environmental management of their operations. Targets and related solutions are again reported and disseminated. In general, the investigated good practice examples are in line with both the theoretical principles and the generic regulative framework and transport policy orientations.

Nevertheless, due to the nature of the survey (primarily desk research) some areas require further investigation in order to conclude on whether the corporate rhetoric is actually in line with the undertaken actions and whether the different schemes, systems and initiatives work in practice and deliver environmental improvement. Further research is therefore suggested for the investigation of issues such as quality assurance of management and information, performance indicators that track progress over objectives and targets, assessment on whether the environmental issues are factored in into the business plans, and level of integration of existing systems in terms of format and application (questions of cost effectiveness, harmonisation and practicability).

6.4 Collaborative industry initiatives

Selected initiatives are analytically discussed in this section as they present an interest towards the overall aim of the thesis to develop guidelines for an environmental management system for the logistic chain. Those initiatives bring together different players in the chain on environmental grounds and it is of significance to investigate the ways and the aims of such attempts. Between the initiatives that emerged from the survey (Michail 2005-2006a), 3 were found to present a particular interest towards this direction and are discussed in the following paragraphs. Those were the Clean Cargo and Green Freight groups, the Business Leaders Initiative on Climate Change (BLICC), and the Responsible Care initiative of the chemicals' industry.

6.4.1 The Clean Cargo and Green Freight Initiatives

The Clean Cargo and Green Freight working groups are aiming to promote sustainable product transportation by sea and land. Clean Cargo focuses on ocean freight while Green Freight focuses on international and intermodal transportation (Business for Social Responsibility - BSR 2005). Each group is composed of leading multinational manufacturers and retailers (shippers), and carriers (transport operators). Shippers increasingly include the environmental performance of their transport into their corporate footprint and environmental management systems. Carriers realised their responsibilities as well as opportunities to improve environmental performance of freight transport as an industry.

Recognising the need for action, the Clean Cargo and Green Freight Working Groups are developing voluntary environmental management guidelines and metrics to help evaluate and improve the performance of fleets and carriers and spur broader movement towards a sustainable transportation future. In addition, the groups have identified core focus areas where industry collaboration can foster environmentally preferable practices. The Clean Cargo and Green Freight Working Groups are unprecedented partnerships that allow cross-industry dialogue and networking. The cooperative and multi-industrial approach enables significant advances in environmental stewardship and sustainability in an otherwise very competitive industry.

In the spring of 2001, the Clean Cargo group launched with a core group of companies representing 20 percent of the top 50 U.S. importers of containerised cargo by volume (of TEUs, twenty-foot equivalent units) and invited carriers to participate. Today the group includes marine cargo carriers representing nearly 60% of the global containerised cargo capacity. The main goal of the group is to develop cost-effective environmental specifications for marine carrier service providers in order to significantly improve air quality (e.g., by reducing emissions and improving fuel/engine efficiency) and reduce the introduction of aquatic nuisance species (e.g., by endorsing process standards for ballast water exchange and treatment). The Group's intent is to reduce these environmental impacts in major shipping routes globally.

Despite being the most energy efficient mode of transport based on ton-of-cargo per distance, ocean transport is a significant source of air pollution globally. Marine vessels emit significant amount of pollutants locally and along major shipping routes, primarily due to the low quality fuel in use. The appropriate legislative body is the International Maritime Organization and several Conventions and Resolutions regulate basic environmental and safety requirements. However, current rules provide little guidance for continuously improving environmental performance, for example in air quality or biological resource protection. Therefore, a business approach (e.g. one based on markets and economic incentives) is needed to speed efforts to reduce the environmental impacts of marine shipping transportation globally (Business for Social Responsibility - BSR 2005).

In the autumn of 2001, the Green Freight Group was formed, increasing the influence of 20 major companies, including 11 Fortune 500 companies. The group focuses on international and intermodal transportation along corporate supply chains. Its aim is to promote sustainable freight transportation internationally. The group is composed of leading multinational manufacturers and retailers and their freight forwarders. The main goal of the group is to develop cost-effective environmental performance standards for truck and rail service providers to significantly decrease their impacts on air quality and climate change. In order to accomplish this, the working group is striving to reduce emissions and improve fuel efficiency in the United States, as well as in Asia, Latin America, and Europe where many products are manufactured and sold. The group is predominantly focused on air emissions, but other environmental impacts associated with ground transportation may be addressed in subsequent phases of the Green Freight program.

The benefits reported by the Clean Cargo and Green Freight initiatives for both business and the environment are presented on the following tables 36, and 37.

Table 36: Clean Cargo, Green Freight reported benefits for business

Benefits for Business
• Increased Trust - By working to address environmental challenges, shippers and carriers build mutual trust and are more likely to gain the support of outside stakeholder groups. • Enhanced Brand Recognition - In a crowded marketplace, leadership companies attract both consumers and investors, many of whom are placing increasing emphasis on the environmental performance of companies. • Increased Efficiency - The multi-industry partnership enables solutions that increase efficiency and overall corporate performance, for shippers and carriers. • Competitive Advantage - By proactively managing the environmental impacts of product transportation and minimizing emissions, company's gain first-mover advantages while setting up systems to mitigate the financial impact of future regulations

Table 37: Clean Cargo, Green Freight reported environmental and societal benefits

Benefits for Community and the Environment
• Abating Global Warming - Participating in the global effort of abating greenhouse gases emissions.

- Healthier Cities - Reducing emissions eases the disproportionate toll transport operations and commercial vehicle emissions take on people living in urban neighbourhoods located near freight terminals or busy delivery zones.
- Improved Stakeholder Relations - Pro-active engagement for better environmental performances improves the position when negotiating with industry and non-industry stakeholders.
- Enhanced Labour Conditions - Improved health and safety conditions for workers on board and on shore.
- Root-Cause Improvements - Business-based solutions operate independent and in advance of national or international standards. Those that address the root causes of emissions, rather than simply off-setting them, help to spur innovation in the sectors where it is most needed.

6.4.2 Business Leaders Initiative on Climate Change

The Respect Business Leaders Initiative on Climate Change (BLICC) programme is based on an initiative taken by Respect Table companies in September 2000. The Respect Table network was created to stimulate climate change action in the business sector and collaborate jointly with the European Commission to take an active lead along these lines. The first discussions were held in Brussels in September 2000. Respect Table is a network of companies from Europe and the USA, and is initiated by Respect, a European-based consultancy group (BLICC 2004). The Respect BLICC highlights business commitment to act in order to reduce greenhouse gas emissions. Respect BLICC brings together key stakeholders – including local and national governments, business, employees, civil society organisations, and the European Union in order to; (1) generate dialogue between industry peers and stakeholders, (2) increase transparency through better emissions monitoring and reporting, and (3) share best practice in the areas related to customer activism, renewable energy and transportation (BLICC 2005). BLICC's commitment to reducing greenhouse gas emissions leads to new business opportunities, encourages full participation of a diversity of stakeholders, and drives an innovative business agenda (BLICC 2004). The following table 38 presents the main objectives of the BLICC initiative.

Table 38: BLICC initiative objectives

RESPECT BLICC PROGRAMME OBJECTIVES	
Monitoring & Reporting	Systematically monitor and report the impact our companies have on communities around the world, placing the interests of the customer at the heart of our business objectives. Respect BLICC uses the GHG Protocol, developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), as its reporting standard.
Target Setting	Challenge other companies, governments and decision-makers to participate in the efforts. Special emphasis is placed on Customer Activism (stimulating consumer knowledge and action), Emphasising on Energy Efficiency (promoting renewable energy alternatives) and Transportation (creating sustainable transportation solutions) as they relate to GHG emission reductions.
Tools for Change	Involve employees in the efforts to work for global sustainability. Work with suppliers to ensure that they comply with standards. Companies are actively engaged in both dialogue and action to enhance their in-company knowledge and skills.
Verification & Accountability	Bring together experts and advisors on climate change. Respect BLICC reports are available to all stakeholders, including the general public.
Communication	Communicate cutting edge results of climate change and social responsibility to opinion leaders, politicians, business communities and the public at large. Widespread communication is key to acceptance of the Respect BLICC approach, and supports the overall goals of accountability and transparency.

Compiled from (BLICC 2004; BLICC 2005)

Although The BLICC initiative focuses in particular on climate change and greenhouse gases emission reduction, it is interesting to note that it specifically addresses freight transport and that its consortium brings together major shippers such as IKEA and Stora Enso together with major carriers such as Maersk Sealand.

6.4.3 Responsible Care – Chemicals Industry

Responsible Care is the chemical industry's voluntary global initiative on environmental, health and safety best practices, under the umbrella of the International Council of Chemical Associations (ICCA). The national industry associations are responsible for the detailed implementation of the initiative in the different countries. Individual countries' Responsible Care programmes are at different stages of development and have different emphases but are monitored and coordinated by ICCA. Nowadays, the Responsible Care initiative is expanding its reach globally (47 countries on six continents, representing 85% of the world's chemical production) and tackling new issues, such as sustainable development and more recently security considerations surrounding the threat of terrorism. ICCA's future plans involve spreading the implementation of Responsible Care as broadly as possible within the chemical and allied industries, and up and down the supply chain. ICCA promotes Responsible Care's extension to partners in related industries who are encouraged to tailor the initiative to fit their own organisations (ICCA 2005).

The Responsible Care initiative is often referred to in industrial journals as an exemplary best practice case (Anon 2003). In his speech during the opening section of the third ECOPORTS conference, at Genoa, in December 2006, Professor Radermacher encouraged the port sector to focus on the experience of the chemical industry and specifically on Responsible Care as an example of best practice. The guiding principles of the Responsible Care initiative are summarised on the following table 39.

Table 39: Guiding principles of the Responsible Care initiative

Responsible Care guiding principles:
• To seek and incorporate public input regarding products and operations. • To provide chemicals that can be manufactured, transported, used and disposed safely. • To make health, safety, the environment and resource conservation critical considerations for all new and existing products and processes. • To provide information on health or environmental risks and pursue protective measures for employees, the public and other key stakeholders.

- To work with customers, carriers, suppliers, distributors and contractors to foster the safe use, transport and disposal of chemicals.
- To operate facilities in a manner that protects the environment and the health and safety of employees and the public.
- To support education and research on the health, safety and environmental effects of products and processes.
- To cooperate with other parties in order to resolve problems associated with past handling and disposal practices.
- To lead the development of responsible laws, regulations and standards that safeguard the community, workplace and environment.
- To practice Responsible Care by encouraging and assisting other parties to adhere to its principles and practices.

Analysis shows that transport is specifically pointed out as an area of interest of Responsible Care for the implementation of environmental, health, safety and security aimed good practices. The initiative embeds six main codes of management practice; (1) Community awareness and Emergency Response, (2) Distribution, (3) Process Safety, (4) Health & Safety, (5) Product Stewardship, and (6) Pollution Prevention (Chemical Industries Association 2005). Between those, of particular interest for the logistic chain are the Distribution and Product Stewardship management codes. The Distribution code focuses at reducing the risk of harm posed by chemical distribution to employees, communities and the environment. The Product Stewardship code ensures that health, safety and environmental protection are integral parts of designing, manufacturing, marketing, distributing, using, recycling and disposing of products.

In the United States, and following a review in 2002, the American Chemistry Council (ACC) significantly toughened the programme's requirements. All ACC member firms are nowadays required to have an independently audited and certified Responsible Care Management System (RCMS). Globally the programme remains voluntary but there are increasingly recommendations to follow the US example. The impact of the initiative has been significant. Thanks to Responsible Care, council members and partners are reported to be four and one-half times safer than all other manufacturing industries combined. They have reduced emissions by 58 percent from 1988 to 1997, while increasing production by 18 percent. Since 1996, Responsible

Care companies have experienced 8 percent fewer process safety incidents and 21 percent fewer incidents with off-site impacts. Since 1995, they have seen an 11 percent reduction in rail distribution incidents (American Chemistry Council 2005).

The RCMS is based on benchmarked best practices of leading private sector companies, initiatives developed through the Global Environmental Management Initiative, ISO and other bodies, and requirements of national regulatory authorities. The Responsible Care 14001 certification process combines ISO 14001 and Responsible Care and allows participating organisations to gain accredited certificates for both ISO 14001 Environmental Management Systems and Responsible Care 14001 Management Systems in a single audit. RC14001 was developed in cooperation with the Registrar Accreditation Board (RAB) and members of the auditing/registrar community.

The American Chemistry Council also developed the Partnership Program to extent the benefits of Responsible Care to companies outside the membership. The Partnership Program enables participating companies and associations to work more closely with others involved in the chemistry industry chain of commerce. Sharing safety, health and environmental concerns leads to safer workplaces, communities, transportation procedures and a cleaner environment (American Chemistry Council 2005). The Partnership Program is open to companies responsible for chemical transportation, distribution, storage, or treatment and disposal. The program currently represents industry segments including third party logistics providers, warehousing, distribution, oil production, emergency response, and treatment and disposal, as well as rail, barge and trucking. Partners are fully committed to implementing Responsible Care, following the exact same set of guidelines and obligations as American Chemistry Council members. This includes implementing the Responsible Care Management System, reporting on performance measures, and submitting to a third-party certification. The following table 40 summarises the benefits of the Responsible Care Partnership Program as those were expressed by partner companies.

Table 40: Benefits of the Partnership Program (Responsible Care)

• Networking with manufacturers on safety, health and environmental issues • Establishment of the right customer contacts to achieve common goals through common language • Improvements in efficiency and processes • Promoting collaboration on safety issues and encourages action • Access to Responsible Care resources, networks, materials and workshops • Improves dialogue with communities and other stakeholders

The American Chemistry Council worked jointly with the other appropriate industry associations to develop and revise carrier safety protocols. The protocols are intended to help member and Partner companies fulfil their Responsible Care commitment, and to provide companies with a mechanism to gather Environmental, Health and Safety information from companies. The following carrier protocols are available; Barge protocol, Rail protocol, Complete terminal protocol, Complete warehouse protocol, Container protocol, Distributors protocol, Customer-Supplier self-assessment, Motor carrier assessment protocol, Contract manufacturer self assessment. Those protocols are questionnaires addressing environmental performance areas such as General Company Information, Administration and Management assessment, Safety, Health and Environmental Protection, Operational Practices, and Risk Management and Assessment.

6.4.4 The significance of the selected initiatives

After presenting the three most relevant to the research scope collaborative industry initiatives that emerged from the survey, this section aims at discussing their significance for some of the main concepts in the thesis.

The consortia of the initiatives are bringing together representatives of the major influential parties in the logistic chain. Transport buyers and transport operators appear to work together in order, beside other initiative-specific objectives; to tackle logistic chain related environmental aspects. The BLICC initiative focuses at CO_2 emission reductions including those arising from transport related operations, the

Clean Cargo and Green Freight initiatives focus on several sea and land transport related environmental aspects (e.g. exhaust emissions, ballast water), and the Responsible Care initiative places the focus on transport and distribution while tackling safety, security and environmental aspects related to the chemical industry. It can be observed that the environmental aspects targeted by the examined initiatives are high in the environmental agenda and the whole debate of sustainable transport.

In all initiatives there is a strong focus on the communication between the transport buyers and the transport providers and operators. This can be derived from the various tools specifically designed for this purpose. For example, the Environmental Performance Survey developed by the Business for Social Responsibility (BSR) Clean Cargo working group, and the Carrier Safety Protocols developed under the Responsible Care initiative. The initiatives' consortia generally consist of manufacturers (shippers) from sensitive industrial sectors such as the chemical and the timber industry, which are in the public limelight with regard to their environmental performance. The transport operators that most often participate in such initiatives are dominantly ocean carriers and multimodal transport operators. It can be observed that large companies on which the lights of public's and governments' interest are concentrated appear to be more active in participating in voluntary environmental management initiatives. Thus, the theoretical model developed in section 6.2.3 (figure 49) and referring to the catalysts and mechanisms that could trigger the operation of greener logistic chain appears to be validated. The initiatives report benefits for both environmental performance and business efficiency. It can be said that at least up to a certain extent the environmental performance imperatives are not mutually exclusive with the economic ones.

6.5 Conclusions

This chapter discussed the role of the main industry players and operators of the logistic chain, namely shippers and transport operators, in relation to its environmental management, and their response as they face the challenge to operate a sustainable logistic chain. It established the principles for the operation of a "greener" logistic chain and how those are translated in terms of responsible operators' practices. On the practical level, a survey was set on the interest and practises of selected firms in order to reveal the good or best practice trends related to the proactive environmental management of freight transportation and the logistic chain. In addition, and apart from the single firms' good practices, the survey revealed, demonstrated and analysed some collaborative initiatives involving various players in the chain. The main conclusions of the chapter are summarised in the following paragraphs.

The review of the major players identified current trends in practices and interests. Good practice examples from both transport buyers and operators as derived from the outcomes of the survey, appear to be generally towards the desired direction as this was formulated while theorising greener logistic chains in section 6.2. The good practices are in line with both the theoretical principles and the generic regulative framework and transport policy orientations. Common practice is acknowledged to be suboptimal but it can be argued that good practice demonstrates trends towards future common practice. Whilst in many cases actions, solutions, and initiatives to improve environmental performance appear to be economically viable and efficient it can reasonably be expected that the number of companies that commit themselves to the proactive environmental management of transport related operations and the logistic chain would increase. Evidence can be provided that good practices can mutually benefit both business and the environment. For example, efforts and success stories are advertised and disseminated in a way so as to enhance the company's profile. A recent collaboration in the UK between the TESCO supermarket chain and haulage company Eddie Stobart Rail in order to move cargo previously transported by road to rail has been given positive publicity by the media based on the inspired "LESS CO_2" slogan as rephrasing "TESCO" (Johnston 2006).

With regard to the role of the different players and their potential to drive the operation of the logistic chain towards sustainability, the influential role of shippers was highlighted. The transport buyers, by practices such as, setting environmental performance criteria and standards for outsourced transport services, and by auditing and assessing carriers and transport providers on those, can indeed initiate the suggested by Preuss (2005) "green multiplier effect" in the logistic chain. The theoretical model developed in section 6.2.3 (figure 49) and referring to the catalysts and mechanisms that could trigger the operation of greener logistic chain appears to be validated. Voluntary self regulating appears to be the more efficient and promising framework for the operation of greener logistic chain. Regulation, in an environment as complex as the logistic chain, can only have a limited potential. On the other hand, the study of voluntary industry driven initiatives reveals that continual environmental improvement is achievable by industry self regulation. In that sense the role of public, environmental groups, trade associations and other stakeholders appear to be significant.

In the direction of the overall aim of the thesis to contribute towards the development of an environmental management framework for the logistic chain the above findings are of significance. The chapter provided insight on the driving forces for environmental improvement and the organisational models and structures that are or can be applied in different cases. The concluding chapter 9 of the thesis synthesizes and further builds on those while adapting the environmental management framework that was introduced in chapter 4 to the administrative and operational requirements of the logistic chain system.

7 Environmental management of seaport areas as major logistic nodes

This chapter focuses on the contribution of logistic nodes in the environmental management of the logistic chain. Seaport areas were selected for such a study as they may be considered the major and arguably most complex of the logistic nodes. Seaport operations impact on the environment and add to the sum-total environmental impact of the logistic chain. Port environmental management is therefore a core component of the environmental management of the logistic chain. The chapter takes mainly a European perspective and examines the progress of port environmental management over time. Specific studies are set in order to evaluate and demonstrate progress, factors that might be influencing port environmental management practices, and tools and methodologies that have been developed and applied in European seaports. Seaport environmental management progressed over the last decade from a "point focussed" approach to an integrated seaport area management concept. In line with this development, the chapter argues that there is potential for further integration as seaports proactively act as facilitators of procedures and of communication between the different parties involved in the logistic chain. In this context, a survey is set in order to investigate and demonstrate the degree that seaports are taking on with regard to the concept of "port - facilitator". Selected good practice examples from European seaports confirm the encouraging trends towards further chain integration.

It should be noticed that although the thesis aims to maintain a holistic perspective with regard to the environmental management of the logistic chain, the in depth analysis of selected components of the chain such as seaports (and environmental noise in chapter 8) enables the generic principles that were established in the previous chapters to be tested in detail in practice. The findings of the specific studies can then be projected back to the general picture (see chapter 9) allowing the drawing of conclusions for the whole chain and contributing towards the main aim of the thesis; the feasibility assessment and then the contribution towards the development of an environmental management framework for the logistic chain.

7.1 Significance of seaport areas

As seen in chapter 3, logistic nodes are the nodal points in the logistic chain were the functions of cargo handling, warehousing and modal transferring take place. Logistic nodes can be dry ports, seaports, inland ports, airports, shunting yards, warehouses, stores, production and manufacturing industrial sites. Considering the definition of the environmental impact of the logistic chain as the sum-total impact of all its embedded components and operations, it can be clearly derived that the environmental management of logistic nodes is a significant component of the environmental management of the logistic chain. In addition, the fact that the logistic nodes are important integrative links in the chain both in terms of operations, multi and intermodal interest, and players involved, add to their significance with regards to their contribution in the concept of holistic chain environmental management. For those reasons it is significant to examine the evolution of nodes' environmental management in order to demonstrate progress and assess the potential for further integration between the nodes and other components of the logistic chain.

Between the different logistic nodes the significance of seaports and seaport areas may be highlighted. Seaports are particularly important points of convergence in the transport network and important geographical areas with a distinctive service-based economy (Whitelegg 1988). They are characterised by a higher degree of complexity and variety of operations in comparison with other nodal links. Port areas are hazardous areas of intense intermodal consideration as all the transport modes coalesce there (figure 51). On its most complex form, the transport network of seaports connects sea routes, inland waterways, roads, railways and pipelines. Airports are situated in proximity or even inside seaport areas (e.g. Port of Genoa) and are closely linked to major ports. Additionally, in most cases port areas are situated next to urban areas and/or other areas of special environmental attention due to the presence of protected species or even due to recreational purposes. The factor of risk is also of increased significance in seaport areas. It may be suggested that the probability of occurrence and magnitude of consequence is exacerbated and indeed compounded in the port area because of the intensity of use, diversity of activities, inherently dangerous nature of certain cargoes and operations, and the natural dynamics of processes at the land-sea-atmosphere interface that constitutes the port system (Wooldridge 2004 b). The multiple types of cargo and related operations in combination with the specific characteristics of the port area fully justify the consideration of seaports as the major logistic nodes.

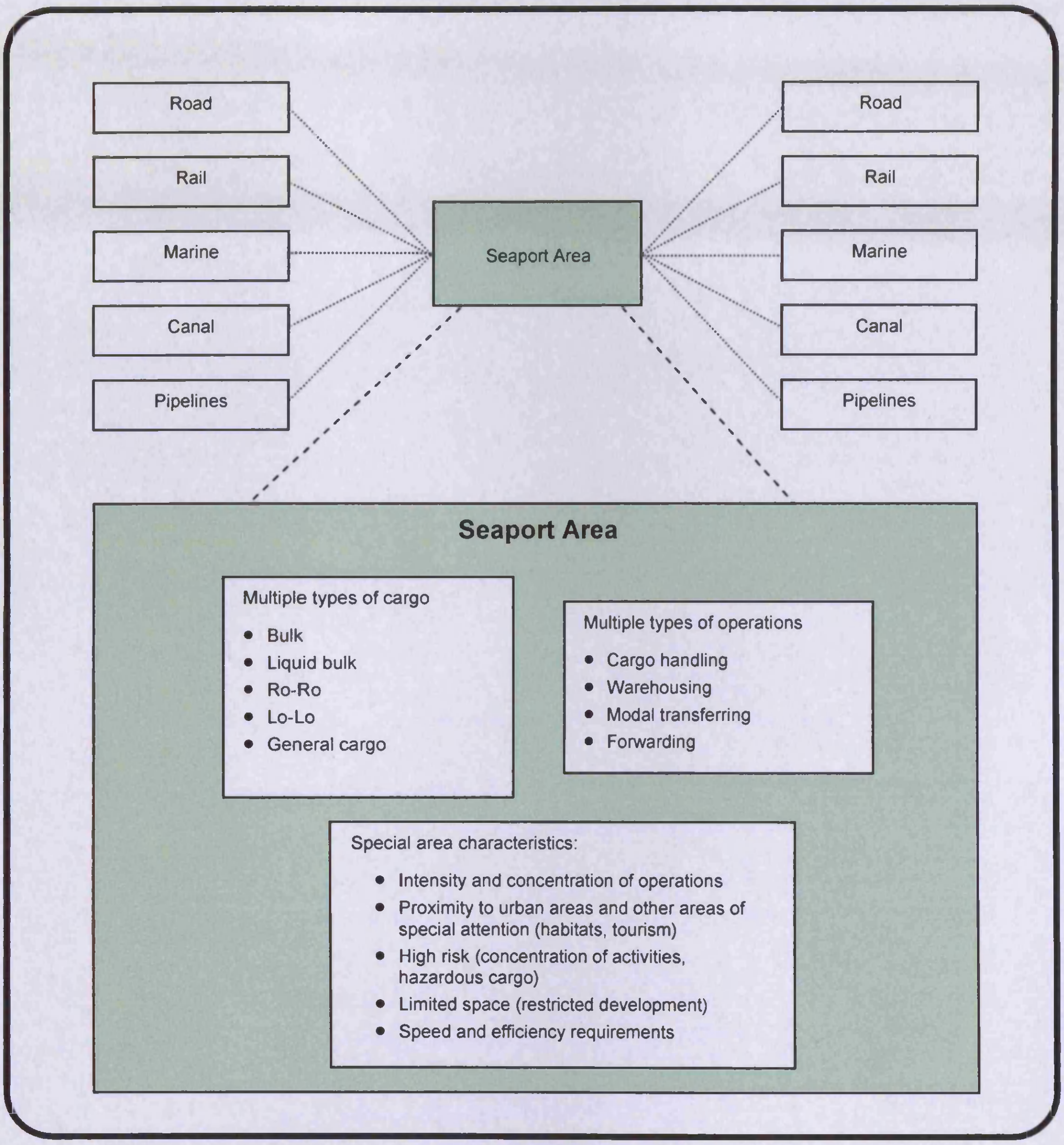


Figure 51: Seaport area characteristics

7.2 Seaport area characteristics

Seaports are complex and dynamic entities, where various activities are carried out by and for the account of different actors and organisations. Ports are very dissimilar in their assets, roles, functions and institutional organisation, and even within a single port the activities or services performed are broad in scope and nature. The same applies to port organisational structuring and ownership models whereby different institutions can be found within the same port setting. Such a multifaceted situation has led to a variety of operational, organisational and strategic management approaches to port systems (Bichou and Gray 2005). Table 41 summarises selected differences occurring between seaports.

Table 41: Differences between seaports

Port differences	
Organisational	Issues of ownership (public versus private) Institutional status (landlord/tool versus service) Social arrangements (labour and manpower)
Operational	Types of cargo handled, ships serviced, terminals operated
Physical and spatial	Location, access, connectivity, available capacity
Legal and regulatory	Trade and transport policy, administrative procedures, safety and security regulations, environment

Port functions can be as limited as simple berthing facilities, ship/shore or intermodal interfaces, or extended to trade, logistics and production centres. A port can range from a small quay for berthing a ship to a very large scale centre with many terminals and a cluster of industries and services. Operational and management features also vary with the type of cargo or ship operated and the extent of services offered. In a typical port setting, there is an extensive portfolio of operations extending across production, trade and service industries, which renders particularly difficult any attempt to consolidate port roles and functions under the same operational, business or market category (Bichou and Gray 2005). The Port of New York/New Jersey is a typical example in this respect. In addition to providing multimodal services through the management and ownership of airport, seaport, rail, bus terminals, bridges and tunnels, the port owned the former World Trade Centre, several industrial parks and a regional bank for urban and city development (The Port Authority of New York and New Jersey 2005).

Institutional dissimilarity is often encountered, as there are several ownership models applicable to world ports, even between those performing similar roles and functions.

A port can be a stevedoring company, a terminal operator, a public authority, a private company or just a cluster of different actors and operators. Port institutional models are widely diverse, including models of landlord, service or tool organisations, or variations and combinations of some or all of these. Apart from their role as the traditional sea/land interface, ports are a good location for value-added logistics but also for other related services including industrial, trade, financial, and even leisure and property development activities. Thus, the port system not only serves as an integral component of the transport system, but also is a major sub-system of the broader production, trade and logistics systems (Bichou and Gray 2005).

Seaports are key components of integrated transport and logistics systems. They pursue their commercial objectives and implement environmental programmes in highly dynamic and sensitive environments. Within European governance, the level of environmental legislation has been steadily increasing and is influencing the patterns of marine conservation and port development and operation (Stojanovic, Ormerod Smith et al. 2006). Nowadays, as much emphasis is often placed on environmental sustainability of port projects and development as on their economic and financial viability (Bichou and Gray 2005). Environmental management of port areas may be seen as one of the most critical tests of control of a system because of the nodal significance. The sea port node can represent the sum-total impact of the logistic chain because of the dense cluster and complex chain related activities-impacts.

7.3 Seaports' contribution to logistic chain management

Seaport areas are significant components of the logistic chain. In terms of environmental management, the analogy that can be naturally derived is that seaport area management is an equally significant component of logistic chain management. The primary contribution of ports to the environmental management of the logistic chain is therefore the constant and systematic management of all the environmental aspects that arise from the operations in seaport areas. It should be noticed that the concept of area management already implies a significant level of integration between stakeholders and operations in seaport areas.

Many port authorities are increasingly active in applying environmental management tools, methodologies and systems to their whole port areas and not just to the immediate vicinity of the waterfront or areas devoted solely to port-related activities. They have been driven by their liabilities and responsibilities as landlords in so far that in the interpretation of some environmental legislation port authorities may reasonably be expected to bring some influence to bear on the environmental performance of their tenants and operators. In identifying their significant environmental aspects, elements of the authority's activities, products or services that can interact with the environment (EN ISO 14001 1996), ports should take into account aspects for which they are legally liable, those of their tenants and operators over which they could bring some influence, and issues of national or local significance pertinent to the port area. Functional organisation of an environmental programme for the port area *ipso facto* implies influence or involvement with environmental facets of the logistic chain. Seaport area environmental management practices are demonstrated and analysed in section 7.4.

The dilemma for the port authority is that as in the case of identifying significant environmental aspects, it may not necessarily be directly, legally responsible for the activities, products and services of the components of the logistic chain, but its overarching administrative role, ownership of the estate (land and sea) and permanency of operational presence, means that the port is the obvious point of contact and readily identifiable player for any environment related issues in the whole port area. The emerging role of port authorities with regard to the environmental management of the logistic chain is therefore that of facilitator.

The concept of ports as facilitators refers to the contribution that ports can make in helping the whole port community (including partners in the logistic chain) to deliver compliance with legislation, prevention of pollution, reduction and mitigation of environmental impacts, sustainable development and evidence of satisfactory performance. Positive steps are being made to achieve these objectives by the development and implementation of appropriate procedures for the exchange of information and cooperation between the different players in the logistic chain, collaboration on research and development of practicable tools and methodologies, and the identification of best practice solutions to common challenges. This approach by the port authority includes providing the necessary communication platforms and coordinating the exchange of safety, health and environmental information between the different port commercial visitors, and the port and other authorities. It also entails working with other parties in tackling the informational, technical and procedural bottlenecks restricting the efficient operation of intermodal transport chains. The concept of ports as facilitators is researched upon and analytically discussed in section 7.5.

7.4 Environmental management of seaport areas

The port sector can contribute to the environmental management of the logistic chain primarily by managing the diverse environmental impacts arising from the port operations. Environmental management of ports and port areas concerns the functional organisation of activities and operations specifically designed to attain high standards of environmental protection and the goal of sustainable development (Wooldridge and Stojanovic 2004). Effective environmental management requires science-based evidence on which to make decisions, the identification of the significant environmental aspects, the monitoring of environmental performance by selected indicators and the commitment towards continuous environmental improvement by setting up and reaching specific objectives and targets on given timescales. This section researches and discusses the evolution, current practice and trends in the field of seaport area environmental management. A European perspective is taken mainly but the links with worldwide practice are made where necessary.

The areas of interest, structure, and approach are schematically presented on the following figure 52.

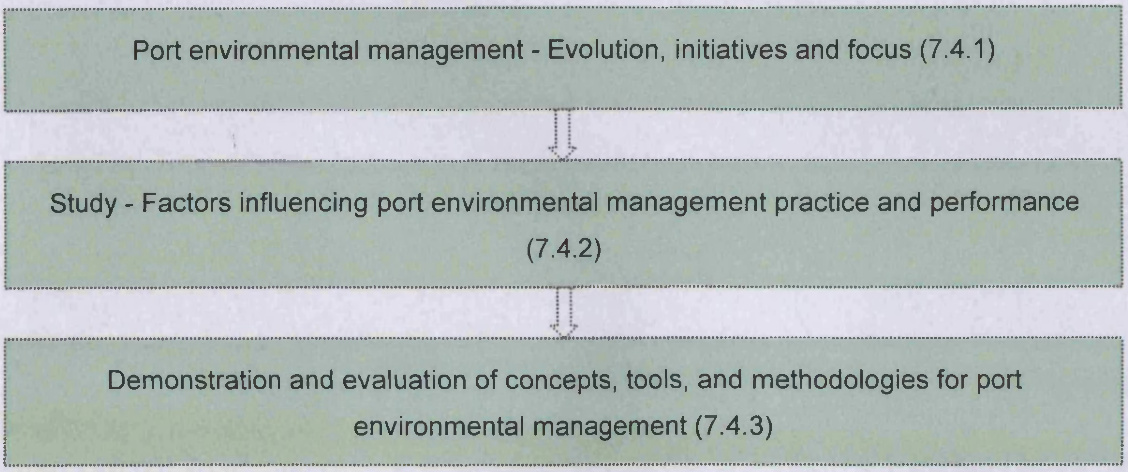


Figure 52: Research areas in the field of port environmental management

The section embeds three main areas of interest; (1) evolution, initiatives, and focus, (2) factors influencing port environmental management, and (3) demonstration and evaluation of tools and methodologies. The research of those follows a multi-method approach.

7.4.1 Evolution, initiatives and focus

The concept of port environmental management has been increasingly developing in Europe during the last 15 years. The progress was driven by mutual collaboration between the port sector, research institutions, and specialist organisations. The framework for this mutual collaboration was developed through joint activities instigated and funded by Primary Port Partners and part-funded by EC Research and Development Programmes such as Eco-Information (1997-2000) and ECOPORTS (2002-2005). The cooperation between port professionals, academic researchers and specialist organisations has proved to be a potent mix in terms of delivering a functional framework of cost-effective solutions developed to implement policies and produce continuous improvement of the port environment (Journée and Wooldridge 2005).

The port sector's policy towards its environmental liabilities is that of voluntary, self-regulation (Stojanovic, Ormerod Smith et al. 2006). Port-inspired voluntary initiatives aimed specifically at protection of the environment through appropriate policy and implementation of best practices can be demonstrated by reference to such benchmark events and activities as presented in the following table 42.

Table 42: Benchmark events in relation to port environmental management

Benchmark events	Year	Description
ECEPA (Environmental Challenges for European Port Authorities) project	1993	Collaborative research into selected environmental issues between ports from different EU member states
ESPO Environmental Code of Practice	1994	Recommendations on environmental policy and objectives.
Eco-Information project	1997 - 2000	An EC programme co-sponsored by ports to develop tools and methodologies for environmental management
ESPO Review	2001	Further recommendations on environmental management
EcoPorts project and formation of the EcoPorts Foundation (EPF)	2002-2005	Developing tools and methodologies for port area environmental management
ESPO Environmental Code of Practice	2003	Containing statements and recommendations on policy and objectives, and an overview of legislation and recommended practices (ESPO 2003)

Compiled after (Wooldridge 2004 b; Journée and Wooldridge 2005)

The benchmark events and initiatives presented on the table guided the evolution of environmental management in European seaports by creating networks for collaboration and exchange of experience and by developing assisting tools and methodologies. The European Seaports Organisation (ESPO) is the representative body that sets the sector's voluntary standards in the field of environmental management. The ECOPORTS project developed tools and methodologies for seaport area environmental management that are adopted and recognised by ESPO as the sector's voluntary standards. The ECOPORTS foundation (EPF) is the organisation entitled to manage and disseminate those tools and methodologies, and to ensure the continuity of research and development initiatives in the field.

The track record of port environmental management initiatives during the last fifteen years guided the progress with regard to the sector's environmental performance.

Evidence of progress can be provided by examining the outcomes of repeated surveys undertaken by ESPO and EPF. The following table demonstrates the progress made by members of ESPO during the period 1996-2006 in implementing key components of an environmental management programme.

Table 43: Progress in implementation of key environmental management activities by ESPO members based on EPF/ESPO Surveys

Environmental management component	1996	1999	2004	2006	% [25] (+ or -)
Environmental Plan?	45	52	62	82	+37
Plan aims for "Compliance-Plus"?	32	41	48	72	+40
Does Plan aim to raise Environmental awareness?	44	62	69	68	+24
Is Environmental Monitoring carried out?	53	60	65	72	+19
Does Plan involve Community & Stakeholders?	53	60	39	78	+25
Is ESPO Code available?	41	48	53	53	+12
Designated Personnel?	55	65	67	88	+33

Source: (Wooldridge 2006; Journée and Wooldridge 2007)

It can be observed that evidence of progress is demonstrated for all the selected environmental management components. Due to the differences on the identities (e.g. number of respondents) of the undertaken surveys, it should be noticed that the trends are more significant than the actual percentages. Those trends though clearly

[25] Given the vagaries of questionnaire survey returns in terms of the extent to which respondents are truly representative of the sector, it may be suggested that the trends are more relevant than the absolute percentage values. In this case, the sector can demonstrate 'continual improvement' which in itself is a positive attribute of an environmental management system. EN ISO 14001 (1996) defines such progress as the process of enhancing the environmental management system to achieve improvement in overall environmental performance in line with the organization's (ports sector) environmental policy. It notes that the process need not take place in all areas of activity simultaneously.

demonstrate continuous and considerable progress. Between the examined environmental management components, it should be noticed that the involvement of the local community and other stakeholders is particularly apposite in the context of the logistic chain.

It is interesting to focus in particular on the results of the European Sea Port Organisation (ESPO) Environmental Survey 2004 carried out by ESPO in collaboration with the ECOPORTS Foundation and with the assistance of Cardiff University, in order to demonstrate some selected environmental performance indicators. The survey identified the issues which are at stake for EU ports in the field of environment and demonstrated the sector's performance in terms of environmental management. It up-dated the results of a similar exercise, which was carried out in 1996, and therefore assessed whether progress has been achieved over those 8 years.

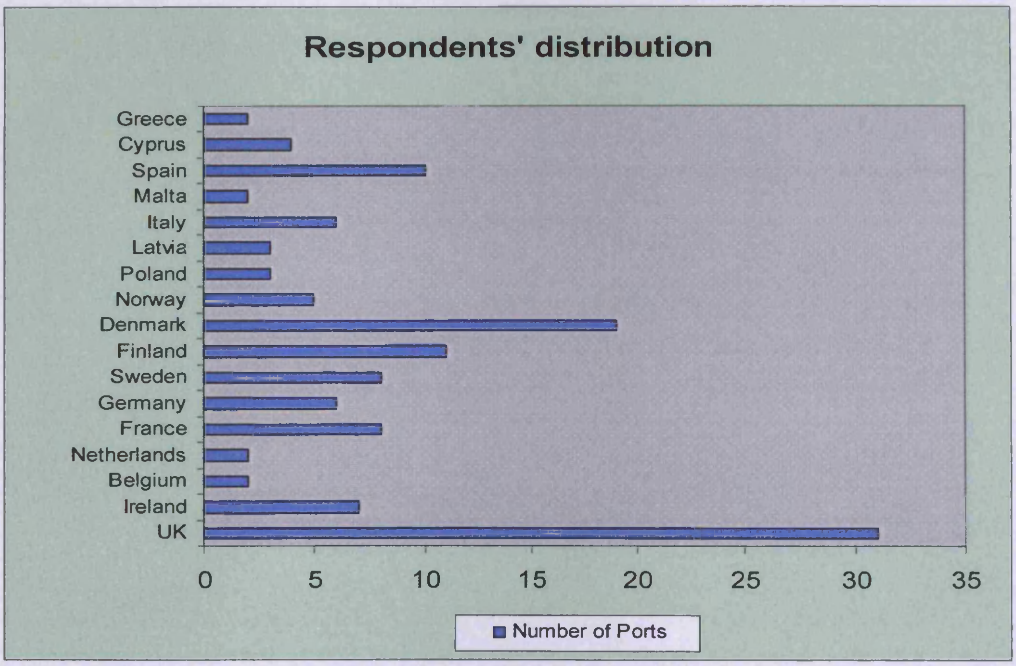


Figure 53: The ESPO survey respondents' distribution

The Survey established a port sector's European benchmark of environmental performance, against which individual ports will also be able to evaluate their own environmental management in relation to some fundamental questions. 129 ports from 17 European countries participated in this survey (figure 53). The response rate and the diversity in ports' typology allowed drawing a representative overview of the EU port sector (ESPO 2005). Some of the selected performance indicators for European ports as occurred from the analysis of the survey results are presented in the following table 44.

Table 44: Selected performance indicators (EU ports) from the ESPO environmental survey 2004

Environmental policy/plan:

- 84 % of ports have an environmental policy or are developing one
- 59% make it available to the public
- 48% aim that their plans improve environmental standards BEYOND those required under legislation
- 69% promote, through their plans, environmental awareness among port users

Personnel:

- 67% of ports have designated environmental personnel
- 21% have an environmental manager – otherwise, the main operational responsibility generally lays with the port manager (30%) and arbour master (27%)
- 58.1% ensure that their personnel attend environmental management training courses

Environmental management:

- 65% carry out monitoring within the port area
- 48% have identified environmental indicators
- 65% carry out environmental impact assessments in connection with development projects

Source: (ESPO 2005)

The results of the survey indicate steady progress with regard to port environmental management. ESPO notes that further progress is expected as ports increasingly implement the recently developed tools and methodologies for port environmental management (ESPO 2005); in particular the Self-Diagnosis Method (SDM) and the Port Environmental Review System (PERS) developed by the ECOPORTS project. SDM is an environmental self-audit which can be used to periodically review performance, either against the port's own baseline or in relation to European benchmarks. PERS is the first basic environmental management system developed specifically for ports. It enables further phased development towards more sophisticated management systems such as ISO 14001, and EMAS.

Frequently, some environmental issues are considered to be more important than others by the port authorities. A ranking of the major environmental issues in seaports (on a statistical basis) has been established from the results obtained from the ESPO Environmental Questionnaire 1996 (ECO-Information 1999) and from the analogous ESPO Environmental Survey 2004, performed in the framework of the ECOPORTS project (Darbra, Ronza et al. 2004). The ranking of the most significant environmental aspects in European seaports as reported by the port managers and their differentiation over time (1996-2004) is presented on the following table 45.

Table 45: Environmental priorities in European Seaports (port managers' view)

	1996		2004
1	Port Development (water)	1	Garbage / Port waste
2	Water quality	2	Dredging
3	Dredging disposal	3	Dredging disposal
4	Dredging	4	Dust
5	Dust	5	Noise
6	Port Development (land)	6	Air quality
7	Contaminated land	7	Hazardous cargo
8	Habitat loss / degradation	8	Bunkering
9	Traffic volume	9	Port development (land)
10	Industrial effluent	10	Ship discharge (bilge)

Source: (ESPO 2005)

The table demonstrates significant changes in port environmental priorities from 1996 to 2004. Many of these reflect prevailing political drivers. For example the implementation of EU Directives, such as the one on Waste Reception Facilities in ports or the Habitats Directive, have an impact on dredging, dredging disposal and port development. New air and noise regulations are also imposing further constraints on port activities. There are also consistently highly prioritised environmental issues (e.g. dredging, dust, port development) for a large majority of European ports, which demonstrate common focus and form a basis for environmental collaboration within the port sector.

7.4.2 Factors influencing seaport area management performance

After discussing the evolution, progress and focus of port environmental management, this section seeks to examine factors that might be influencing seaports' environmental management practice and performance. As discussed, seaports are often dissimilar in several aspects (physical, operational, and organisational) and therefore it is considered significant to examine whether port environmental management practices relate to port differences. The selected factors (Michail 2005a) for such an examination were (1) the port size (amount of cargo handled yearly), (2) the port specific location (e.g. engineered coastline, estuary) and (3) the broader port geographic position within Europe (e.g. North, West, South Europe).

In order to assess the influential degree of those factors in relation to port environmental management practices, a statistical meta-analysis study (Michail 2005a) of the ESPO Environmental Survey data and results was set. The ESPO Environmental Survey was selected as its sample (129 respondent ports from 17 countries) exceeds in quantitative terms the 10% of the total number of seaports in Europe (over 1200 (ESPO 2007)) and allows the further statistical analysis of the factors that might influence port environmental management practices and performance. As seen in the previous section, the ESPO Environmental Survey carried out, in the course of 2004, in collaboration with the ECOPORTS Foundation and with the assistance of Cardiff University. The survey demonstrated the European port sector's progress in terms of environmental management and performance (ESPO 2005).

The methodology followed in the study is schematically presented on figure 54 (Michail 2005a). The overall aim was to assess the influence of different factors in port environmental management practices and to examine whether certain port differences depict in environmental management practices in a systematic way. To do so, access to the databases of analytical responses and results of the ESPO survey was granted[26]. This data was used by the researcher as a starting point for the statistical meta-analysis. The preparation phase consisted also of selecting the questions of the survey that were relevant to the aim of the study, and of deciding on the factors that port environmental management practices would be further examined (Michail 2005a).

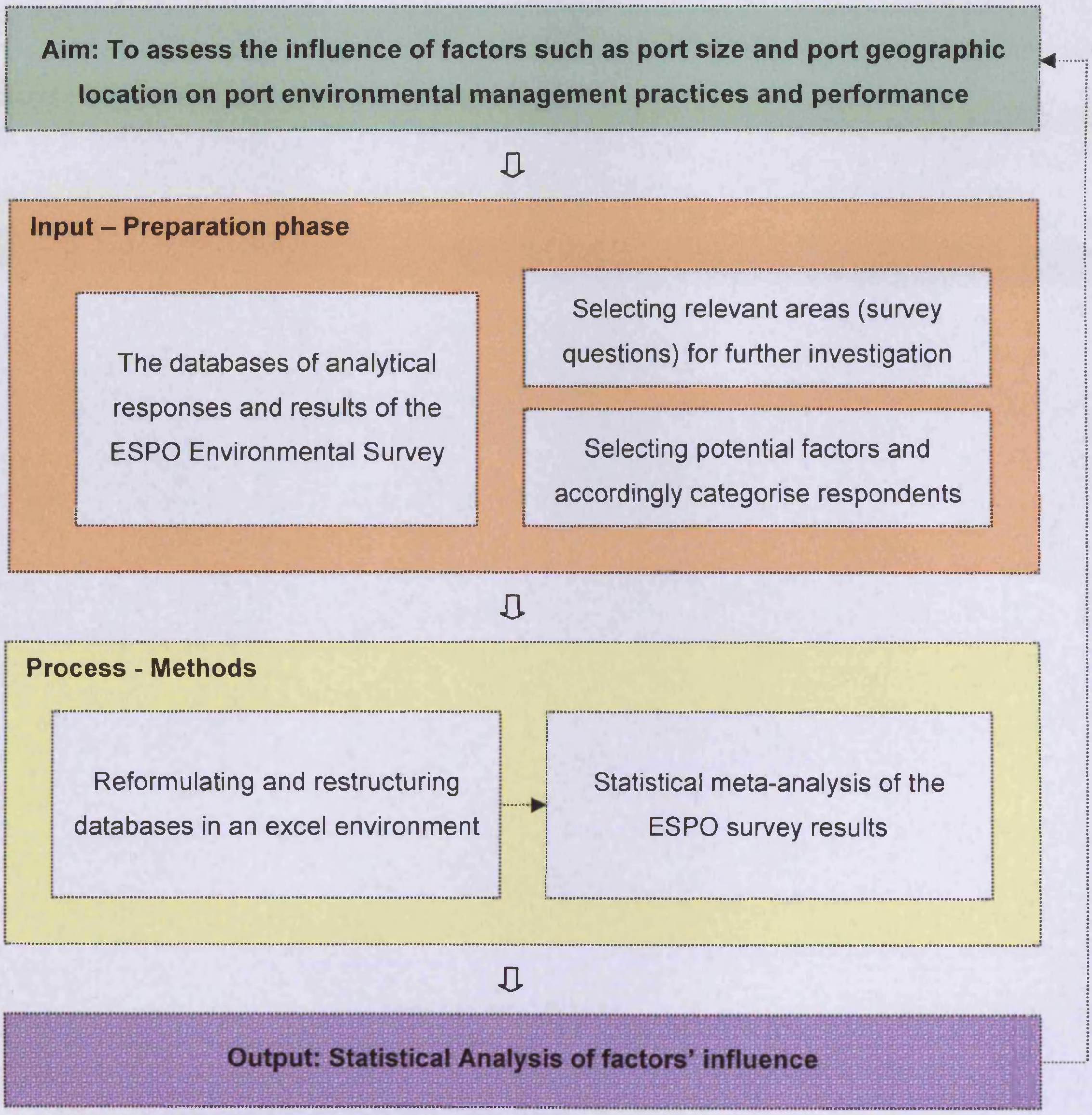


Figure 54: Methodological framework for the analysis on factors influencing port environmental management and performance

[26] Cardiff University actively participated in the data collection and analysis of the outcomes of the ESPO Environmental Survey and therefore this information was available within the Marine and Coastal Environment (MACE) research group at Cardiff.

In the process phase of the study, the available information (survey data) was restructured and new databases were formulated in an excel environment in line with the aims of the study (Michail 2005a). This allowed the statistical meta-analysis of the survey results as it is analytically explained below. Outcome of the study is an analysis of the degree of influence of the 3 selected factors in the environmental management practices of European seaports. The different steps, phases of the study are discussed on the following paragraphs.

First step was the screening of the ESPO survey questionnaire in order to identify the significant questions for further analysis. The ESPO survey questionnaire consists of 35 questions divided in four parts addressing port description, port environmental issues, policy and programmes, and port planning and development (ESPO & EPF 2004). Not all the questions of the survey were considered relevant for the purpose of the statistical meta-analysis. The focus was placed on those questions that specifically address elements and components of environmental management. The following table 46 presents the selected 14 questions that the meta-analysis is focused upon (Michail 2005a). The results (%) of the respondent ports (129) for each question are also provided.

Table 46: Selected survey questions for further statistical analysis

	Selected ESPO Survey questions for further analysis	**Results (%) 129 ports**		
		Y	**N**	**N/A**[27]
1	Does your port have its own environmental policy (or developing one)?	84	12	4
2	Is the policy made available to the public?	59	33	8
3	Does the port carry out an annual Review of its Environmental Programme?	41	53	6
4	Does the port publish an annual Environmental Review or Report?	31	63	6
5	Do your port personnel attend environmental management training courses?	58	37	5
6	Does your port have designated Personnel responsible for co-ordinating environmental policy?	67	26	7

[27] Not answered

7	Does your port have an Environmental Management System (EMS)?	21	79	
8	Has your port identified environmental indicators to measure progress in environmental management?	48	47	5
9	Does your port's Environmental Policy aim to improve environmental standards BEYOND those required under legislation?	49	41	10
10	Does your policy involve the promotion of environmental awareness by all port users?	69	24	7
11	Is there a defined procedure for involving all port users in the development of your environmental programme?	34	59	7
12	Is there a defined procedure for consulting with the local community on its environmental programme?	36	58	6
13	Has you port undergone an environmental impact assessment in connection with new development during the last 5 years?	64	32	4
14	Is your port involved with other organisations in a coastal or estuary management plan?	55	40	5

The second phase of the study included determining the potential influential factors, and grouping respectively the respondent ports. Three were the factors that were selected as potentially having an influence over port environmental management practice and performance (Michail 2005a); (1) the size of the port, (2) its location, and (3) its specific geographical position in Europe. For the needs of the research on the degree of influence of each factor the ports were categorised accordingly. As the criterion for the classification of ports according to their size the total tonnage of cargo handled yearly was selected. According to their annual tonnage the respondent ports were divided in three categories; small, medium and large as seen on the following table 47.

Table 47: Classification of respondent ports according to their annual tonnage

Division according to the size	Annual Tonnage (million tonnes)	Number of ports	Percentage of ports (% number/129)
"Small"	<5	65	50.4%
"Medium"	5<20	24	18.6%
"Large"	>20	34	26.4%
Unclassified	Did not answer	6	4.7 %

(Michail 2005a)

The data on port annual tonnage was already available from the ESPO survey responses. One of the survey questions was addressing the annual tonnage of the respondent port following the same tonnage division classes as in table 47.

Ports are located in different physical areas that can be generally grouped under estuary, river, marine inlet, embayment, protected coast, and engineered coastline. It was felt that the location (physical surroundings) of the port might have an influence to environmental management practices. In order to further investigate this, the respondent ports were classified according to their physical surroundings. The classification was again assisted by the already available responses of the ESPO survey. Ports were asked to select their physical surroundings from the options presented in figure 55 (ESPO & EPF 2004).

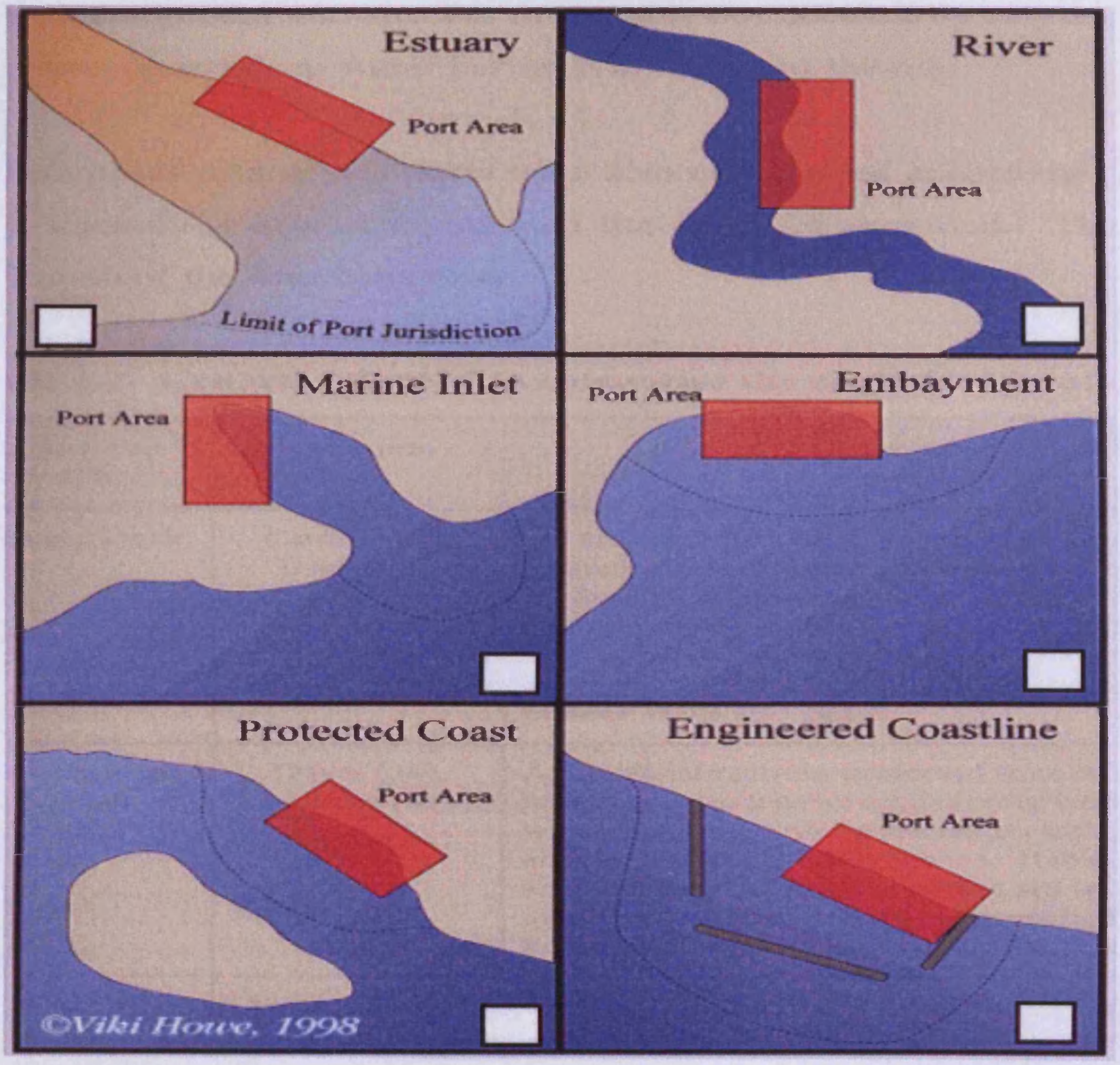


Figure 55: Classification of ports according to their location

Table 48 presents the emerged classification of ports according to their physical surroundings and its quantitative characteristics.

Table 48: Classification of respondent ports according to their location

Division according to the location	Port Location	Number of ports	Percentage of ports (% number/129)
1	Estuary	40	31 %
2	River	10	7.8 %
3	Marine Inlet	19	14.7 %
4	Embayment	10	7.8 %
5	Protected Coast	13	10.1 %
6	Engineered coastline	27	20.9 %
Unclassified	Not answered	10	7.8%

(Michail 2005a)

The third potential influential factor that was selected was the geographic position of the ports inside the European continent. It was considered significant to examine whether cultural differences depict in European port environmental management practices. The sample of respondent ports was then further divided in three geographic categories; North Atlantic and North Sea, Baltic Sea and Scandinavian, and South Europe seaports. Table 49 presents the classification and its quantitative characteristics.

Table 49: Classification of respondent ports according to their geographic position in Europe

Division according to the geographic position in Europe	Port Geographic position in Europe	Number of ports	Percentage of ports (% number/129)
A	North Atlantic / North Sea	54	41.9
B	Baltic Sea / Scandinavian	50	38.8
C	South Europe	25	19.4

(Michail 2005a)

Figure 56 (Michail 2005a) graphically demonstrates the three selected geographical divisions of the respondent ports. It should be noticed that the geographical subdivisions were selected in such way so that they both reflect potential cultural differences in different parts of Europe and form sufficiently populated groups.

Figure 56: Classification of ports according to their European geography

After selecting the relevant ESPO Survey questions, deciding on the factors to be examined, and dividing accordingly the sample of respondent seaports, the actual results and analysis phase initiated. This included the calculation of group results and their systematic comparative analysis with the overall ones as it is explained in the following paragraphs.

The results for the different identified groups of ports have been first calculated in order to reveal the percentage of positive and negative answers by each group to the selected questions (Michail 2005a). The calculations took place on an excel environment where the appropriate databases of information were previously created, structured, and stored. For example, the percentage of medium-sized ports that positively replied to the question 1 – does your port have its own environmental policy (or developing one)? – was calculated and found to be 92%. This figure could then be compared with the relevant already available figure of overall positive responses (84%) that was presented in table 46. The systematic comparison between the relevant group and overall figures indicated trends and enabled the assessment of the degree of influence of the three different identified factors to port environmental management performance. This systematic comparison was enabled by the study of the analytical results in the structured form of the following matrix (table 50).

The "Question ID" column refers to the selected 14 questions from the ESPO survey questionnaire as those were presented in table 46. The "All ports' results" column provides the results with regard to the positive and negative (%) responses by the whole sample of ports (129 ports). The non-answered cases are not presented on the matrix for reasons of simplicity and because they do not influence the comparative analysis. This is the reason why the sum of the positive and negative answers does not always add up to the 100%. The "Factor 1 – Size" column presents the calculated group positive and negative (%) responses for the three size-defined groups; small, medium, and large ports. For example, in question 2 - Is the policy made available to the public? -, the 59% of large ports replied positively. The "Factor 2 – Location" column presents the calculated group positive and negative (%) responses for the six location based groups as those were set in table 48. For example, in question 3 - Does the port carry out an annual Review of its Environmental Programme? -, the 50% of ports located on or near an estuary (location 1 on the matrix) responded positively. The "Factor 3 – Geography" column presents the calculated group positive and negative (%) responses for the three geography-based defined groups as those were set in table 49. For example, in question 4 - Does the port publish an annual Environmental Review or Report? -, the 68% of South European ports (geography C on the matrix) gave a negative response. The "Average" row sums up the results of all the positive and negative responses given in the total of the questions. For example the 51% of "all ports' responses" in the total of the 14 questions were positive and the 43% negative. The relevant "Average" figure for medium sized ports only, was 61% and 38% respectively.

Table 50: Matrix of analytical results

Question ID	All port results		Factor 1 - Size						Factor 2 – Location												Factor 3 - Geography					
			Small		Medium		Large		1		2		3		4		5		6		A		B		C	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
1	84	12	84	12	92	8	84	15	85	15	80	20	95	5	70	10	100	0	81	19	87	9	86	8	72	24
2	59	33	58	38	67	33	59	29	58	43	50	50	68	26	40	40	77	23	63	30	59	33	66	28	44	44
3	41	53	34	62	58	42	50	47	50	48	20	80	42	58	30	50	62	38	41	56	43	54	46	46	28	64
4	31	63	26	70	46	54	35	62	33	65	10	90	42	58	40	40	54	46	22	74	31	63	34	60	24	68
5	58	37	49	48	75	25	74	26	68	32	40	60	47	53	60	20	77	23	48	52	54	43	66	28	52	44
6	67	26	63	32	79	17	76	21	73	25	80	20	58	42	60	20	85	15	59	33	65	28	68	26	72	20
7	21	79	17	83	33	67	26	74	25	75	30	70	26	74	0	80	38	62	7	93	11	85	30	64	20	76
8	48	47	40	57	63	37	62	38	58	42	50	50	42	58	30	50	62	38	41	59	44	52	48	46	56	40
9	49	41	43	46	58	42	59	35	55	40	60	40	32	53	60	20	54	46	37	56	61	33	44	46	32	48
10	69	24	68	26	79	21	71	26	70	28	80	20	74	26	80	0	62	38	63	30	76	20	70	22	52	36
11	34	59	32	63	38	58	38	59	23	73	50	50	53	47	30	50	23	77	37	59	35	59	36	56	28	64
12	36	58	43	55	33	63	29	68	20	78	50	50	37	63	50	40	77	23	30	67	26	70	58	36	16	76
13	64	32	57	42	83	17	76	24	73	27	60	40	63	37	80	10	62	38	63	37	67	31	60	34	68	28
14	55	40	57	40	50	50	59	41	70	28	60	40	53	47	50	40	69	31	37	63	69	30	44	48	48	48
Average	51	43	48	48	61	38	57	40	54	44	51	49	52	46	49	34	64	36	45	52	52	44	54	39	44	49

(Michail 2005a)

The colour coding applied in certain matrix areas assisted in the comparative analysis of the results and the overall concluding remarks. The light yellow colour is applied to highlight the results for the initial sample of the 129 ports and the dark yellow colour the averaged values of those. The green and red colours highlight positive and negative trends respectively. The light green is applied in cases that a significant positive variation is observed between the value where the colour is applied and the relevant overall "light yellow" value. As significant it is considered a value that positively differs by at least 10 units in percent scale. For example, in question 5 - Do your port personnel attend environmental management training courses? -, the 75% of medium-sized ports that positively replied varies significantly from the overall figure of 58% (75-58=17≥10) in a positive direction and is therefore coloured light green. The light red is applied in cases that significant negative variations are observed. The threshold of 10 or more percentage units is the applied criterion to assess the significance of the variation. For example, in question 12 - Is there a defined procedure for consulting with the local community on its environmental programme? -, the 76% of South European ports (geography C on the matrix) that gave a negative answer differs significantly from the relevant 58% for the whole sample of respondent ports (76-58=18≥10) in an undesired direction. The value 76% is therefore coloured light red. The darker green and red colours are applied to the "Average" row and follow the same logic but with regard to the averaged values. Due to that, a less demanding threshold was set in the process of screening for significant positive or negative variations. The significant variation threshold set for the average values was set to be at least 5 units in the percentage scale. For example, the medium-sized ports replied positively to the total of questions at a rate 61%. The relative figure for all ports was 51% (dark yellow colour coded). Due to the observed significant positive variation (61-51=10≥5) the 61% value was dark green coloured.

From the study of the matrix the degree of influence of each of the selected three factors (size, location, and geography) to port environmental management practices and performance has been assessed. It should be noticed that all the questions that were examined were given equal significance in the assessment. The exercise did not apply different weights for the different questions since it was felt that they all address components of port environmental management of equal importance. The conclusions with regard to the way that the port size, location, and geography influence the port environmental management practice and performance are presented and explained on the following table 51.

Table 51: Conclusions on the influence of the selected factors

Factors	Influence assessment and analysis
Port Size	With regard to the environmental management of ports of different sizes, classified as small, medium and large according to their total annual tonnage of goods handled, the following observations can be made: Small ports tend to pay less attention in elements of their environmental management in comparison to medium and large ports. This remark could be explained due to the fact that as a general rule the environmental considerations increase up to a certain extend with the size of the port and the increased variety of port operations and related environmental considerations. The analysis of the results though, does not conclude in general that environmental management is improving with the port size. The "medium" sized ports of the sample appear to perform in general better than the "large" ones in terms of environmental management.
Port Location	The picture is more complex while examining the performance of environmental management of ports in locations with different natural characteristics. This is primarily due to the fact that certain sub-divided groups are insufficiently populated. For instance the numbers of respondent ports that are located next to rivers, embayment, and protected coasts are only 10, 10, and 13 respectively. Those samples are generally not sufficient for statistical analysis. Nevertheless some general trends can be derived on the degree of influence of port location to port environmental management performance. The analysis of the results demonstrates that ports located in protected coasts (location 5) and embayment (location 4) tend to perform better in terms of environmental management than ports located in engineered coastlines (location 6) and rivers (location 2).
Port Geography	Concerning the environmental management of ports in different geographic locations within Europe the following can be observed: Ports located in South Europe appear to under-perform in comparison with ports in West and North Europe. This could be reflecting the cultural and legislative differences between South and North Europe. Ports situated in West and North Europe do not present significant variations with regard to the examined environmental management performance indicators.

(Michail 2005a)

7.4.3 Evaluation of tools and methodologies

After researching and establishing the factors that have an influence over port environmental management practice and performance, this section aims to demonstrate and evaluate the existing tools and methodologies that were developed by port inspired initiatives during the last decade. The dominant concept that guides the efforts of the European port sector towards environmental management is that of ports sharing experience and good environmental practices on a voluntary self-regulation basis. The evaluation of tools and methodologies takes place via examining their contribution in this context. A conceptual model is developed that presents a phased approach to the process of sharing experience and implementing good practices. Tools and methodologies that have been developed under the umbrella of port-inspired research and development projects and initiatives are examined on whether and how they contribute to the phased conceptual framework. In such way the practicability of those tools and methods is highlighted, and the overall consistency between the port sector's rhetoric, the developed products, and the actual evidence based progress is evaluated.

The main element of the port sector's environmental policy is the creation of a level playing field with regard to port environmental management practices, by keeping the environment out of inter-port competition. Central pillar of such an approach is the sharing of environmental experience between ports, and the common implementation of best practices. ECOPORTS, one of the port sector's benchmark initiatives, is deliberately focussed on practicable and robust solutions for use by port professional managers. Several existing tools and methodologies assisting port environmental management have been developed by port-inspired initiatives, in line with the broad sector's environmental policy principles. In order to demonstrate the application and evaluate the contribution of those products, the methodology presented in figure 57 was selected and followed.

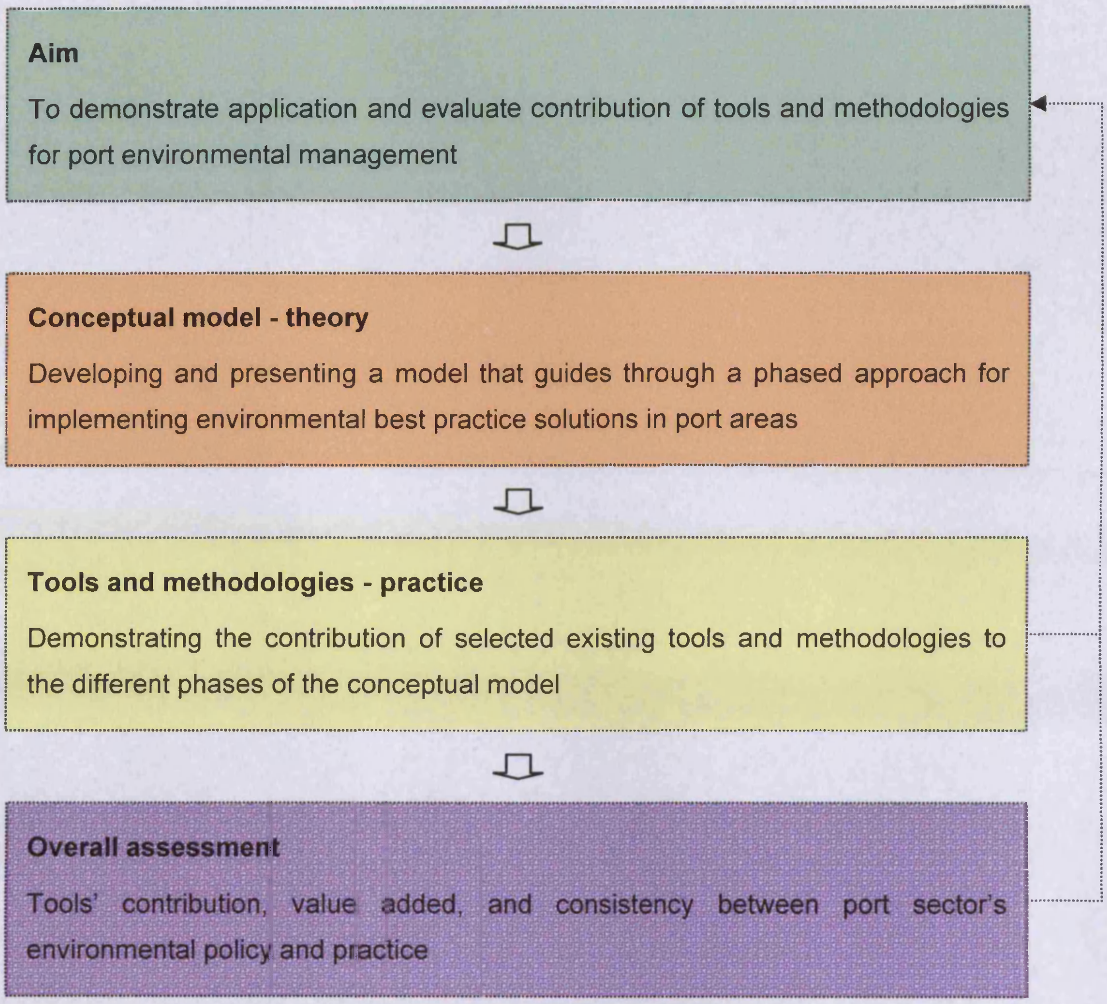


Figure 57: Approach to demonstrating and evaluating port environmental management tools

The aim is to demonstrate and evaluate the contribution of existing tools and methodologies in the field of port environmental management. Inspired from the port sector's environmental policy, a model is developed that presents a phased approach guiding the process of ports sharing experience and implementing best practice environmental solutions. Then, existing tools and methodologies are demonstrated and examined on their potential to assist in the process. It should be noticed that the conceptual model addresses central elements of the sector's environmental approach while the tools and methods indicate trends in actual sector's practice. Thus, the hypothesis is that if the tools fit well in the process described by the model, then there is consistency between policy statements and practice.

With respect to the described methodology the section is divided in three parts. Section 7.4.3.1 presents and explains the conceptual model. Section 7.4.3.2 demonstrates application and examines the contribution of tools and methodologies to the different identified steps. Section 7.4.3.3 evaluates the contribution of tools and examines the level of consistency between the port sector's policy and practice.

7.4.3.1 Generic conceptual model

The model consists of a non stop five-step circular methodology aiming towards continuous environmental improvement by constantly identifying environmental challenges, generating, evaluating and implementing practical environmental solutions. The five steps are; (1) identification of environmental challenges, (2) generation of alternative environmental solutions, (3) evaluation of the alternative solutions and decision making, (4) solution implementation, and (5) environmental monitoring. The model is schematically presented in figure 58 (Michail 2005c).

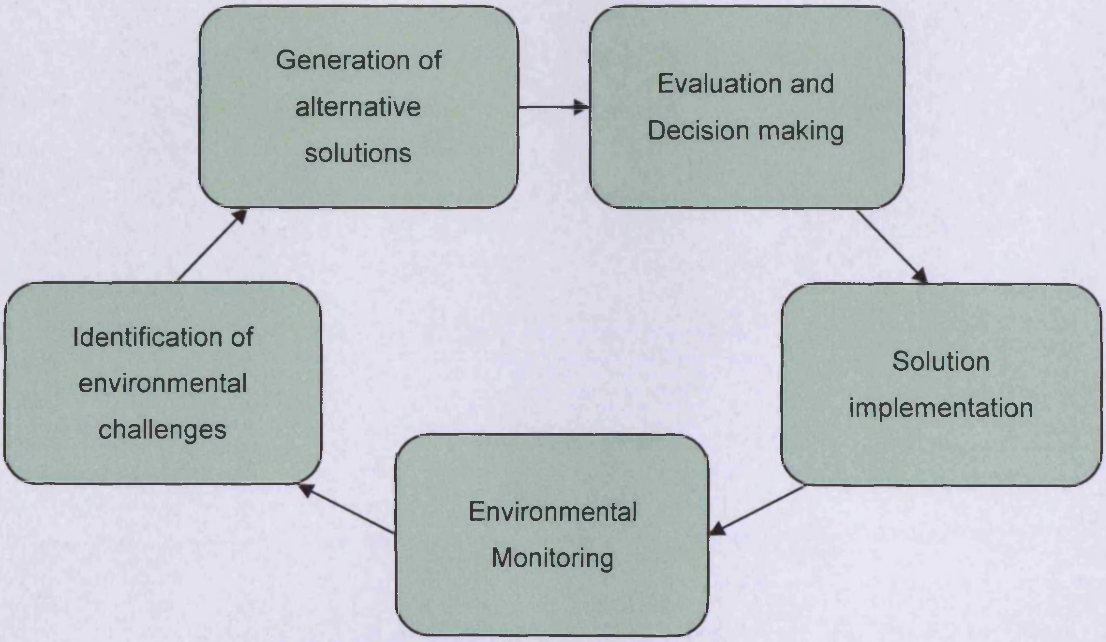


Figure 58: Theoretical model - Ports sharing experience and good practices

The starting point is the identification of the main port environmental challenges. Elements of port activities, products, and services interact directly or indirectly with the environment in an undesired manner. The analysis of those interactions leads to the identification of the port significant environmental aspects. The further assessment of the port environmental performance with regard to those aspects will highlight and prioritise the main environmental challenges to be tackled. There are different possible solutions that could be applied in order to tackle a specific environmental challenge. Environmental solutions could be technical, procedural, or managerial. Furthermore there are various available technical, procedural and managerial options addressing the same challenges. Second step then towards the implementation of environmental solutions in port areas would be making an inventory of the different available options. Evaluating and assessing the alternative solutions is the next logical step of the suggested methodology. The aim here is to decide on the optimal available option. Once the desired solution is identified the implementation phase can start. The implementation of an environmental solution is unlikely to be an instant process. It is usually an iterative process and requires careful planning and proper communication between the involved parties in order to achieve a high level of commitment. Environmental monitoring is the following step. Monitoring assists in assessing the impact of the implemented environmental solutions demonstrating the progress that has been achieved. Additionally, regular monitoring schemes provide the mechanisms for the constant identification of further environmental challenges, thus enabling continual improvement.

7.4.3.2 Contribution of tools and methodologies

This section discusses the contribution of existing tools and methodologies in the five-step circular process that was presented above. The first step is the identification of the main environmental challenges and consists of two elements: The identification of the port significant environmental aspects and the assessment of the port environmental performance with regard to those aspects. Two tools that have been developed by the ECOPORTS project can assist port environmental managers in coping with those elements: The Strategic Overview of Significant Environmental Aspects (SOSEA) and the Self Diagnosis Method (SDM).

SOSEA is a methodology that has been designed to help port managers identify the Significant Environmental Aspects (SEAs) in seaport areas and reinforce the awareness about them in order to prioritise work in environmental management (Darbra, Ronza et al. 2005). It is based on ISO 14001 vocabulary and requirements and it can be considered as the base for the implementation of any Environmental

Management System for port communities. Moreover, SOSEA assists the Ports in getting a proper knowledge of the management carried out as to the environmental aspects that actually represent a concern for them (ECOPORTS project 2005 a). SOSEA assists in particular in the screening for the significance of different aspects. The relative importance of the diverse aspects depends on the characteristics of each port (e.g. its activities, size, location, type of coastline), on the relevant environmental legislation affecting these aspects, and on the third parties involved (e.g. neighbouring population). SOSEA makes use of specifically designed matrices (figure 59) and it presents a methodology for weighting the relative importance of environmental aspects.

		ACTIVITIES																			
		Port Authority							Port Area												
									Tenants							Other Agencies					
		Coastal Engineering	Dredging	Marine engineering	Administrative and Planning Activities	Shipping and Navigation	Emergency Situations	....	Cargo handling operations	Cargo storage	Port based industry	Fisheries & Aquaculture	Ship building and repair	Stakeholders activities	....	Waste Management	Port installations maintenance	Land traffic	Recreation and tourism	Bunkering	Result
ASPECTS	Emissions to air																				
	Emissions to water																				
	Emissions to soil																				
	Emissions to sediments																				
	Noise																				
	Waste production																				
	Changes in terrestrial habitats																				
	Changes in marine ecosystems																				
	Odour																				
	Resource consumption																				
	Port development (land)																				
	Port development (sea)																				

Figure 59: SOSEA matrix for the identification of significant environmental aspects

The main benefits of SOSEA are presented on the following table 52.

Table 52: Main benefits of the SOSEA methodology

Benefits of SOSEA
• Assists Ports in identifying significant environmental aspects (SEAs). • Reinforces the awareness about SEAs. • Provides knowledge on port activities and aspects related with them. • Assesses the current management carried out for each Significant Environmental Aspect by the Port. • Identifies the reasons why the aspect is important for the Port. • Assists Ports to prioritise the most important actions to be carried out concerning the environmental management • Checks compliance with relevant environmental legislation. • Links the different ECOPORTS tools within Environmental Management Information System, EMIS (SOSEA is directly related with SDM and is the base for other environmental management tools such as PERS, EMS-VAL, ISO 14001, EMAS) • Provides the means for periodical self-assessment of the Port's environmental improvement; • Motivate the Port Authority towards environmental management and raising staff environmental awareness.

Source: (ECOPORTS project 2005 a)

The Self Diagnosis Method (SDM) has been developed and evaluated in ports throughout Europe as part of the ECOPORTS network. SDM is a tool designed to support port managers in their efforts to regularly review the environmental management performance in their port (figure 60). This approach is recommended by ESPO in its Environmental Code of Practice 2003. SDM can be used to establish initial or baseline performance and can then be applied to year by year comparison of the port's environmental improvement. Moreover, it provides an opportunity for the port to compare its response with that of the benchmark performance of the European Port Sector (ECOPORTS project 2003).

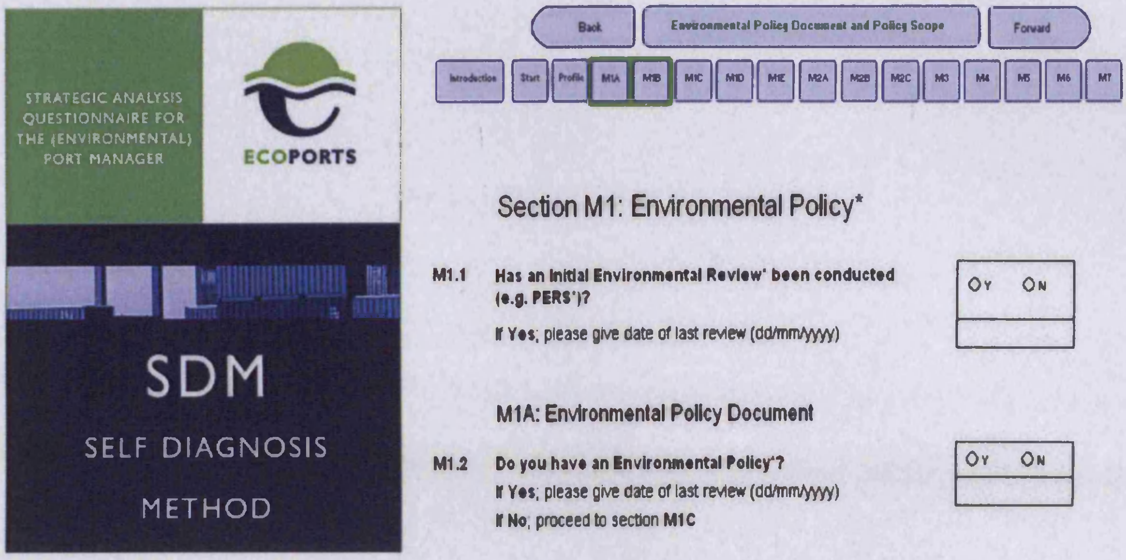


Figure 60: Cover page and questions' example of the SDM questionnaire

The SDM questionnaire concentrates on the response of the Port's Management to Environmental Issues. The main objective is to review the management activities and procedures regarding the environment, and the way in which the port authority is dealing with its significant environmental aspects. The results highlight points requiring attention, as well as confirming existing best practice. Findings can be used to review and then plan the port's environmental programme.

The second step of the model for implementing good practice solutions in port areas is the phase of generating alternative solutions. An assisting tool for generating alternative solutions in response to environmental challenges is the ECOPORTS online solution database (figure 61). The ECOPORTS database contains practical, proven and cost-effective solutions for reduction of the ports' environmental burden. The database includes information supplied by port managers and meant for port managers (both of port authorities and port users). It is a unique tool to exchange proven information, to neutralise competition on environmental issues and to elevate the level of environmental management in ports. The database is accessible on-line through the ECOPORTS web-site (www.ecoports.com). As seen in figure 61 the user can search different solutions by environmental issues, port activities, or keywords. The database can therefore contribute significantly on making an inventory of the different available options and provides evidence of ports sharing experience.

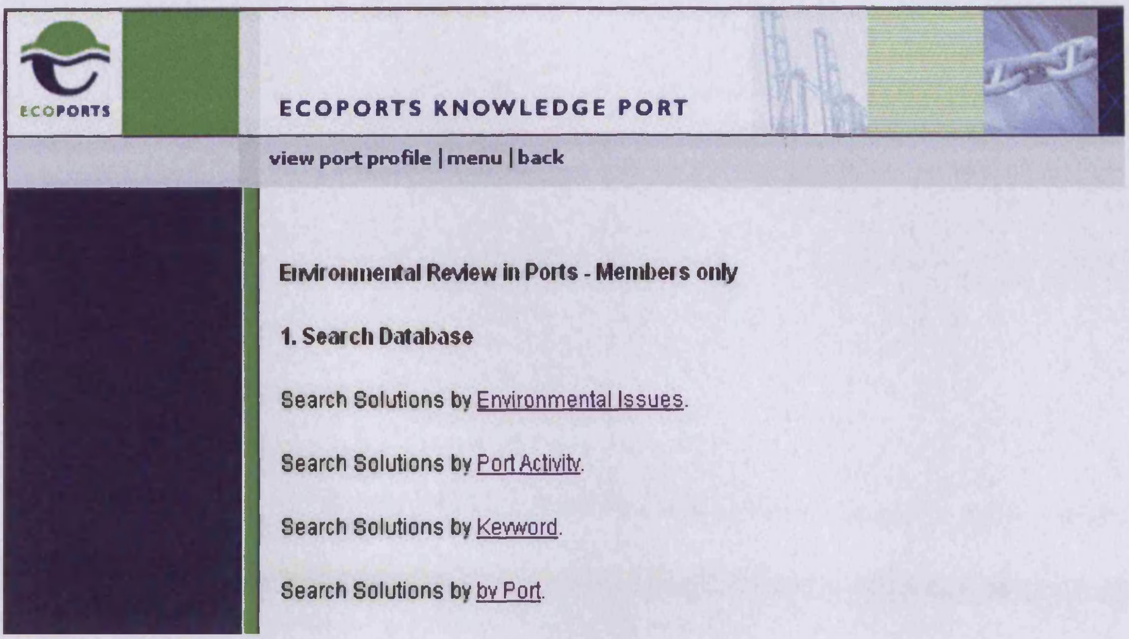


Figure 61: Screenshot of the online ECOPORTS solution database

Evaluating and assessing the alternative solutions is the next logical step of the suggested methodology. The aim here is to decide on the optimal available option. The ECOPORTS Decision Support System (DSS) is a quick scan method aiming at supporting port managers in taking decisions on how to tackle environmental challenges (figure 62). Among several possible solutions, DSS allows port managers to evaluate and decide on the optimal solution addressing a specific environmental problem (ECOPORTS project 2005 b).

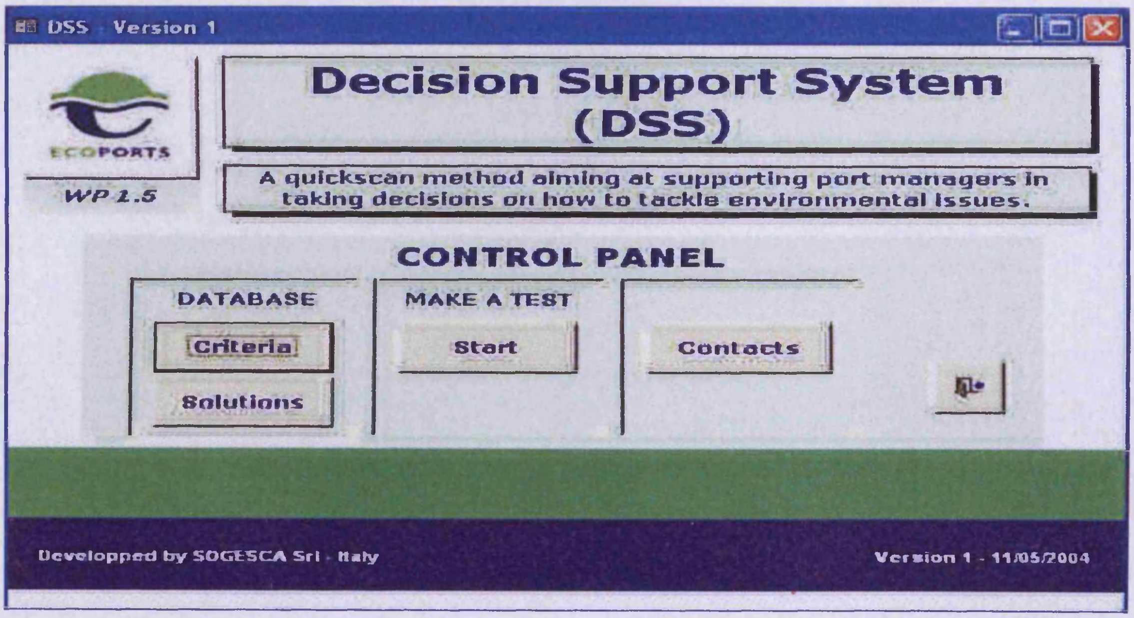


Figure 62: Screenshot of the ECOPORTS DSS

Some of the benefits of using the ECOPORTS DSS are highlighted on the following table 53.

Table 53: Benefits of using the ECOPORTS DSS

Benefits of ECOPORTS DSS:
• Identifies the potential actions (solutions) and the criteria to benchmark the solutions. • Builds a "traceable" pattern, so that all decisions are documented. • Supports communications with internal and external stakeholders about the rationale of decision making.

Once the desired solution is identified the implementation phase can start. The implementation of an environmental solution is unlikely to be an instant process. It is usually an iterative process and requires careful planning and proper communication between the involved parties in order to achieve a high level of commitment. Environmental monitoring is the next model item and an essential component in the process of continuous environmental improvement. It helps assessing the impact of the implemented solution by demonstrating the progress that has been achieved. Additionally, regular monitoring schemes provide the mechanisms for the continuous identification of further environmental challenges feeding the next circle of the presented circular methodology.

Although several attempts are being made by individual ports to develop appropriate tools for monitoring environmental performance, there is a lack of common practice. The ECOPORTS project, aiming towards a common tool for environmental monitoring in European ports, commissioned two research projects in 2003 and 2005 in cooperation with the University of Amsterdam (Michail, De Leffe et al. 2003; Berends, Cavalcoli et al. 2005). The major output of those efforts is the ECOPORTS set of core Environmental Performance Indicators (EPIs) that could be commonly applied for monitoring performance in European ports (figure 63).

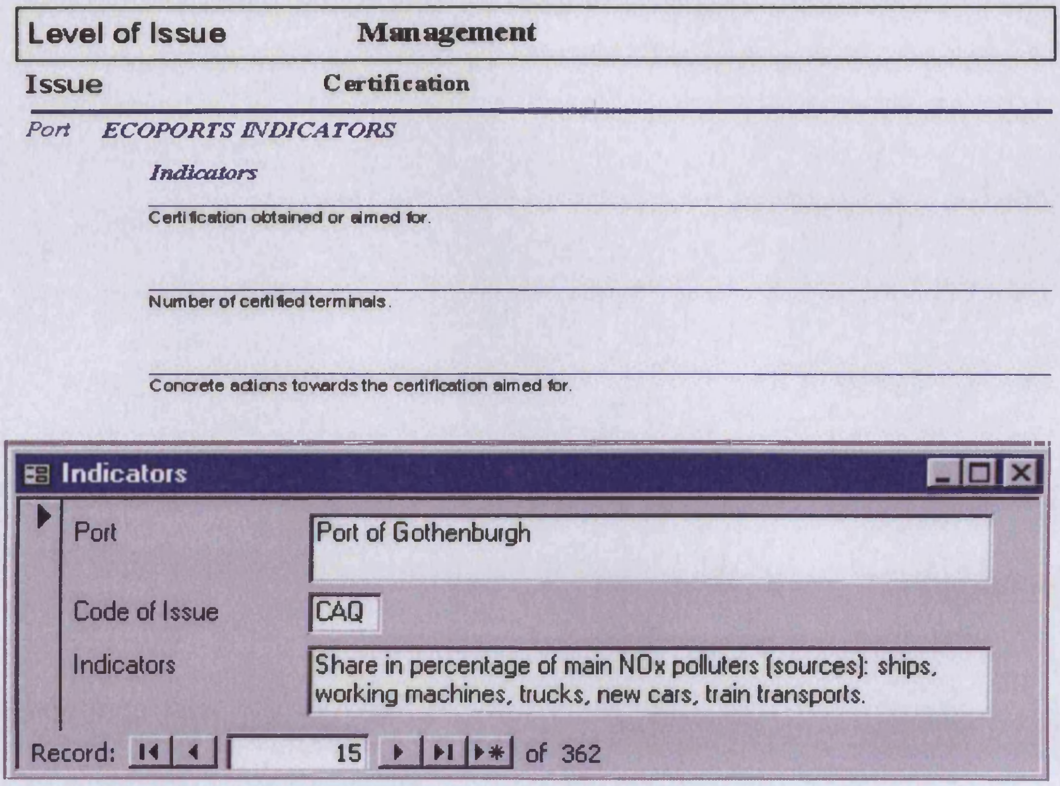


Figure 63: Database of environmental performance indicators

Port managers could use the practical experience of other ports with respect to the use of Environmental Performance Indicators as well as the developed set of ECOPORTS EPIs adapting them to their needs and interests. The EPI set and the produced reports are available through the ECOPORTS Foundation.

7.4.3.3 Assessment of tools and methodologies

As established in the previous section, several of the tools and methodologies that were developed under the umbrella of port-inspired projects and initiatives can actively assist port managers in the process of responding to environmental challenges by implementing proven and effective solutions and best practices. For every identified step of the conceptual model that was developed guiding that process, the potential contribution of those products is considered to be significant. The effectiveness of the tools can be confirmed by port professionals and managers that experience in practice the benefits of using them as can be derived from the evidence providing statements on the following table 54.

Table 54: Evidence statements on the effectiveness and practicability of tools and approach

"What makes ECOPORTS approach so successful is that it is based on voluntary collaboration and the exchange of knowledge and experience between European ports" – Guido van Meel, Port of Antwerp (2005).
My team of young and educated environmental managers see the ECOPORTS tools as a recognisable and professional approach" – Ryszard Wocial, Port of Gdansk (2005).
The structured and standardised way in which environmental information on my port is made transparent and manageable by the ECOPORTS tools is very useful. It keeps the citizens and the port companies well informed about the port's progress in sustainable management." – Xavier Solé, Port of Barcelona (2005).

It can be confirmed that there is a satisfactory level of consistency between the port sector's policy approach as this is expressed in the ESPO and ECOPORTS policy statements, and the actual sector's practice as derived from the development and application of tools assisting port environmental management on the set voluntary, self-regulating basis.

7.5 The concept of seaports as facilitators in the logistic chain

After establishing and examining the primary contribution of seaports in the environmental management of the logistic chain, being the port environmental management itself, this section examines the concept of seaports acting as "facilitators" in the chain. It is argued that the way forward with regard to the contribution of ports to the environmental management of the logistic chain is realising and undertaking their role as facilitators. Ports are one of the few networking sites that bring together various members in the logistics channel. In recent years, there has been some interest in conceptualising ports through a channel approach, particularly with the increasing recognition of the integrative role of ports in international logistics and distribution systems. The concept of seaports - facilitators refers to the contribution of ports in facilitating procedures, information exchange and cooperation between the different players in the logistic chain. In this content ports could actively contribute in; (1) providing the necessary platforms for, and coordinating the exchange of safety, health and environmental information between the different port commercial visitors and the port and other authorities, and (2) working with other parties in tackling the informational, technical and procedural bottlenecks restricting the efficient operation of intermodal transport chains. The section is respectively divided in two parts. First a survey is set to investigate the extent to which seaports currently act as facilitators in the logistic chain (Michail 2005b). The survey is analytically presented in section 7.5.1. Then, selected good practice examples of collaborative efforts between port authorities and other parties in the logistic chain that are aimed towards efficient intermodal transportation, are highlighted in section 7.5.2.

The concept of seaports as facilitators in the logistic chain has been researched under the umbrella of the EC funded ECOPORTS project. The author was the appointed researcher in the field. As such he was responsible for designing the research pathway, data collection and analysis, and reporting to the project team and the European Commission.

7.5.1 Survey – Ports facilitating the exchange of information

The concept of ports promoting and coordinating the informational exchange in environmental grounds between the different port commercial visitors and the port and other authorities is researched in this section. A survey was set focusing on the online provided environmental information by ports to different categories of port commercial visitors (carriers and transport operators of all modes, logistic service providers) (Michail 2005b). The investigation of the range and nature of online provided information enables the assessment of whether or not ports consider themselves as a point of contact, actively provide appropriate information, and facilitate communication between chain partners. The research approach of the survey is schematically presented on figure 64 (Michail 2005b).

The input-preparation phase consisted of defining the commercial visitors in port areas, establishing their needs for environmental information, developing a checklist of information in order to assist the relevant data collection, and applying criteria for the selection of the port research sample. The actual survey process involved researching the websites of the selected ports for relevant information in line with the checklist previously developed, and classifying the data in respectively structured databases. The data analysis enabled the evaluation of current practice and trends towards the role of seaports in providing environmental information and facilitating the communication between different parties in the logistic chain.

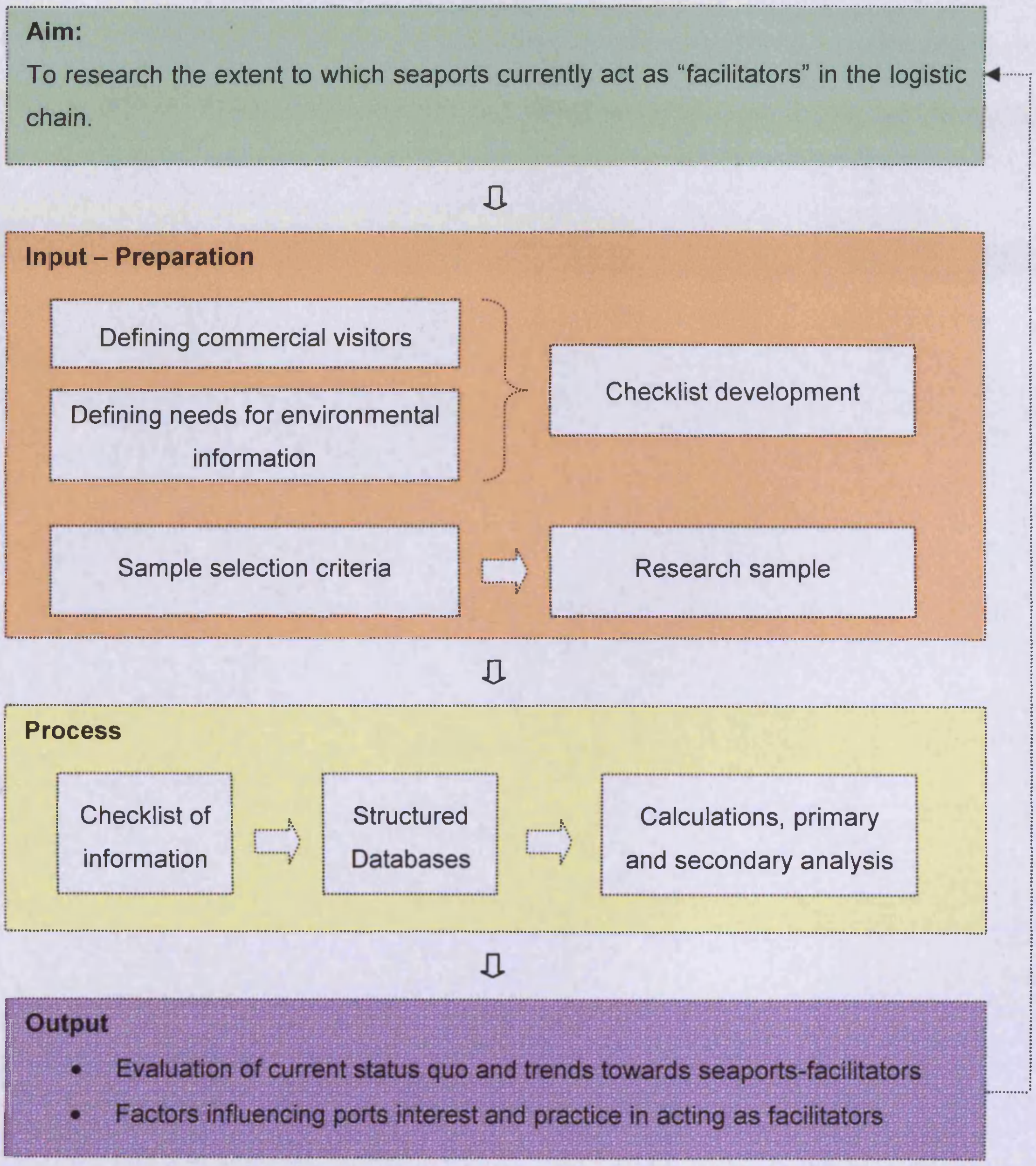


Figure 64: Research approach of the survey

The first step of the approach identified the commercial visitors in port areas and researched the nature of environmental information that those visitors might need in their interaction with the port authorities. The following categories of port commercial visitors have been identified as significant; ocean, road, and rail carriers, shipping agents, companies located in the port area (current and future), and employees in the port. Those visitors were then categorised according to the nature of environmental information that could be relevant to them and their business as seen at the following table 55.

Table 55: Nature of environmental information for different commercial visitors

	General environmental information	SEA-side environmental information	LAND-side environmental information
Relevant for which commercial visitors	All commercial visitors	Ocean carriers	Companies located in the port area
	General public	Shipping agents	Road carriers
			Rail carriers

(Michail 2005b)

Following a systematic approach 38 port websites, of which 30 of European ports (15 countries) and 8 of world ports (4 continents), have been deliberately researched on the provided environmental information for commercial port visitors. For maximising the efficiency of the web research, a detailed checklist assisting and directing the process has been developed. The exercise reflected:

- An initial inventory concerning the nature of environmental information that port commercial visitors might need in order to conduct their business in a sensible way,
- the available information provided on the website of the port of Amsterdam that was used as a starting example,
- the validation of the initial checklist by consulting a number of freight carriers, ship agents and port area based companies,
- and the consultation of a panel of experts. The panel consisted of port managers (on both operational and senior level), environmental management consultants, and academics. It was formulated for the needs of the ECOPORTS project working groups discussing the role of ports in the logistic chain (ECOPORTS project 2005 c; ECOPORTS project 2005 e).

In addition, it has been considered important to categorise the provided information in three different categories: General environmental information, SEA-side environmental information and LAND-side environmental information (table 55). The General health, safety and environmental information is relevant to all the commercial visitors to the port plus other interest groups (general public, NGOs, stakeholders). The General Information Checklist is presented in table 56 and consists of 8 selected items. The second and third column of the table present and explain the selected checklist items. The fourth column justifies the relevance of the selected item to health, safety, environmental and security considerations.

Table 56: General Environmental Information – Checklist and explanation

Relevant to	Checklist item	Explanation	Relevance
All commercial visitors	Separate environmental section	Is the environmental information provided in a separate section at the port website?	The existence of a separate section makes the access of information easier to the user
	Environmental management and major environmental issues	Information given on the environmental efforts (main environmental issues, policy, targets) of the port authority.	Relevant environmental information describing the efforts made by the port
	Directions-optimal route towards companies, quays	Informing every visitor on the location of, and the optimal route to their destination in the port area	Facilitating port visitors. Reducing congestion on the port road network.
	Announcements section (alert to activities, alterations in regulations)	Is there a separate announcements section informing port visitors for emerging alert to activities and/or alterations in regulations	The existence of a separate section makes the access of information easier to the user
	Security information	Information concerning port security (e.g. ISPS implementation)	Security of operations. Possible emerging requirements for the port visitor

	Promoting intermodal transportation	Efforts of the port towards a more sustainable transport system	Environmental benefits of intermodal transportation
	Information on modal split	Figures on the way that freight is transported through the port area (Percentages of road, rail, inland shipping). Efforts to increase the percentages of the "environmental friendly" modes of transportation.	Environmental benefits of rail transport and inland shipping over road transport
	Emergency contacts/procedures	Contact information and/or procedures to follow in case of an emergency situation.	Relevant health and safety information

(Michail 2005b)

SEA-side health, safety and environmental information concerns activities and operations such as safe navigation, ship arrival and berthing and ship waste delivery. The provided information is relevant to the commercial visitors that have an interest on those activities, namely the ocean carriers and the shipping agents. The SEA-side Information Checklist is presented in Table 57 and consists of 9 selected items. Table 57 follows the same structure as Table 56.

Table 57: SEA-side environmental information – Checklist and explanation

Relevant to	Checklist item	Explanation	Relevance
Ocean carries and shipping agents	Procedures concerning arrival notification	The procedures to follow before, during and after the arrival of a ship to the port	Safe navigation and berthing. Health, safety and environmental relevant information
	Info on pilotage and tagging	Procedures and regulations for ships that need assistance to enter the port	Safe navigation and berthing. Health, safety and environmental relevant information
	Info on quays, buoys, tugs	Additional info guiding the safe entrance and berthing of the ship to the port	Safe navigation and berthing. Health, safety and environmental relevant information

	Waste reception facilities and procedures	Informing the ships on the waste reception facilities of the port and the related procedures and regulations	Waste management. Health and Environmental relevant information
	Online forms for reporting waste products	Does the port website provide online the necessary forms for reporting ship waste before arrival	The availability of online forms makes the procedure for reporting waste easier to the user
	Carriage of dangerous goods procedures	Information on procedures and regulations applied when a ship is carrying dangerous goods	Health, safety, environmental and security relevant information
	On-line forms for arrival notification (dangerous goods)	Does the port website provide online the necessary forms for reporting carriage of dangerous goods before arrival	The availability of online forms makes the procedure for reporting dangerous goods easier to the user
	Local regulations	Other local regulations and procedures applied with regard to the arrival, berthing and departure of a ship	Health, safety, environmental and security relevant information
	National regulations	Other national regulations and procedures applied with regard to the arrival, berthing and departure of a ship	Health, safety, environmental and security relevant information

(Michail 2005b)

The LAND-side Information Checklist addresses information related to all LAND-side activities and operations. Consisting of 16 items, it separately depicts the informational needs of companies located in the port area (current and future), road carriers and rail carriers. It is presented in the following table 58 in the same format as previously explained.

Table 58: LAND-side environmental information – Checklist and explanation

Relevant to	Checklist item	Explanation	Relevance
Port area based companies (current and potential future)	Storage procedures	Information on storage and warehousing procedures/regulations for stevedoring companies operating in the port area	Relevant health, safety and environmental information
	Loading and unloading procedures	Information on cargo handling procedures and regulations for stevedoring companies operating in the port area	Relevant health, safety and environmental information
	Initiatives and projects on area management and planning	Information on the port's policies and practice in locating companies in the port area	Industrial ecology, reduced transport distances, better health, safety and environmental management
	Info on waste collection and management	Information related to waste collection and management schemes in the port area	Relevant health and environmental information
	Use of renewable energy	Information on the energy policy applied in the port area with particular reference to the use of renewable energy sources	Relevant environmental information
	Info on wastewater treatment	Information on wastewater management and treatment practices	Relevant health and environmental information
	Noise (e.g. noise zones, planning)	Information on the noise zones in the port area and the related policies and regulations	Relevant health and environmental information
	Soil contamination policy when locating new companies	Policy with regard to the soil contamination monitoring and treatment	Relevant health and environmental information
Road carriers	Parking facilities and regulations	Parking facilities and regulations for trucks entering the port area	Relevant health, safety and environmental information

	Procedures concerning arrival notification	Procedures and regulations concerning the arrival of trucks in the port area	Safe movement. Relevant health, safety and environmental information
	Carriage of dangerous goods procedures	Procedures and regulations concerning trucks transporting dangerous goods	Health, safety, environmental and security relevant information
	On-line forms for arrival notification (dangerous goods)	Does the port website provide online the necessary forms for reporting carriage of dangerous goods before arrival	The availability of online forms makes the procedure for reporting dangerous goods easier to the user
Rail carriers	Promoting rail transport (environmental benefits)	Information on projects, initiatives and efforts to increase the modal share of rail transport	Environmental benefits of rail transport over road transport
	Procedures concerning arrival notification (rail)	Procedures and regulations concerning the arrival of trains in the port area	Safe arrival. Relevant health, safety and environmental information
	Carriage of dangerous goods procedures	Procedures and regulations concerning trains transporting dangerous goods	Health, safety, environmental and security relevant information
	On-line forms for arrival notification (dangerous goods)	Does the port website provide online the necessary forms for reporting carriage of dangerous goods before arrival	The availability of online forms facilitates the communication on dangerous goods

(Michail 2005b)

There are over 1200 seaports in Europe (ESPO 2007) and therefore a set of selection criteria has been developed and applied in order to define the research sample of 30 European ports. The presentation of the selection criteria follows in two levels: the selection of countries and the selection of the specific ports.

Table 59: Research sample selection criteria

Criteria applied for the selection of countries: • Include all countries with ECOPORTS partner ports. (The Netherlands, Belgium, UK, Germany, Spain, Italy, Sweden, France, Poland) • Preference to EU countries (14 EU countries have been selected plus Norway) • Geographical variety of the sample in order to represent all the different geographical areas in Europe in an equal way. (9 southern European ports, 10 in the north Atlantic and North Sea area and 11 in the Baltic sea and Scandinavia)
Criteria applied for the selection of ports: • Two ports per country were selected • Include ECOPORTS partner ports when available (13 ECOPORTS partner ports were selected) • Representative sample (Geographical variety). Even inside the countries geographical variety was prioritised (e.g. In France one port facing the Atlantic Ocean; Le Havre, and one facing the Mediterranean Sea; Marseille, were selected) • Prioritise the selection of relatively large ports. (More commercial visitors, increased need for environmental information) • Only seaports to be included in the sample • Rail ports when possible. (In order to research the environmental information provided for rail carriers) • Ports with industry located in the port area (In order to research the environmental information provided for port based industry and companies)

(Michail 2005b)

The European ports that were finally selected for the survey are presented on table 60.

Table 60: European ports' survey sample and sources of information

Country	Ports	Website
Belgium	Antwerp	www.portofantwerp.be
	Zeebrugge	www.zeebruggeport.be
Denmark	Aarhus	www.aarhushavn.dk
	Aalborg	www.aalborghavn.dk
Finland	Helsinki	www.hel.fi/port
	Pori	www.pori.fi/port
France	Le Havre	www.havre-port.net
	Marseille	www.marseille-port.fr
Germany	Hamburg	www.port-of-hamburg.de
	Rostock	www.rostock-port.de
Greece	Piraeus	www.olp.gr
	Thessalonica	www.thpa.gr
Ireland	Cork	www.portofcork.ie
	Dublin	www.dublinport.ie
Italy	Genoa	www.porto.genova.it
	Livorno	www.portauthority.li.it
Norway	Bergen	www.bergenhavn.no
	Oslo	www.ohv.oslo.no
Poland	Gdansk	www.portgdansk.pl
	Gdynia	www.port.gdynia.pl
Portugal	Leixoes	www.apdl.pt
	Lisbon	www.portodelisboa.com
Spain	Barcelona	www.apb.es
	Valencia	www.valenciaport.com
Sweden	Gothenburg	www.portgot.se
	Malmo-Copenhagen	www.cmport.com
The Netherlands	Amsterdam	www.amsterdamports.nl
	Rotterdam	www.portofrotterdam.com
United Kingdom	Dover	www.doverport.co.uk
	Tyne	www.portoftyne.co.uk

(Michail 2005b)

Figure 65 maps their geographical distribution in the European continent.

Figure 65: Geographical distribution of the research sample

Additionally 8 ports from the four other main continents (America, Asia, Africa and Oceania) have been included to the research sample. It was felt useful having even a slight first indication with respect to the worldwide practices in comparison with the European one.

Table 61: World ports' survey sample and sources of information

Continent	Country	Ports	Website
America	U.S.A	Boston	http://www.massport.com/ports
	U.S.A	Seattle	www.portseattle.org
Asia	Singapore	Singapore	www.mpa.gov.sg
	China	Hong-Kong	www.mardep.gov.hk
Oceania	Australia	Brisbane	www.portbris.com.au
	Australia	Melbourne	www.portofmelbourne.com
Africa	Egypt	Alexandria	www.emdb.gov.eg
	South Africa	Durban	www.npa.co.za

(Michail 2005b)

The websites of the selected ports were researched on the provision of information with respect to the above presented checklist items. The exercise used a range of online available information, including online available environmental reports, handbooks, newsletters and other referenced material. In the following paragraphs the results of the exercise are presented, summarised and analysed.

The collected data from the ports' websites was stored in specifically designed databases on excel environment. For demonstration, an example of a database is partly presented on the following table 62. It refers to the General Environmental Information provided by the 30 European ports. The appearance of the unit (1) in the table indicates that the port under question (table rows) provides online information for the category under examination (table columns). The website of the port of Rotterdam for instance, provides information with regard to the environmental management and the major environmental issues in the port, although this is not done in a separate environmental section.

Table 62: General environmental information results database

		General Environmental Information (All commercial visitors)							
		Separate environmental section	Environmental management and major environmental issues	Directions-optimal route towards companies, quays	Announcements section (alert to activities, alterations in regulations)	Security information	Promoting intermodal transportation	Information on modal split	Emergency contacts/procedures
1	Rotterdam		1	1	1	1	1	1	1
2	Antwerp	1	1	1	1	1		1	1
3	Hamburg				1	1	1		
4	Genoa			1	1				
5	Aarhus					1	1		
6	Marseille	1	1			1			
7	Amsterdam	1	1	1	1	1	1	1	
8	Bergen			1		1			
9	Valencia	1	1	1					
10	Barcelona	1	1	1		1			1
11	Zeebrugge	1	1	1				1	
12	Havre	1	1	1	1	1	1	1	
13	Livorvo		1	1					
14	Lisbon		1						
15	Gothenburg	1	1	1	1	1			
16	Piraeus								
17	Thessaloniki			1					
18	Dublin		1		1	1			1
19	Rostock			1		1			1
20	Gdansk	1	1	1	1	1	1		1
21	Malmo		1	1	1	1	1		
22	Gdynia	1	1		1	1			1
23	Helsinki	1	1	1	1	1			
24	Leixoes		1	1					1
25	Pori	1	1	1		1			1

26	Cork				1	1			
27	Oslo		1			1			
28	Tyne	1	1	1	1				1
29	Dover	1	1	1	1	1			
30	Aalborg								

(Michail 2005b)

In addition to databases of such format as table 62, the actual online provided information (text and figures) was stored on a separate report for each individual port. After the collection and classification of information the first collective and summarised outcomes emerged. The following table 63 presents the percentages of positive "answers" given on the researched port websites to the different checklist items/questions. Taking as an example the existence of a separate environmental section on the ports' websites, it can be observed that 14 out of 30 (Table 62) had a separate section which equals the 47% appearing in table 63.

Table 63: Survey's summarised outcomes

Category	Relevant to	**Checklist Item**	**European average (30 ports)**
General Environmental Information	All commercial visitors	Separate environmental section	47%
		Environmental management and major environmental issues	70%
		Directions-optimal route towards companies, quays	67%
		Announcements section (alert to activities and regulations)	50%
		Security Information	67%
		Promoting intermodal transportation	23%
		Info on modal split	17%
		Emergency procedures/contacts	33%
SEA-side Environmental Information	Ocean carriers and shipping agents	Procedures concerning arrival notification	50%
		Info on pilotage and tagging	80%
		Info on quays, buoys, tugs	73%
		waste reception facilities and procedures	60%
		Online forms for reporting waste products	30%
		Carriage of dangerous goods procedures	33%
		On-line forms for arrival notification (dangerous goods)	30%

		Local regulations	50%
		National regulations	50%
LAND-side Environmental Information	Port based companies (current and future)	Storage procedures	20%
		Loading and unloading procedures	23%
		Initiatives and projects on area management and planning	23%
		Info on waste collection and management	33%
		Use of renewable energy	17%
		Info on wastewater treatment	13%
		Noise (e.g. noise zones, planning)	13%
		Soil contamination policy when locating new companies	3%
	Road carriers	Parking facilities and regulations	10%
		Procedures concerning arrival notification	13%
		Carriage of dangerous goods procedures	20%
		On-line forms for arrival notification (dangerous goods)	13%
	Rail carriers	Promoting rail transport (environmental benefits)	27%
		Procedures concerning arrival notification (rail)	3%
		Carriage of dangerous goods procedures	13%
		On-line forms for arrival notification (dangerous goods)	10%

(Michail 2005b)

From the study of the table the following observations can be made:

- Information is provided for all the different checklist items.
- The percentages, showing how many ports provided information for a specific checklist item, are varying from 3% (1 port) to 80% (24 ports).
- Concerning the General Environmental Information: The majority of European ports provide information on environmental management efforts (70%) and on port security aspects (67%). Few ports provided information on issues such as intermodal transport (23%) and modal shift (17%).
- Concerning the SEA-side Environmental Information: Most of the ports provide information on aspects related to the safe arrival and berthing of ships

(80%, 73%). Nearly one out of three ports provides online available forms for reporting ship waste and carriage of dangerous goods.

- Concerning the LAND-side Environmental Information: One out of three ports provides online information on waste collection and management. From the 30 ports only one provided information on the arrival procedures of trains in the port area.

Table 64 provides the "average score" of the 30 European ports for each of the main three identified categories of provided environmental information (General, SEA-side, LAND-side). The average score for a specific category of information is an indicator equal to the average percentage of positive answers given to all the checklist items under the category in question. For example concerning the General Environmental Information:

$$AverageScore = (0.47 + 0.7 + 0.67 + 0.5 + 0.67 + 0.23 + 0.17 + 0.33) \div 8 = 0.47$$

Table 64: Average scores for the different categories of information

Category of information	Average Score (30 ports)
General Environmental Information	0.47
SEA-side Environmental Information	0.51
LAND-side Environmental Information	0.16

(Michail 2005b)

The main observation that can be made is that the amount of LAND-side provided environmental information is significantly less than the General and the SEA-side one.

A second level of analysis of the survey outcomes was set in order to highlight possible differences in practice between different groups of European ports. Different possible groupings of ports were introduced and examined in order to draw conclusions on the factors that influence the range and nature of the online provided environmental information. Three different tests were selected:

1. ECOPORTS partner ports in comparison with other European ports
2. Comparison between ports of different sizes
3. Comparison between ports from different geographical areas in Europe

The first of the tests aimed to make the comparison between the online provided environmental information by ECOPORTS partner ports and other ports in Europe. For that reason the "average scores" of the 30 European ports were compared with the ones of the ECOPORTS partner ports (13 ports) as well as with those of the Top 10 European ports in terms of provided environmental information (Table 65).

Table 65: Average scores ECOPORTS partners versus other Ports

	General	SEA-side	LAND-side	Overall average[28]
European ports (30)	0.47	0.51	0.16	0.33
ECOPORTS ports(13)	0.58	0.54	0.25	0.41
Top 10 European ports	0.71	0.76	0.37	0.56

(Michail 2005b)

The following figure 66 is the represents graphically the data of table 65.

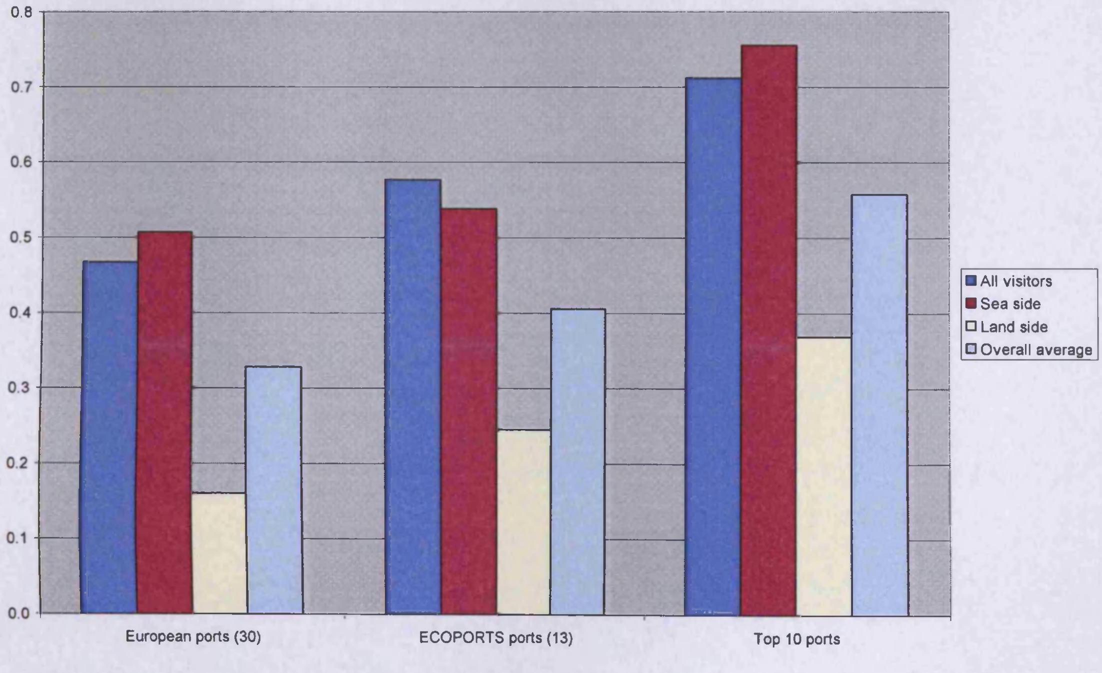


Figure 66: Average scores ECOPORTS partners versus other Ports

It can be observed that the ECOPORTS partner ports provide in average more online environmental information that the European ports. The difference can be considered significant especially for the General and LAND-side provided environmental information. 8 out of the Top 10 European ports are ECOPORTS partner ports.

---

[28] The overall average is the "average score" for all the checklist items.

The second test aimed to investigate if there is any correlation between the range of online provided information and the size of the port. For this reason the 30 selected ports were divided to three categories (Large, Medium and Small) according to their total annual tonnage as shown at Table 66:

Table 66: Classification of ports according to their annual tonnage

		Annual tonnage (Million tonnes/Year)							Annual TEUS (Thousands/Year)						
		< 5	5 < 15	15 < 25	25 < 50	50 < 100	> 100		< 250	250 < 500	500 < 1000	1000 < 2000	2000 < 3000	3000 < 5000	>5000
1	Rotterdam						1	Large ports							1
2	Antwerp						1								1
3	Hamburg						1								1
4	Genoa					1						1			
5	Aarhus					1					1				
6	Marseille					1					1				
7	Amsterdam					1			1						
8	Bergen					1			1						
9	Valencia				1			Medium ports					1		
10	Barcelona				1							1			
11	Zeebrugge				1							1			
12	Havre				1							1			
13	Livorvo				1						1				
14	Lisbon				1						1				
15	Gothenburg				1						1				
16	Piraeus			1								1			
17	Thessaloniki			1						1					
18	Dublin			1						1					
19	Rostock			1					1						
20	Gdansk			1					1						
21	Malmo			1					1						
22	Gdynia		1					Small ports		1					
23	Helsinki		1							1					
24	Leixoes		1							1					
25	Pori		1												
26	Cork	1							1						
27	Oslo	1							1						
28	Tyne	1							1						
29	Dover	1													
30	Aalborg[29]														

(Michail 2005b)

[29] No online available information provided

Table 67 compares the "average scores" of the large, medium and small ports.

Table 67: Average scores for ports of different sizes

	General	SEA-side	LAND-side	Overall average
Large ports (8)	0.52	0.53	0.17	0.35
Medium ports (13)	0.45	0.52	0.17	0.33
Small ports (9)	0.43	0.47	0.14	0.3

(Michail 2005b)

Figure 67 is the graphical representation of table 67.

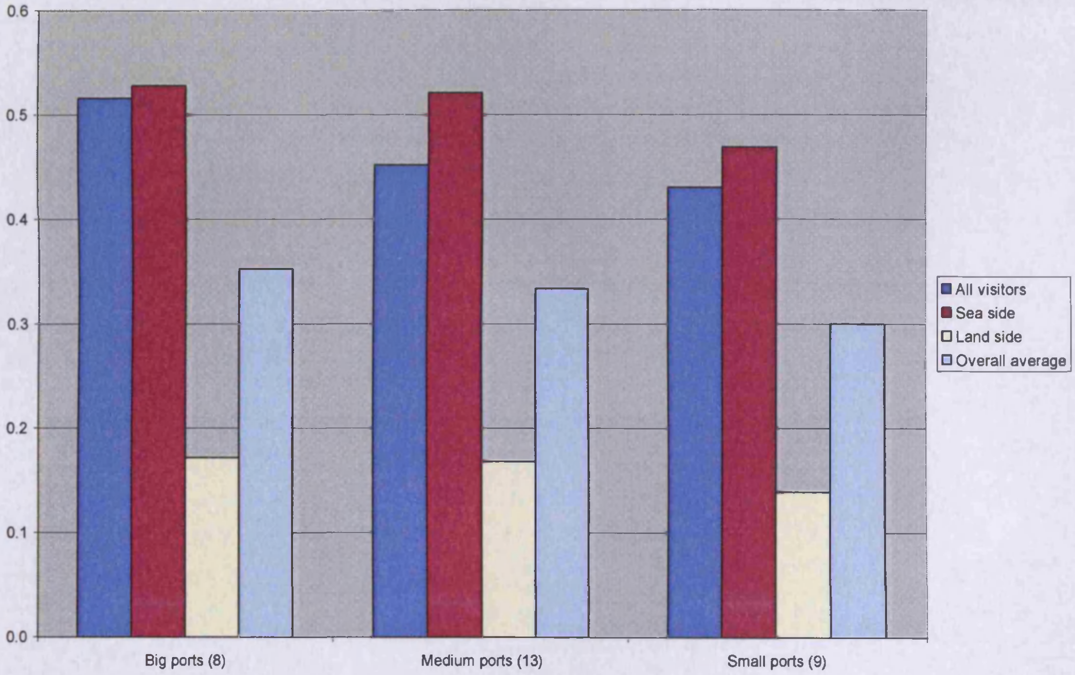


Figure 67: Average scores for ports of different sizes

A small but not really significant difference between the online environmental information provided by small, medium and large ports can be observed. As a general tendency the amount of information provided increases with an increase in size of the port.

The third test aimed at identifying potential correlation between the geographical location of the ports and the amount of provided environmental information. The research sample of the 30 ports was divided in three categories according to the port geographical position in Europe (figure 68). The three categories were: South

European ports (9 ports), North Atlantic and North Sea ports (10 ports), and Baltic Sea and Scandinavian ports (11 ports).

Figure 68: Classification of ports according to their geographical position within Europe

The average scores of the ports under the different categories are presented at the following Table 68.

Table 68: Average scores for ports from different European regions

	General	SEA-side	LAND-side	Overall average
South Europe (9)	0.28	0.37	0.15	0.24
North Atlantic/North Sea (10)	0.63	0.57	0.24	0.42
Baltic Sea/Scandinavian (11)	0.47	0.57	0.10	0.32

(Michail 2005b)

By graphically analysing the data of table 68 the graph of figure 69 emerged.

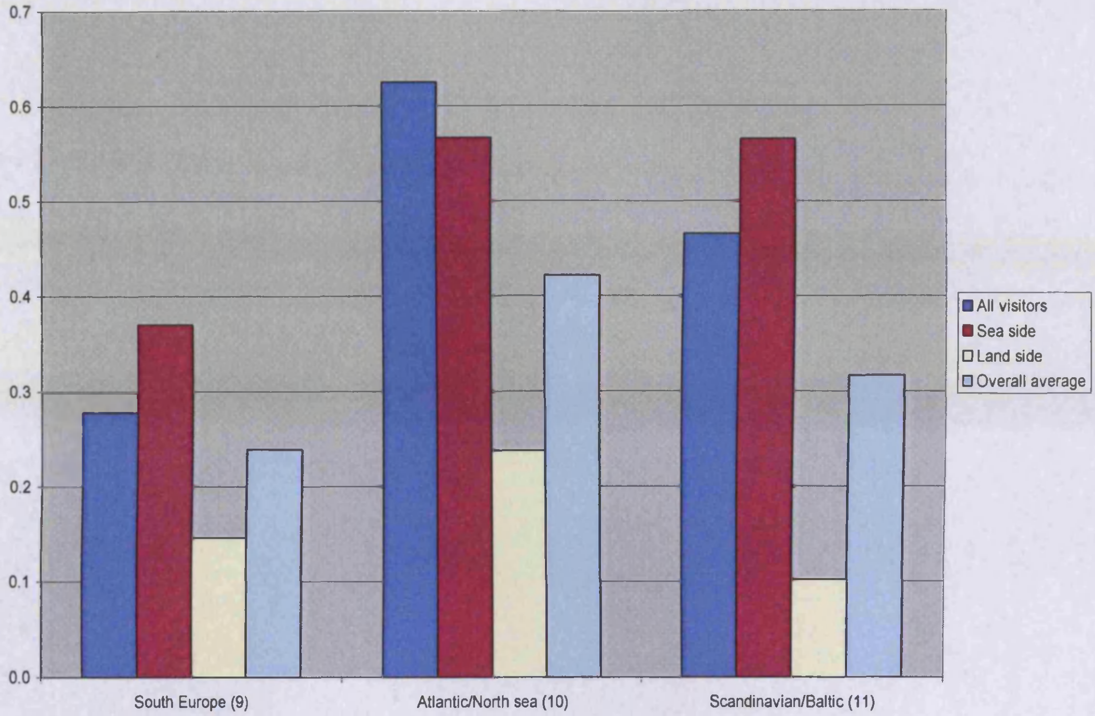


Figure 69: Average scores for ports from different European regions

Significant differences are observed between ports from different regions within Europe. South European ports provide on average less environmental information for all different categories of port commercial visitors. Baltic Sea and Scandinavian ports are quite close to the overall European average with regard to the online availability of environmental information. North Atlantic and North Sea ports provide in average more online environmental information, especially for the categories of General and LAND-side information.

7.5.2 Selected good practice examples and initiatives

This section reviews some good practice examples of ports acting as facilitators and participating in cooperative initiatives that aim towards the operation of more sustainable freight transport systems. Specific attention is paid on the Port Railway Information and Operation System (PRIOS) established in the port of Hamburg in order to facilitate and promote the modal shift of freight traffic through the port from road to rail transport solutions. The PRIOS system is analysed and its benefits are discussed in section 7.5.2.1. The study and analysis of the PRIOS case was undertaken by the author in cooperation with the Port of Hamburg on behalf of the EC research project ECOPORTS (Michail 2005c). Additional selected initiatives are outlined in section 7.5.2.2.

7.5.2.1 Case study: Port Railway Information and Operation System

The environmental policy of the Port of Hamburg targets the efficient and environmentally friendly organisation and handling of the growing cargo flows through the port. Special attention is paid to the promotion and expansion of the Port Railway. The infrastructure of the Port Railway provides the services of the reliable sorting, marshalling, positioning and collection of around 4,500 freight cars per day as required by clients in the port, and in addition the formation and dispersal of approx. 160 - 180 goods trains daily, including the "container block trains" that daily connect the port directly with all German conurbations (Hamburg Port Authority 2005; Port of Hamburg 2005). Hamburg is a "railway port". In 2003 cargoes totalling 29.2m t were shifted by rail, or nearly 28 % of total throughput (figure 70). Over one million containers TEUs were conveyed by some 40,000 goods trains consisting of 1.2m freight cars. Of all rail borne freight traffic to and from Hamburg, 80 % consists of seaport traffic and that also represents about 8% of the Deutsche Bahn AG's entire fee-paying goods traffic. In hinterland traffic involving distances of over 150 km, 70% of containers are transported by rail, the figure rising to 75% for distances of over 250 km. The percentage proportion here climbs with increasing distance.

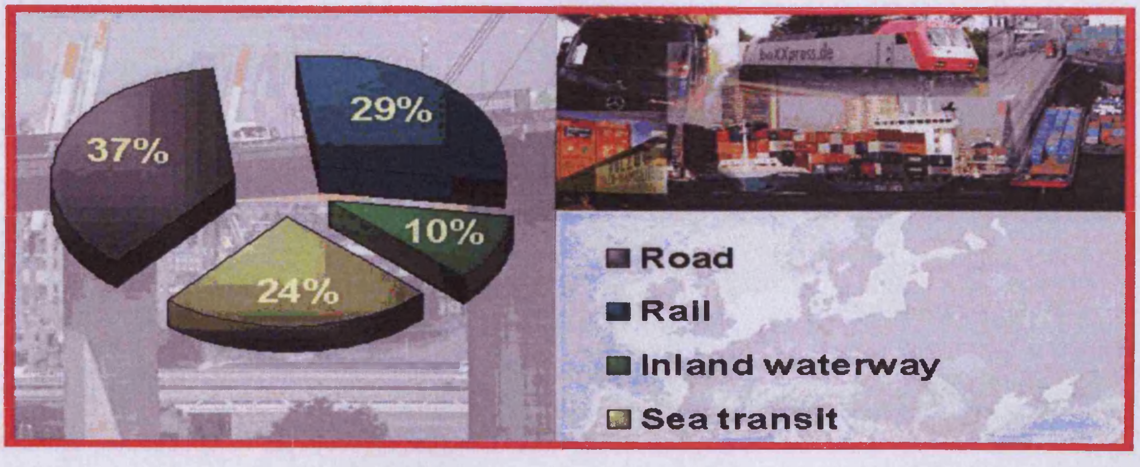


Figure 70: Modal Split –Port of Hamburg

Every terminal in Hamburg accordingly owns a private rail siding and its own facilities, of which many are currently being expanded. For 2004 a rise of nearly 8% was achieved in total volume transported through the port, with container traffic growing by more than 13%. In line with this, total volume for the Port Railway increased by over 7% and container traffic by 17%. For 2010 the Port Railway should be capable of handling 2.5m – 2.8m TEU, and then approx. 3.5m TEU in the year 2015. The number of goods trains to and from the port will thus double to more than 400 trains per day. This would correspond to relieving the roads and motorways in the environs of the port of approx. 14,000 truck journeys per day.

Figure 71: Container Terminals Waltershof – Port of Hamburg

In an "overnight leap", goods transhipped in Hamburg reach major trading/industrial centres of Germany, Austria and Switzerland within 24 hours. Rail services ensure rapid accessibility to and from Eastern Europe and Scandinavia. Those services could only be maintained and further expanded through constant adaptation and continuous expansion of the Port Railway that utilize state-of-the-art rail technology. Between 1993 and 2001 the Free and Hanseatic City of Hamburg (FHH) invested €120m in the modernization and expansion of the Port Railway, of which some €20m went towards further developing the Port Railway Information and Operation System (PRIOS). Around €13m per year are made available for maintenance of the facilities. The Port Railway is operated by the FHH (as owner and operator of the infrastructure) and

Deutsche Bahn AG / Railion HH-port (conducting marshalling operations under contract to the FHH) in close cooperation with trade and industry in the Port of Hamburg (as owners of private sidings). The Port Railway operating agreement between the Free and Hanseatic City of Hamburg and Deutsche Bahn AG dates from the year 1929. Currently covering about 350 km, the Port Railway network, to which at least 250 km of private sidings owned by companies in the port business community are at present linked, connects cargo-handling locations in the port with railway routes extending inland.

Figure 72: PRIOS Control tower

Apart from the commercial and operational driving forces that guided the development of PRIOS, environmental considerations played an important role. The inherent advantages of rail transport are proven and widely accepted. The expansion and efficient operation of the rail network offers significant environmental benefits. In comparison to truck and airplane, the considerably better energy efficiency (about three times better than road), lower emissions, high security (less economic damage/accidents) and little space requirements have to be stated as major aspects. The attempts of policy, in legitimate concern for environment and ecology, therefore aim to relocate the transportation of as many passengers and goods as possible onto the railway, as well as the general promotion of railway-suitable traffic.

The Port Railway Information and Operation System (PRIOS), widely known as HABIS (Hafenbahn Betriebs und Informationssystem) in Germany, is an IT-system owned by the City of Hamburg aiming to optimise rail transport operations. It has been operational since the late 1980's and has been constantly extended during that time. Railway companies, haulage contractors, terminals, shipping agents, customs and others are connected to PRIOS via system interfaces. Together, all involved parties use the "programs" and functions provided centrally for the port railway by the

City of Hamburg in order to optimize the tightly interlocked and inter-coordinated operational procedures of freight haulage, and to cope with the constantly increasing volume of goods. PRIOS serves to optimize the operational handling of individual customer transport contracts as well as all-round control of the deployment of resources on the Hamburg Port Railway (locomotives, wagons, track occupancies), including preliminary planning, deployment and post-contract runs.

PRIOS is used to manage the movements of both incoming and outgoing (export / import) railcars. All the data required for operation and handling is available and accessible during the time that the railcars are located in the Port Railway system. Furthermore, locations and utilization of the sidings can be graphically presented and observed on the large, high-resolution screens with the aid of the so-called “siding monitors” (figure 73).

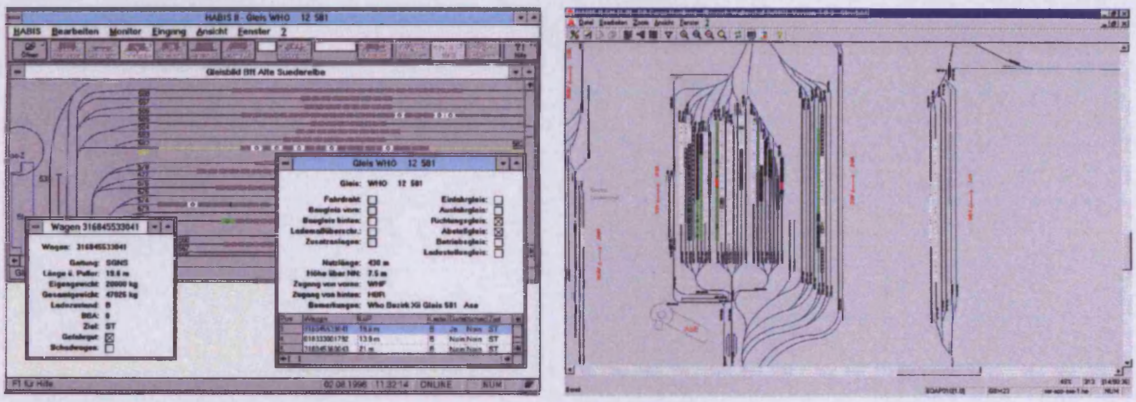


Figure 73: PRIOS display surfaces

In recent years the use and expansion of PRIOS in the Port of Hamburg has repeatedly enabled optimisations in the transport chain. This will also cater for the high growth rates predicted for the next few years. With the progressive spread of Electronic Data Processing (EDP) systems the idea was that all organisations working in the port should be put in a position to receive, to process and transmit to other parties all the data essential for the discharge of their special responsibilities within the port business community with the aid of just one technical link.

The main identified success factors for the implementation of PRIOS are summarised on the following table 69.

Table 69: Success factors for the implementation of PRIOS

- It has been a new and common IT system for all users in the Port of Hamburg
- It is financed by the Government and the Deutsche Bundesbahn (exempt from charges for users)
- The system was established following a phased approach
- All stakeholders were involved in the design of the system with the interest to find common and practical solutions
- The basis for participation in the system is the data exchange between all railway partners. They give their data into the system and at the same time they benefit from the broad offer of information.
- The customs started working with PRIOS at an early stage and this resulted in time-efficient operations and increased transparency.
- It is an absolutely reliable system running 24 hours per day.
- It optimises the usage of technical equipment, improves the assignment of personnel and the economy of time.
- It supports the flexibility of the Port.

(Michail 2005c)

The main identified benefits of efficient rail transport planning with PRIOS are summarised on the following table 70:

Table 70: Main benefits of PRIOS

- Shuttle engines (electric engines) conduct more runs (directly into the terminals – diesel engines consume more energy)
- Prevention of engine deadheads, unnecessary runs and interruption of runs (reduced energy consumption)
- Efficient advance planning (fast and reliable data exchange)
- Routeing optimisation (constantly available information about railroad car and engine locations)
- Flexible utilisation of facilities during capacity overloads
- Avoidance of unnecessary transport of empty railroad cars by coordination of loading and unloading (e.g. dispatching empty railroad cars, entrainment planning, reloading at the terminal)
- IT- and radio technology enables the flexible deployment of engines (e.g. by radio remote control)
- Supporting intermodal transport (rail/marine)
- Trans-shipment planning (containers on railroad cars)

- Direct connection to marshalling yards (data transmission to marshalling yards in the hinterland and within the port)
- Optimised utilisation of the available infrastructure (e.g. flexible planning of traffic, use of existing transportation space)
- Support of automated partial procedures (e.g. humps/train-assembly and – disassembly yard)
- Time optimisation (e.g. railroad car idle time, direct and fastest routes)
- Reduced expenditure (including time) and less strain on resources through optimised processes
- Information and data exchange between all parties of the transport chain and within the Port logistic node
- Access of many users to few databases (e.g. master file)
- A cascading system of categorised information through single access point with practical guidance.
- Constantly available information on hazardous materials for users and rescue services, and direct link to hazardous material information system
- Reduction of expensive single-car traffic by promotion of block train traffic (no separation of car units) and return shuttle transports (point-to-point traffic)

(Michail 2005c)

The following table 71 highlights some quotes from users of the PRIOS system providing evidence with regard to its efficient operation and benefits. The comments also reflect on challenges and suggestions for future development of the system.

Table 71: Evidence of efficiency – users' comments

1. Software developer and electronic data processing centre of PRIOS

DAKOSY, Mr. Wrage (Speaker of the Board of Directors):
"The system of PRIOS is unique in the ports of the Hamburg-Le Havre range. Its main advantage is to realise the paperless flow of all railway-related information in the port and the management of rail traffic. As a result the handling of goods in the port of Hamburg has become faster. For the future PRIOS has to be transformed from a reactive to a more active system integrating all relevant operational aspects."

2. Railway undertaking

Railion Deutschland AG, Mr. Lawrenz (Head of the DB Cargo Centre, Port of Hamburg):
"In former times container handling required the exchange of a high volume of paper borne information. The new IT net and PRIOS have taken over most of these tasks. The

development made it possible for the port railway to handle 1.2 m TEU each year. Due to the expected increase in turnover and the change in user-standards there is the urgent need to modernise PRIOS in the near future."

3. Customers

EUROKOMBI (Subsidiary of EUROGATE and Kombiverkehr, multimodal terminal operator), Mr. Völkoi (deputy leader of the disposition centre):
"PRIOS is used both intensively and comprehensively by our organisation. The main advantages are related to the management of import and export processes and all container activities in cooperation with Railion Deutschland AG. The PRIOS IT platform is user friendly but, nevertheless, it is necessary to upgrade the system and accelerate its processes."

Transfracht international (Railway operator), Mr. Wörner (leader operation German ports/sales Hamburg) and Mr. Flasch (expert):
"For the railway PRIOS is an essential element of the container handling. It is unique in Germany in that it links all partners: railways, customs, operators and customers. The main advantages are fast information exchange and no need for additional transport documents. The result is faster customs clearance and optimized time management in the port. For the future we need an updated version of PRIOS which will be even more user friendly and allow Europe-wide networking."

(Michail 2005c)

7.5.2.2 Other selected examples

Concerning the active role of ports in tackling the informational, technical and procedural bottlenecks of intermodal transport some further selected good practice examples are referenced below:

- Portinfolink – Port of Rotterdam: Port Infolink is a port-wide IT platform used in the port of Rotterdam aiming towards one single Port Community System. The Port Community System enables all the links within the port of Rotterdam's logistics chain to efficiently exchange information with one another (Port infolink 2005).
- AMSbarge – port of Amsterdam: AMSbarge is an inland navigation ship which has its own heavy container crane and can load and unload containers independently of terminals or cranes on the quay – provided there are mooring

facilities. The concept has been developed by the Port of Amsterdam in cooperation with a number of large shippers (Port of Amsterdam 2006).

- Dutch ports – Distrivaart system: An example of an innovative logistic system is the Netherlands's Distrivaart inland waterways-based distribution system for Fast Moving Consumer Goods (abbreviated as FMCG, e.g., groceries with a high turnaround rate in retail such as toilet paper and beer). This system replaces a large part of existing road-based transport for the distribution of these goods by inland waterways transport. Intermodality, in this example, involves the synergic use of two modal systems: roads for shipments needing high responsiveness, and inland waterways for the steady flows (Nationale Havenraad 2003).

7.6 Conclusions

This chapter discussed in detail via a series of specifically designed surveys and case studies the contribution of seaports, arguably the most complex and critical of the logistic nodes, to the environmental management of the logistic chain. Port environmental management is a core component of holistic chain management.

The chapter established that port environmental management has progressed steadily in Europe during the last decade and further progress is achievable through the pro-active, collaborative programmes of the sector itself aimed specifically at compliance with legislation and the attainment of high standards of environmental protection through voluntary, self-regulation. The port sector can demonstrate an established track record of sustained activity aimed at improving benchmark performance, building port-based expertise and competence, and setting new standards of effective management which is demonstrably leading to continuous improvement and greater environmental protection. The trends towards expanding the use and application within the European port sector of the existing port-inspired tools and methodologies justify an optimistic outlook with regard to the future performance. Adapting and further developing the Work port evolution model (Beresford, Gardner et al. 2004) the following figure summarises the evolution of port environmental management practices from 1960s onwards.

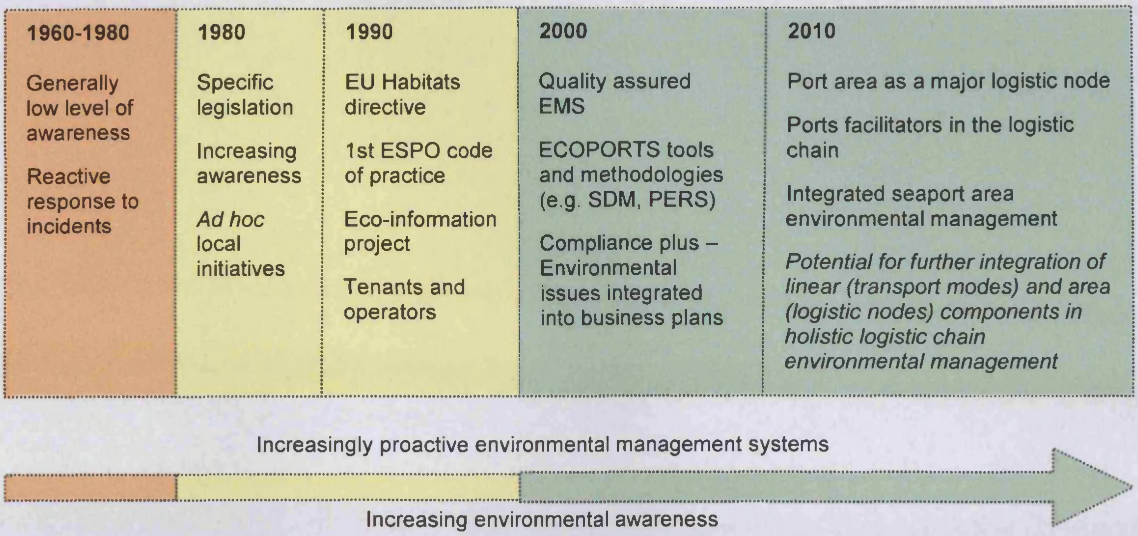


Figure 74: Evolution model of port environmental management interest and practice

From a logistic chain perspective it is of particular interest to note the integrative evolution regarding the scope of environmental management efforts. Broadening of scope can be observed from port authority's activities management (60s – 80s) to considering tenants' and operators' activities (80s-90s) over which an influence may reasonably be expected and finally to integrated seaport area environmental management (2000 onwards). Seaport environmental management progressed from a sector-by-sector point focussed approach to an integrated seaport area management concept. In line with this development, the chapter argued that there is potential for further integration as seaports proactively act as facilitators of procedures and of communication between the different parties involved in the logistic chain. The role of port authorities as facilitators within the logistic chain is poised to make a substantive contribution towards the goal of effective environmental management throughout the transport system. The way forward is likely to be that of further integration of linear (transport modes) and nodal (logistic nodes) components under holistic management frameworks. These likely future trends have significant implications regarding the feasibility assessment of an holistic environmental management framework for the logistic chain and they overall justify an optimistic standpoint.

8 Environmental management response options: the example of noise

The previous chapter discussed in detail the contribution of the logistic nodes and particularly seaport areas, in the environmental management of the logistic chain. This chapter aims to demonstrate environmental management response options in order to tackle environmental challenges that arise from the operation of logistic chains. For that purpose, the example of environmental noise, one of the major environmental aspects associated with transport and the logistic chain, was selected. The focus is placed on the analysis of environmental noise management in the logistic chain and the available management response options for the chain's links, components and players. The matrices that were designed in chapter 5 form the basis of a noise management tool that is presented, explained and analysed. Then, by selecting seaport areas as a demonstrative example, the application of noise management, and associated tools and methodologies are presented. Specific attention is paid to noise monitoring, prediction and mapping as the main and arguably most effective noise management tools. Selected noise monitoring and mapping applications are designed in order to investigate and demonstrate the contribution of those tools in assisting noise action planning and evidence based noise management decision making.

Sections 8.1 and 8.2 introduce environmental noise, its significance for the logistic chain, its characteristics, main impacts and indicators. Section 8.3 discusses noise management in the logistic chain by presenting a generic management framework and by outlining its components. Sections 8.4 to 8.8 focus on seaport areas in order to analytically demonstrate tools, methodologies, and response options for integrated noise management. Finally, section 8.9 concludes the chapter by summarising the main findings and their implications.

8.1 Significance of noise in the logistic chain

As discussed throughout the thesis and analytically in chapters 4 and 5, the environmental impacts of logistic chains' operations are multiple affecting air, water and soil quality, landscape, ecosystems, biodiversity and human health. In order to investigate and demonstrate available environmental management response options that contribute to the operation of more sustainable logistic chains, the case of environmental noise management was selected. Generation of noise, the acoustical phenomenon producing a sensation perceived as disagreeable or disturbing by an individual or a group (Linster 1990), is arguably one of the major environmental aspects associated with logistic chain operations. Noise is generated by the operation of all the freight transport modes, it is a high priority issue in all major logistic nodes (e.g. airports and seaports), and it is "the nuisance most often cited in connection with transport (Lamure 1990)". The following table summarises some evidence statements from various sources that demonstrate the significance of noise as a major environmental aspect associated with transport and related operations.

Table 72: Evidence statements on the significance of noise

Statements on the significance of noise	**Source**
Noise is one of the most obvious environmental impacts of transport activity	(Quinet 2003)
Noise warrants special consideration because it is arguably the most widespread and characteristic nuisance associated with land transport	(Lamure 1990)
• Transport is by far the prime source of noise • .. the most serious and frequent environmental complaint • .. people consider noise to be a more serious nuisance than air pollution	(OECD 1988)
People feel more directly affected by noise pollution than by any other form of pollution	(OECD 1997)
Environmental noise ... one of the main environmental problems in Europe	(European Parliament 2002)
The number of European citizens that are annoyed by environmental noise shows an ever growing tendency	(IMAGINE project 2007)

Noise pollution, the excessive or annoying degree of unwanted sound in a particular area, has become an increasingly significant environmental issue for many port authorities. Noise is arguably one of the most transboundary phenomena requiring operational control, is an issue throughout the logistic chain and a major consideration in the often sensitive relationship between port and city.	(Wooldridge 2007)
Aircraft noise is a key issue for the local community and its effective management is an important part of our ability to develop in a responsible way.	(Southampton Airport 2007)
Although rail transport has a low environmental impact overall, noise from goods trains remains a major problem	(Hubner 2000)

The degree of complexity of environmental issues varies and depends on parameters such as the applied regulative framework, the magnitude, scale, and causal mechanisms of the arising environmental impact. An issue can therefore be very complex and this could apply for instance to exhaust emissions of air pollutants, dust, and noise. In line with their degree of complexity, some issues can be controlled relatively easily and others are more difficult. Effective environmental management as stated in ISO is dedicated to controlling the impacts of operations. The bigger the number of operations/activities (sources) that contribute to an environmental impact, the more its effective management gets challenging. Noise is clearly a complex, transboundary, multi-source generated, difficult to control and effectively manage environmental aspect. Its selection was deliberate in order to demonstrate management response options and apply concepts and principles. If effective and integrated noise management can be achieved in the logistic chain, then arguably, integrated management may also be considered achievable for others, and often less complex environmental issues.

In addition, and apart from its established significance as one of the major environmental aspects of the logistic chain, noise is considered to be a representative example for investigating the practicability of integrated logistic chain environmental management. This is due to the relevance of the holistic principles and arguments in the case of environmental noise management. Despite the plethora of activities and sources that generate noise, the noise management interest should focus on the sum-total outcome (noise levels) and its associated effects on the physical and psychological health of humans and other living organisms. It can be argued that it would be ineffective to abate noise on a purely sector-by-sector basis. An approach to management that incorporates the holistic principles appears to be more effective and such an approach often implies collaboration between different parties and coordination of efforts in order to control, manage, and mitigate the arising impact. For all the above reasons the research selected to focus on environmental noise for the purposes of demonstrating management options and assessing whether or not integrated management in the logistic chain is feasible and practicable.

8.2 Environmental noise: characteristics and indicators

Measuring the magnitude of noise pollution is complex. Noise levels are measured in decibels (dB), based on a logarithmic scale correction for ear sensitivity at lower levels that is expressed by the A-weighting dB(A). However, a number of different parameters must be factored into an indicator of noise; volume, pitch, frequency, duration, and variability. Noise indicators are typically an average of volume and duration over a fixed period of time. Because noise level changes all the time, averaging is termed equivalent noise level (L_{eq}). L_{Aeq} refers to the energy equivalent average sound pressure level measured using the A-weighting which is most sensitive to speech intelligibility frequencies of the human ear (EEA 2007 a).

As the same noise is judged differently between day time and night time, the EU proposed time periods for calculations are (Wooldridge 2007):

- L_{day} is the A-weighted long-term average sound level 07:00-19:00 (12 hours)
- $L_{evening}$ is the A-weighted long-term average sound level 19:00-23:00 (4 hours)
- L_{night} is the A-weighted long-term average sound level 23:00-07:00 (8 hours)

The overall day-evening-night noise level is expressed by the L_{den} indicator. L_{den} is a descriptor of noise level based on energy equivalent noise level (L_{eq}) over a whole 24 hour day with a penalty of 10 dB(A) for night time noise (23.00-7.00) and an additional penalty of 5 dB(A) for evening noise (19.00-23.00) (EEA 2007 a). In accordance to its definition the L_{den} indicator is described by the following logarithmic equation.

$$L_{den}=10\log_{10}\left(\frac{12}{24}\times 10^{\frac{L_{day}}{10}}+\frac{4}{24}\times 10^{\frac{L_{evening}+5}{10}}+\frac{8}{24}\times 10^{\frac{L_{night}+10}{10}}\right)$$

Typical noise values are quoted as: conversation 60 dB(A), living areas 70 dB(A), industrial areas 80 dB(A) and the threshold of pain 140 dB(A) (Wooldridge 2007). The following figure 75 is adapted from (OECD 1988) and presents some further typical noise values of human activities and/or conditions.

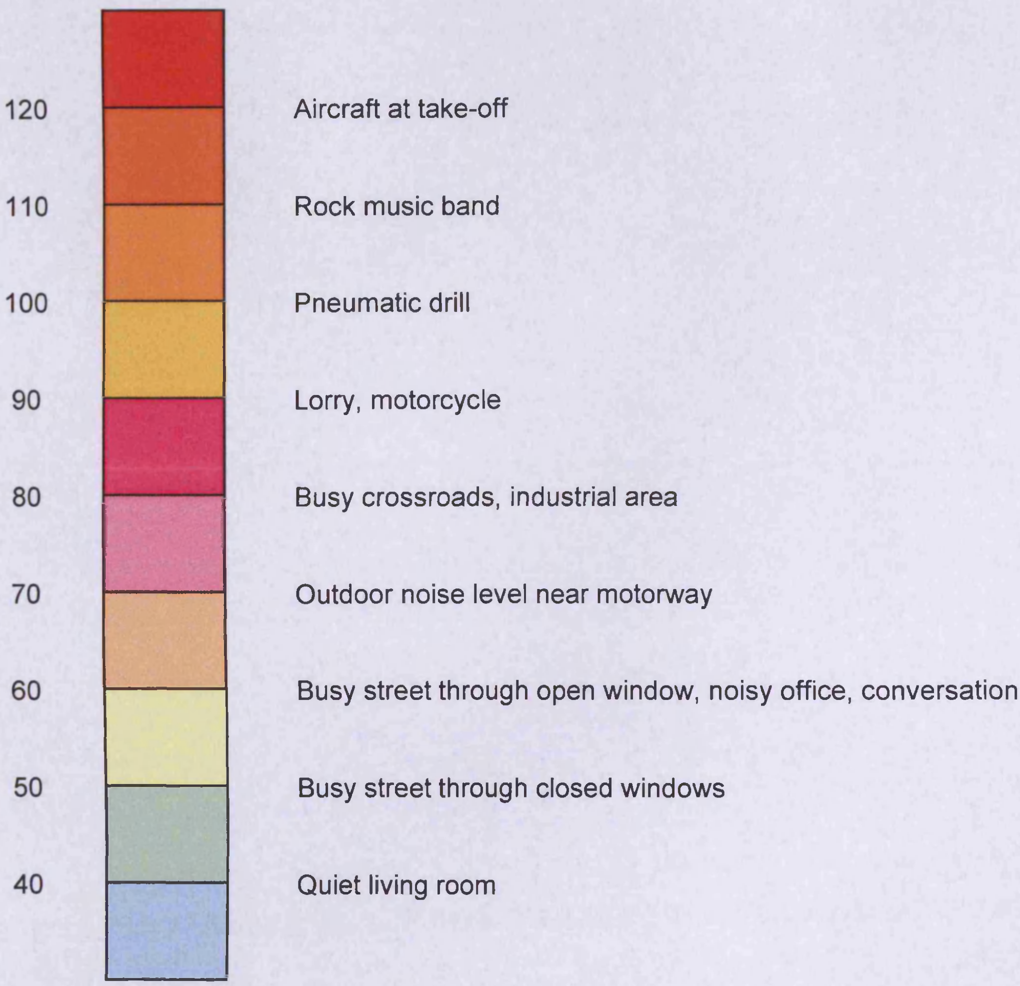


Figure 75: Typical noise levels (dB) by different sources

The context in which the noise occurs is important; a noise level which may be considered acceptable in a working environment during the day would be unacceptable in a residential neighbourhood at night. Similarly, noise which is expected, for example the acceleration of a truck which is visible, may be less annoying than unexpected noise, such as the same truck when the auditor cannot see it. In addition, the same volume of noise may be more tolerable when it is intermittent than when it is constant; thus railway noise can be more acceptable than quieter but more constant noise from road traffic. Noise exposure is frequently qualified by the number of people or share of the population exposed to this level of noise, or exposed to it for more than a fixed per cent of the time.

Transport noise causes undesirable social disturbances, affects human wellbeing, and can damage physical and psychological health. Hearing defects can be caused by noise levels above 85 dB(A), while lower levels, above 60 dB(A), may cause nervous stress reactions, such as an increase in the heart rate, an increase in blood pressure, and hormonal changes (Rothengatter 2003). The following table 73 summarises some of the main impacts of noise to human health and behaviour.

Table 73: Noise impacts to physical and psychological human health

Impacts of noise:
• Undesirable social disturbances • Annoyance • Behavioural changes (closing windows, shift of activities to quieter rooms, less use of outdoors amenities) • Stress effects • Hearing damages • Physiological reactions • Disorders in the cardiovascular and digestive systems • Effects on the duration and quality (from deep to light) of sleep • High blood pressure • Greater proneness to heart and circulatory diseases • Interference with verbal communication • Obscuring auditory warnings

Transport noise is, unlike most forms of air pollution, specific in space and especially in time. Noise causes nuisance only at the time and place it is emitted although the effects may be longer lasted. Transport is a major source of noise annoyance in most societies, partly due to its concentration in denser areas (Nijkamp, Ubbels et al. 2003).

8.3 Noise management in the logistic chain

This section discusses noise management throughout the logistic chain. It starts by presenting a generic model for logistic chain noise management based on the four main phases that are commonly encountered in environmental management systems; Plan, Do, Check, and Act. The main components of the model are then discussed. Firstly, the various sources in the chain that generate noise are presented in a systematic way. The section then focuses on the relative policy and regulative framework in Europe. The European Noise Directive (END) is highlighted and its provisions and implications are discussed. Selected initiatives that respond to identified noise management challenges are presented. Then the focus is placed on tools and methodologies for noise management. By further developing the scope of the matrices that were presented in chapter 5, a generic noise management assisting tool that links together the various sources of noise with applicable regulations and potential management response options is developed and analysed. The contributory role of monitoring and mapping in noise management decision making is highlighted and the main principles of those tools are outlined. Overall, the section provides an overview of noise management components, parameters and options in the logistic chain. The detailed demonstration of those follows analytically in the remaining sections of the chapter.

8.3.1 Generic model for integrated noise management

The generic model for integrated noise management in the logistic chain consists of four main phases reflecting the Plan, Do, Check and Act components that are usually encountered in environmental management systems such as ISO and EMAS. The four phases are: (1) Identifying challenges and prioritise objectives and targets, (2) Formulating a noise action plan and implementing noise mitigation measures, (3) Checking and assessing the efficiency of the taken measures, and (4) Reviewing the whole process and outcome and accordingly setting new objectives and targets, thus enabling continuous improvement of the noise situation. The model is schematically presented on the following figure 76 (Michail 2006c).

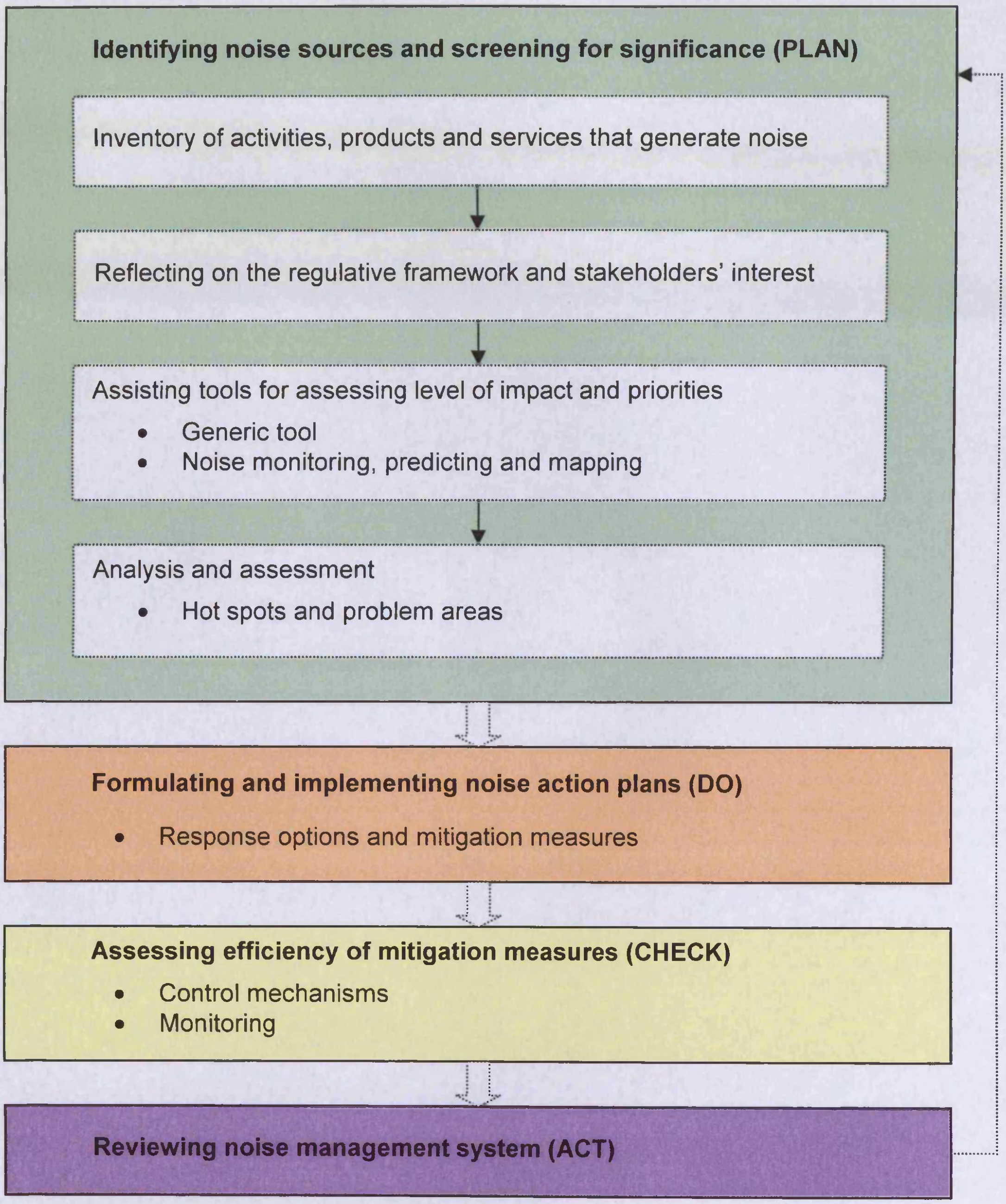


Figure 76: Generic model for integrated noise management

The following sections discuss the elements and components of the first phase in particular. The analysis of the noise impact of the logistic chain and transport related operations starts with the identification and study of those activities that generate noise. Then, the relative significance and contribution of the identified activities and operations to the noise situation is assessed. Reflecting on the applied regulative framework is important towards that direction. The application of tools and methodologies, such as noise monitoring and mapping, and the analysis of their outcomes, provide the necessary evidence for decision making on formulating action plans and prioritising and implementing mitigation measures.

8.3.2 Noise sources in the logistic chain

In order to highlight those activities, products, and services in the logistic chain that contribute to the generation of noise, the matrices that were presented in chapter 5 on the significant environmental aspects of the logistic chain, were modified as appropriate. In chapter 5, it was suggested that a potential application of using the matrices would be to isolate an environmental aspect and to focus upon its causal mechanisms throughout the logistic chain. This approach is demonstrated here while selecting to focus on the generation of noise. The matrix presented below occurred by extracting all noise related information from the 6 matrices presented in chapter 5. Some columns' modification has been considered relevant for reasons of synthesis (information of 6 matrices merged into one) and for avoiding repetition. The common environmental aspect of all the presented activities and operations is the generation of noise.

Table 74: Sources of noise in the logistic chain

Transport mode	Group activity	Activity
Road	Vehicle operation	Engine operation
	Vehicle operation	Tyres on road surface
	Vehicle operation	Body and suspension rattle
	Vehicle operation	Brake squeal
	Infrastructure operation	Terminals operation (cargo handling, warehousing, auxiliary fleet and equipment)
Rail	Train operation	All train types
	Train operation	Train signalling
	Infrastructure construction	Terminal and railway construction
	Infrastructure operation	Terminal operations (cargo handling, warehousing, auxiliary fleet and equipment)

Marine	Vessel operation	Ship manoeuvring in ports
	Vessel operation	Engine operation in ports (for electricity generation)
	Vessel operation	Vessel signalling
	Vessel operation	Vessel engine
	Infrastructure operation	Port operations (cargo handling, warehousing, auxiliary fleet and equipment, port generated traffic)
	Infrastructure operation	Port industrial area operations
Inland waterway	Barge operation	Barge engine
	Infrastructure operation	Inland port operations (cargo handling, warehousing, auxiliary fleet and equipment, port generated traffic)
	Infrastructure operation	Inland port industrial area operations
Air	Aircraft operation	Engine operation.
	Aircraft operation	Engine testing
	Aircraft operation	Supersonic aircrafts
	Aircraft operation	Aircrafts en route
	Airport operation	Airport operations (cargo handling, warehousing, auxiliary fleet and equipment, airport generated traffic)

(Michail 2006c)

The table demonstrates the range of activities related to the operation of different transport modes and logistic nodes that generate noise. It broadly identifies the areas that logistic chain noise management should focus upon. The table can be further adapted and modified according to specific applications. For example, in the case of studying a specific logistic chain (e.g. the transport chain of a given company from point A to point B), some of the presented activities would be naturally given priority over others that would not be so relevant (e.g. no air transport involved in that specific chain). A more detailed analysis of the prioritised relevant activities and how those affect the noise situation would then be expected. In the case of managing noise in a logistic node (e.g. seaport), the node specific operations that generate noise (e.g. cargo, handling, warehousing, auxiliary fleet and equipment and port generated traffic) would have to be analysed in greater detail.

8.3.3 Policy, challenges and initiatives

In order to assess the significance and prioritise between the various identified noise sources it is important to reflect on the applied regulative framework regarding those. This section takes mainly a European perspective and discusses the European policy with regard to environmental noise arising in particular from transport and logistic chain related operations. Selected challenges in noise management are presented and an overview of selected initiatives aiming towards tackling those challenges is presented. Environmental noise is a topic of growing concern in Europe, both on a central policy level and amongst European citizens. In spite of noise regulations and legislation that have existed for long time in many member states, the number of European citizens that are annoyed by environmental noise shows an ever growing tendency. The area where a quiet atmosphere can be experienced is reduced by the increased density of urban areas and particularly by the growing mobility (IMAGINE project 2007).

8.3.3.1 European Policy controlling environmental noise

The European legislation with regard to environmental noise dates back to the early 70s, with the Directive 70/157/EEC that introduced the first noise emission standards for motor vehicles. Those have been gradually tightened over time. The following table summarises the main European Commission's Directives and Decisions that address and regulate transport related generation of noise (EC DG Environment 2007 a).

Table 75: EU Directives addressing transport related noise

Noise source	EC Directives and Decisions	Addressing in specific
Road traffic noise	Directive 70/157/EEC	Motor Vehicles
	Directive 2001/43/EC	Tyres for motor vehicles and their trailers and their fitting
Aircraft noise	Directive 80/51/EEC	Subsonic Aircraft
	Directive 89/629/EEC	Subsonic Jet Aeroplanes
	Directive 92/14/EEC	Limitation on operations of Aeroplanes

	Directive 2002/30/EC	Operating restrictions at Community airports
Railway noise	Directive 96/48/EC Directive 2004/50/EC	Interoperability of the Trans-European high-speed rail system
	Decision 2002/735/EC	Technical specification for interoperability (TSI) relating to high-speed rolling stock
	Decision 2002/732/EC	Technical specification for interoperability (TSI) relating to high-speed railway infrastructures
	Directives: 2001/16/EC and 2004/50/EC Decisions 2004/446/EC and 2006/66/EC	Interoperability of the conventional Trans-European rail system
Equipment operation	Directive 2000/14/EC	Noise from Equipment for Use Outdoors

Source: (EC DG Environment 2007 a)

In order to assess objectively the exact size of the noise problem on a European scale and to monitor the efficiency of plans to control and reduce the effects, the European Noise Directive was set up. On 18 July 2002, the Directive 2002/49/EC (Environmental Noise Directive - in brief: END) entered into force by publication in the Official Journal of the European Communities. The European Community followed the noise protection policy outlined in the Green Paper "Future Noise Policy" by means of legal regulations including the issue of environmental noise emissions. The European Parliament, in its reaction to the Green Paper on Future Noise Policy, had noticed among others the lack of reliable, comparable data regarding the situation of various noise sources in Europe. The Environmental Noise Directive (2002/49/EC) responded to that by defining a common, harmonised set of noise indicators and a common approach to the production and presentation of noise data from the member states. Member states shall produce strategic noise maps for all major roads, railways and airports, and for all agglomerations with more than 250.000 inhabitants initially and 100.000 at a later stage.

The fundamental goal of the Directive is "to achieve a high level of health and environmental protection...". For this it is necessary "to avoid, prevent or reduce on a prioritised basis the harmful effects of noise, including annoyance" (European Parliament 2002). The associated objectives of the END are:

- Production of strategic maps to determine exposure to environmental noise using a method of assessment common to member states
- Development of action plans based on noise maps to prevent and reduce environmental noise particularly where exposure levels are harmful to human health, and to preserve existing noise quality where it is good
- Provision of information on environmental noise and its effects to the public
- Data submission to the Commission

Six annexes and their associated articles detail the methodologies and requirements related to noise indicators, strategic noise mapping and action plans. It is important to note that throughout the END, harmonisation of approach and methodology by member states is a major objective (Wooldridge 2007). In order to achieve this, fundamental criteria are specified for the assessment methodologies. The six annexes of the END are highlighted on the following table 76:

Table 76: Annexes of the European Noise Directive 2002/49/EC

- Annex I defines the day-evening-night level L_{den} and the night-time noise indicator L_{night}.
- Annex II describes the interim computation and the interim measurement methods for L_{den} and L_{night}.
- Annex III gives a very brief overview over possible assessment methods for harmful effects such as annoyance or sleep disturbance.
- Annex IV provides the minimum requirements for strategic noise mapping.
- Annex V provides the minimum requirements for noise action plans.
- Annex VI lists the data to be sent to the Commission distinguishing between agglomerations and major traffic noise sources.

The Directive shall apply to environmental noise to which humans are exposed to in particular in built-up areas, in public parks or other quiet areas in an agglomeration, in quiet areas in the open country, near schools, hospitals and other noise-sensitive buildings and areas. For this reason strategic noise maps are to be produced for:

- Agglomerations (part of a territory having a population exceeding more than 100.000 persons and a typical population density for urbanised areas)

- Major roads (regional, national or international roads, with an annual traffic of more than three million vehicles)
- Major railways (railways with an annual traffic of more than 30.000 trains)
- Major airports (civil airports with an annual traffic of more than 50.000 movements of aircrafts)

Strategic noise maps for agglomerations shall put special emphasis on the noise emitted by road traffic, rail traffic, airports, and industrial activity sites, including seaports. The requirements of the END have to be fulfilled according to the time-scale as shown in Table 77:

Table 77: Time-scale for the production of strategic noise maps and action plans

Area / source to be investigated	Strategic noise maps until	Action plans until
Agglomerations		
>250,000 inhabitants	30 June 2007	18 July 2008
>100,000 inhabitants	30 June 2012	18 July 2013
Major roads		
>6,000,000 vehicle passages per year	30 June 2007	18 July 2008
>3,000,000 vehicle passages per year	30 June 2012	18 July 2013
Major railways		
>60,000 train passages per year	30 June 2007	18 July 2008
>30,000 train passages per year	30 June 2012	18 July 2013
Major airports		
>50,000 movements per year	30 June 2007	18 July 2008

The purpose of these maps is not only to provide data to the Commission, but more specifically to represent a source of information to the citizens and to form the basis for noise action plans. This requirement sets specific demands for the character of the noise maps and the way in which are to be produced. In communicating noise maps to the public, the maps should be understandable, straightforward, unambiguous and credible. Particularly for the last criterion, there is often a call for measured data, which by nature seems to have more credibility than estimates.

8.3.3.2 Challenges and initiatives

The Commission acknowledges the need for improvement of the existing noise calculation methods, particularly for noise mapping but also for other purposes (IMAGINE project 2007). Various calculation methods for noise levels are used by different European countries. Table 78 presents the results of applying different calculation methods from different countries to a single simple case study (Lang 1986) of road generated noise emissions. A significant maximum deviation of 6 dB can be observed. Although the study dates back in 1986, it is important to note that the heterogeneity of noise calculation methods in Europe is still a reality and a main challenge.

Table 78: Variations between different calculation methods

Country	L_{Aeq} (dB)
Austria	67
(Czechoslovakia)	72
France	73-74
Germany	68
Hungary	73
Netherlands	70
Scandinavian countries	70
Switzerland	68
United Kingdom	68
EC	68

Source: Lang 1986

Lamure (1990) argues that the heterogeneity of noise calculation methods is challenging international comparison and exchange of knowledge between European countries and therefore there is a need to harmonise the different methods in Europe. The following table 79 (EC DG Environment 2007 b) summarises some of the main EC supported research and development projects that address different elements of environmental noise management.

Table 79: Summary of main EU projects and initiatives on noise management

Initiative	Description
The EU Noise Expert Network (1998)	The European Commission created an EU noise Expert Network, whose mission was to provide assistance in the development of the European noise policy
Harmonoise (2001 - 2005)	The Harmonoise project has produced methods for the prediction of environmental noise levels caused by road and railway traffic. These methods are intended to become the harmonized methods for noise mapping in all EU Member States. The methods are developed to predict the noise levels in terms of Lden and Lnight, which are the harmonized noise indicators according to the Environmental Noise Directive 2002/49/EC (HARMONOISE project 2006).
Imagine (2004 - 2007)	The IMAGINE project developed new calculation methods for railway, road, industrial and aircraft noise. IMAGINE built on the experience and outcomes of the Harmonoise project in order to standardise noise prediction methods and provide guidelines on how to use these methods for noise mapping and noise action planning in the EC (IMAGINE project 2007).
NoMEPorts (2005 - 2008)	The main objective of NoMEPorts is reduction of noise, noise-related annoyance and health problems of people living around port industrial areas through demonstration of a noise mapping and management system. The demonstration leads to definition of relevant noise in industrial port areas in noise maps and definition of proposals for action plans to reduce noise annoyance (NoMEPorts project 2007).
GipSynoise (2002 - 2005)	The GipSynoise project created an integrated Geographical Information System tool to match the instructions of the END with regard acoustic mapping and related statistical data.
SILENCE (2007 – ongoing)	SILENCE aims to develop an integrated methodology and technology for improved control of surface transport noise in urban areas. Issues that are covered, include noise control at the source, noise propagation, noise emission, and the human perception of noise.
Q-CITY (2005 - 2009	The aim of the project QCITY is to develop an integrated technology infrastructure for the efficient control of road and rail ambient noise by considering the attenuation of noise creation at source at both vehicle/infrastructure levels. A major objective is to provide municipalities with tools to establish noise maps and actions plans and to provide them with a broad range of validated technical solutions for the specific hot-spot problems they encounter in their specific city.

SILVIA project (2002 -2005)	The SILVIA project provided decision-makers with tools to rationally plan traffic noise control measures. The main final product was a "European Guidance Manual on the Utilisation of Low-Noise Road Surfacing" integrating low-noise surfaces with other traffic noise control measures including vehicle and tyre noise regulation, traffic management and other noise abatement measures.
RoTraNoMo (2002 -2005)	ROTRANOMO (Road Traffic Noise Model) project developed tools for road traffic noise calculations. Those included detailed models for traffic flow and vehicle noise.
X-NOISE (2006-2010)	X-NOISE is a collaborative network project in the area of aeroacoustics. The main aim is to lower the exposure of community to aircraft noise.
SOURDINE II (Ongoing)	SOURDINE II is a Research, Technology development and Demonstration project aimed at providing solutions on airport approach and departure procedures. The aim is the reduction of the environmental (noise and emissions) impact around airports.

Compiled from (EC DG Environment 2007 b) and associated project websites

It is important to observe the wide range of elements that are addressed by the various initiatives. The research areas of interest vary from traffic (e.g. road, air) to logistic nodes (e.g. seaport areas, airports) generated noise and from very technical aspects (e.g. harmonisation of computation methods for noise mapping) to more generic guidelines regarding tools and methodologies for noise management.

8.3.4 Tools and methodologies

After discussing the regulative and current research framework in Europe, this section focuses on tools and methodologies that assist the environmental noise management in the logistic chain. The section starts by presenting and discussing a generic noise management tool that links together the different identified noise sources in the chain with the applied regulations and standards and with potential response options. The focus is then placed on noise monitoring and mapping as the main and arguably most effective tools for assessing noise situation and determining the priorities of noise management. It should be noticed that the aim here is to outline the principles regarding the application of tools and methodologies. Those are further and analytically demonstrated on the sections to follow (8.4 – 8.8) where specific case studies are set and discussed.

8.3.4.1 Generic noise management tool

As suggested in chapter 5, the presented matrices could form the basis of a management tool for the significant environmental aspects in the logistic chain. This is demonstrated here with the example of noise and by further developing the table 74 of section 8.3.2. The table is complemented in order to include information on applied regulations for each of the identified activities generating noise, and potential response options that could be adopted by the responsible parties for managing those activities (Michail 2006c). The elaborated matrix is presented below (table 80). It should be noticed that the matrix does not aim to be exhaustive in providing all applied regulations and all possible response options. It demonstrates though how the relevant managers could use such a matrix as a tool to manage and control noise at different levels and overall in the logistic chain.

The table can be further adapted and modified according to specific applications in the same way that was discussed in section 8.3.2. The examination of the identified noise sources in line with the applied regulative framework and potential response options facilitates decision making related to controlling the noise impact. In order to provide evidence on the significance and contribution of the different noise sources to the overall noise situation and thus to enable the prioritising of different actions, assisting tools and methodologies such as noise monitoring and noise mapping could be applied.

Table 80: Generic noise management assisting tool

Transport mode	Group activity	Activity	Selected regulations applied in Europe	Examples of management response options
Road	Vehicle operation	Engine operation	Noise emissions standards for vehicles (per type) END requirements	• Compliance / Compliance plus • Noise mapping and action planning • Various source, propagation, or receiver based mitigation measures (e.g. scheduling flows, noise barriers, and double glazing in affected residences)
	Vehicle operation	Tyres on road surface	Directive 2001/43/EC	• Tyre technologies • Road surface techniques • Eco-driving
	Vehicle operation	Body and suspension rattle	Directive 2001/43/EC	• Quieter technologies • Maintain flat surface (no tracks through roads) • Eco-driving
	Vehicle operation	Brake squeal	Unregulated	• Speed limits • Eco-driving • Maintenance
	Infrastructure operation	Terminals operation (cargo handling, warehousing, auxiliary fleet and equipment)	END requirements Industrial zones noise limits	• Compliance / Compliance plus • Noise mapping and action planning • Various source, propagation, or receiver based mitigation measures • Optimal logistics

Rail	Train operation	All train types	Noise emission standards END requirements	• Compliance / Compliance plus • Noise mapping and noise action plans • Mitigation measures (source, propagation, receiver)
	Train operation	Train signalling	Unregulated	• Minimising train signalling
	Infrastructure operation	Terminal operations (cargo handling, warehousing, auxiliary fleet and equipment)	END requirements Industrial zones noise limits	• Compliance / Compliance plus • Noise mapping and action planning • Various source, propagation, or receiver based mitigation measures
Marine	Vessel operation	Ship manoeuvring in ports	Unregulated	• Scheduling
	Vessel operation	Engine operation in ports (for electricity generation)	Unregulated	• Good practice solutions (e.g. Shore to ship electricity supply)
	Vessel operation	Vessel signalling	Unregulated	• Minimising vessel signalling
	Vessel operation	Vessel engine	Noise emission standards	• Compliance / Compliance plus
	Infrastructure operation	Port operations (cargo, handling, warehousing, port generated traffic)	END requirements	• Noise mapping and action planning • Noise monitoring program • Recording complaints • Various source, propagation, or receiver based mitigation measures
	Infrastructure operation	Seaport industrial area operations	Industrial zones noise limits	• Compliance / Compliance plus • Planning while locating companies

Inland waterway	Barge operation	Barge engine	Noise emission standards	• Compliance / Compliance plus
	Infrastructure operation	Inland port operations (cargo, handling, warehousing, port generated traffic)	END requirements	• Noise mapping and action planning • Various source, propagation, or receiver based mitigation measures
	Infrastructure operation	Inland port industrial area operations	Industrial zones noise limits	• Compliance / Compliance plus • Planning while locating companies
Air	Aircraft operation	Engine operation.	Aircraft noise emissions standards Take-off procedures	• Compliance / Compliance plus • Take-off procedures • Flights scheduling and routing • Strict limits on ground running of aircraft engines
	Aircraft operation	Engine testing	Unregulated	• Strict limits on aircraft engine testing
	Aircraft operation	Supersonic aircrafts	Aircraft noise emissions standards	• Compliance / Compliance plus
	Aircraft operation	Aircrafts en route	Aircraft noise emissions standards	• Compliance / Compliance plus
	Airport operation	Airport operations (cargo handling, warehousing, auxiliary fleet and equipment, airport generated traffic)	END requirements	• Noise monitoring program • Recording complaints

(Michail 2006c) Sources of information: (Hubner 2000; European Parliament 2002; Southampton Airport 2007; EC DG Environment 2007 a)

8.3.4.2 Noise monitoring, predicting and mapping

Noise monitoring and noise mapping are the main applicable assisting methods for estimating and assessing the noise situation in a given area. Monitoring provides actual measured noise values by making use of specialised noise monitoring equipment (sound level meters). Noise mapping provides an overall assessment of the noise situation based on estimations and predictions of actual values by making use of increasingly advanced specialised software packages.

Theoretically, noise monitoring can be seen as the most accurate method in determining noise values in locations of interest. By nature, measured values appear to have more credibility in the perception of general public, regulators and academics. In practice however, accurate monitoring is subject to several challenges. Sound level meters (noise monitoring equipment) measure noise values averaged over the duration of the measurements. The longer the duration of measurement the most representative the final result will be of the noise levels occurring in average at the location under question. In order to measure accurately the yearly averaged noise level on a selected location the duration of the measurement would ideally be a full year. Otherwise, the assumption would be that the selected duration of the measurement is representative of the typical activities and operations (noise sources) that occur during all year. In that case the yearly average would be an estimated value based on assumptions and not on actual values. Of course, non-stop noise monitoring for a full year may be considered impracticable and economically inefficient, especially when a plethora of locations of interest is identified.

Noise mapping aims to provide an overall analysis of the noise situation in the area where applied. It is assisted by advanced specialised software packages. A noise model needs to be created that simulates the noise sources in the area under study. The accuracy of the predicted noise values and assessment is closely dependant on the accuracy of the simulation of the noise sources and the resultant noise model. Generally, noise mapping is a tool primarily applicable to identify problem areas, significant noise sources and hot spots and not so much about accurately predicting the actual noise levels. The relative importance and contribution of single sources and groups of sources (e.g. road traffic, rail traffic, industrial noise) in the overall noise situation of a given geographical area is the main target of noise mapping applications. Apart from their differences in scope and application, both monitoring and mapping are valuable tools that assist managers in assessing the noise situation and in taking decisions regarding noise action planning and mitigation measures. Their fundamental contribution or value is that they form a credible, evidence-based scenario from which Action Plans can be produced. Both tools are analytically demonstrated in sections 8.5 and 8.6 via specifically designed case studies for that purpose.

8.4 Integrated seaport area noise management

After providing an overview of components, tools and methodologies for the environmental noise management in the logistic chain, the following sections of chapter 8 aim to demonstrate their application while focussing on the case of integrated seaport area noise management. Specific case studies are presented in order to demonstrate how the different components of noise management as they were presented in figure 76 could assist in managing noise in seaport areas effectively. The selection of seaports as noise management study areas was deliberate and reflected their significance as major logistic nodes, their complexity, and their specific interest with regard to noise management.

Noise is of particular interest in logistic nodes, due to the concentration of noise generating sources and their usual proximity to residential areas. Cerwerka (1990) argues that the noise exposure problem is concentrated in urban areas and it is probably less serious in long distance traffic. The magnitude of noise impact may be considered higher in logistic nodes. In addition, in logistic nodes most of the noise sources in the logistic chain coalesce. Seaport areas are arguably the most complex between the nodes and the ones with the highest intermodal interest. Integrated noise management in seaport areas is arguably as complex as integrated noise management of the logistic chain. The concept of area management is pertinent because noise is arguably one of the most transboundary phenomena requiring operational control, and a major consideration in the often sensitive relationship between port and city. Port authorities have become increasingly aware of the significance of noise in terms of complaints from local communities, and its importance in planning applications for port developments and in the whole debate on sustainability (Wooldridge 2007). The following figure 77 (Michail 2006c) schematically presents a generic phased approach with regard to port area noise management.

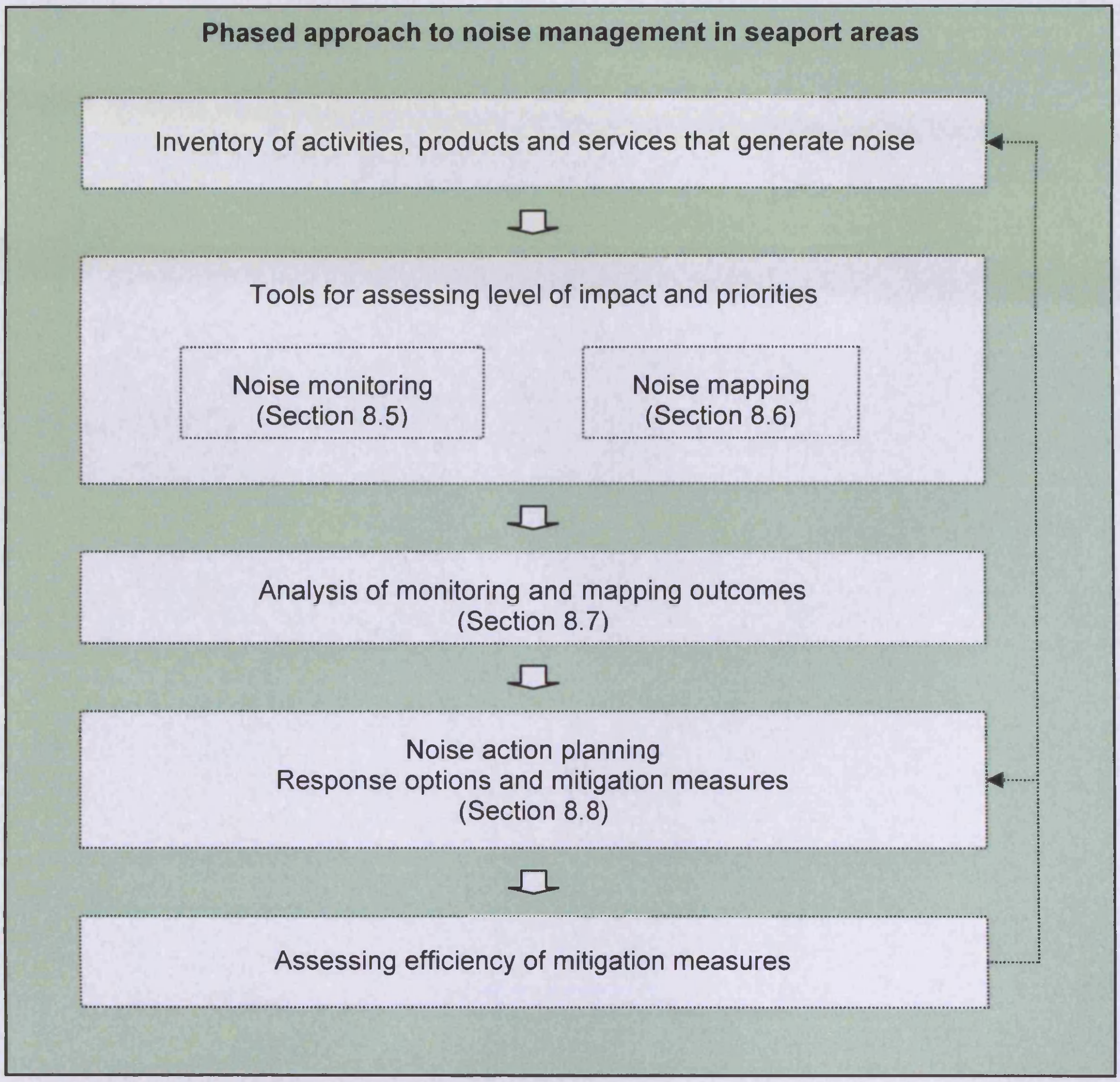


Figure 77: Phased approach to noise management in seaport areas

The figure also dictates the structure followed in the rest of this chapter. Sections 8.5 and 8.6 focus on the demonstration of the tools that are used in order to assess the level of noise impact and the relative contribution of different sources in the overall noise situation, noise monitoring and mapping respectively. Section 8.7 focuses on the analysis of the noise monitoring and mapping outcomes, and section 8.8 on noise action planning, response options and noise mitigation measures.

The research into noise management in seaport areas was based on experience gained from the participation in Cardiff University's role as partner and scientific coordinator of the EU co-funded NoMEPorts (Noise Management in European Ports) project. The constant cooperation and consultation with a European-wide extended panel of experts (acousticians, academics, and port professionals) provided the means for developing and validating concepts, models and approaches for seaport area noise management. In addition, the required technical means (noise monitoring and mapping equipment and software) were made available.

8.5 Noise monitoring in seaport areas

This section focuses on noise monitoring in seaport areas. First, the principles of monitoring are discussed and a generic model guiding the process of setting up and executing a noise monitoring program is developed and presented. Then, the established approach is demonstrated and tested on a specific noise monitoring study in the Port of Piraeus, Greece.

8.5.1 Generic approach to noise monitoring

Figure 78 presents a generic methodology for designing a noise monitoring program in seaport areas and in general (Michail 2006c). Noise monitoring programs may have different objectives according to the case and application. A definition of those objectives would determine the scheduling of the monitoring program and its main components and parameters. Objectives of noise monitoring programs could be:

- Determining noise values in selected locations of interest (e.g. monitoring at the limits of a residential area in order to assess the noise values that residents are exposed)
- Determining the sound power level of machinery and equipment. Such an objective could be applied when in a parallel noise mapping exercise there is uncertainty regarding the sound power level of noise sources (noise data to be included in the noise model). In that case the machinery or equipment under

question could be isolated from other noise sources, and a set of measurements in selected distances of the machinery could be made. The measured values could then serve as an input to specialised software (e.g. Acoustic Determinator, Bruel & Kjaer) in order to estimate the sound power level of the source under question.

- Providing the means for verifying and validating noise mapping outcomes by a series of measurements in selected locations. It should be acknowledged that noise maps indicate trends more than actual noise figures and that their main function is to demonstrate problem areas. Nevertheless, it is considered useful to examine the noise mapping outcomes (predicted, estimated values) in line with some actual values.

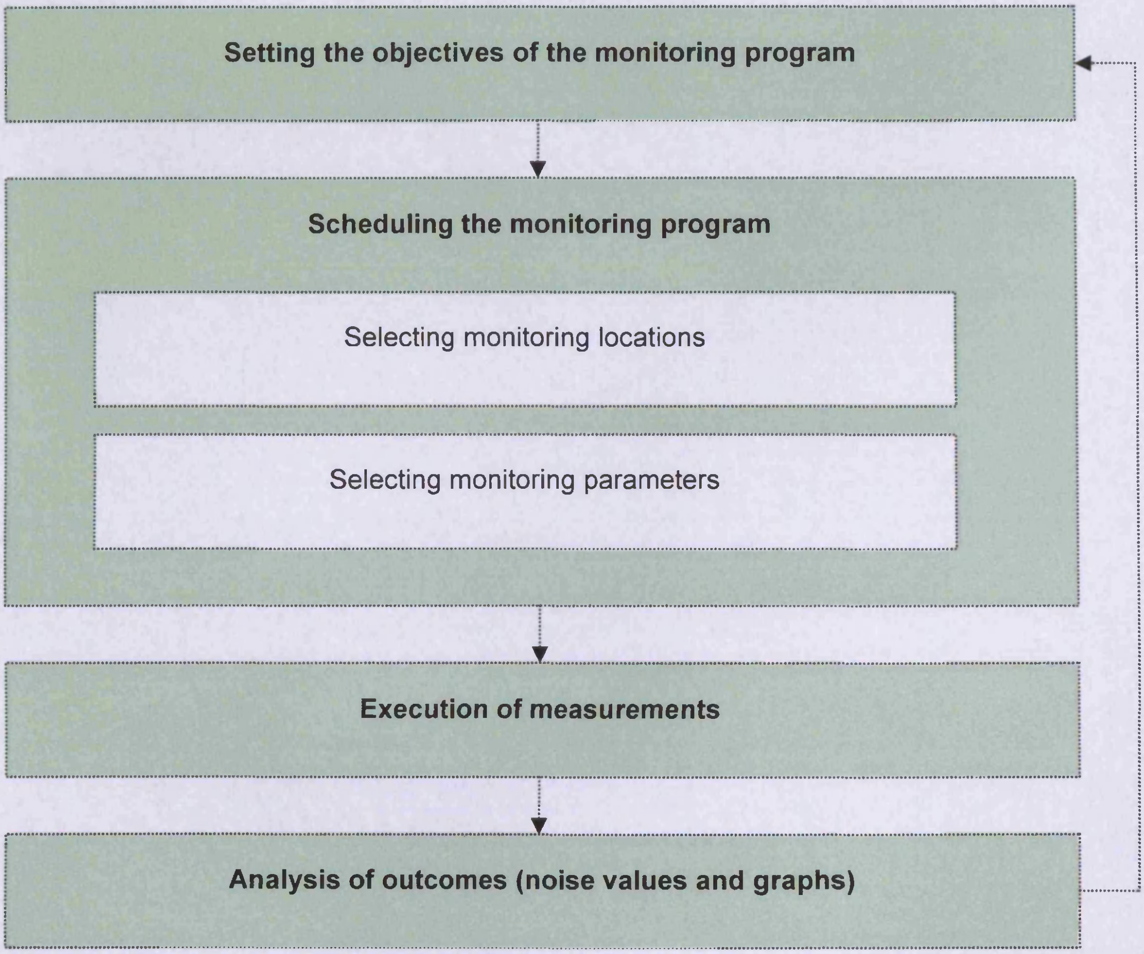


Figure 78: Generic approach to setting a noise monitoring program

From the above it can be demonstrated that the scheduling of a noise monitoring program is dependent on its objectives and application. The scheduling itself involves decision making with regard to parameters such as, the number of locations of interest, technical aspects of the measurements, timeframes, indicators to be used, and amount and duration of measurements per location. After defining those parameters the actual measurements can take place. The outcomes of monitoring are noise values for selected indicators, and noise graphs showing the variations of those indicators over the time period of the measurements. The analysis of the outcomes provides an understanding of the noise situation in the area under question in line with the set objectives.

8.5.2 Case study: Noise monitoring program at the Port of Piraeus

In order to demonstrate noise monitoring methodologies, practices and outcomes a monitoring program was set in the Port of Piraeus, Greece (Michail 2005-2006b). The Port of Piraeus was selected as one of the major large ports in South Europe with a total annual tonnage above 20 million tonnes and a container handling yearly rate of around 1.4 million TEU's (Piraeus Port Authority S.A. 2006). The monitoring program was the result of the cooperation between the Piraeus Port Authority, the University of Piraeus and Cardiff University. The measurements took place during the spring periods of two consecutive years, 2005 and 2006. In 2005, the measurements took place in the period between 14 and 19 of April and included noise monitoring in selected locations in both the Commercial and the Passengers' Port as well as in the City of Piraeus. In 2006, the noise survey took place in the period between 25 of April and 5 of May and consisted of noise monitoring in selected areas of the port's container terminal. The 2006 exercise built on the experience and results of the previous year's monitoring program.

In terms of equipment, two different sound level meters have been used (figure 79). In 2005, the instrument used for the measurements was the CEL-490 Sound Level Meter produced by CASELLA. In 2006, The 2250 Hand-Held Analyser Sound Level Meter produced by Bruel & Kjaer was used. Both sound level meters constitute current (2007) state-of-the art in monitoring environmental noise. They make use of recent developments in digital processors to feature a full 0-140 dB dynamic range on a single uninterrupted scale. In addition, the narrow band versions of these instruments offer real time frequency analysis. Their outcomes in terms of noise values are compatible and comparable, subject of course to the use of the same indicators and same measuring parameters. There is a difference though with regard to the visualisation of the produced noise graphs, since different software and display options are applied.

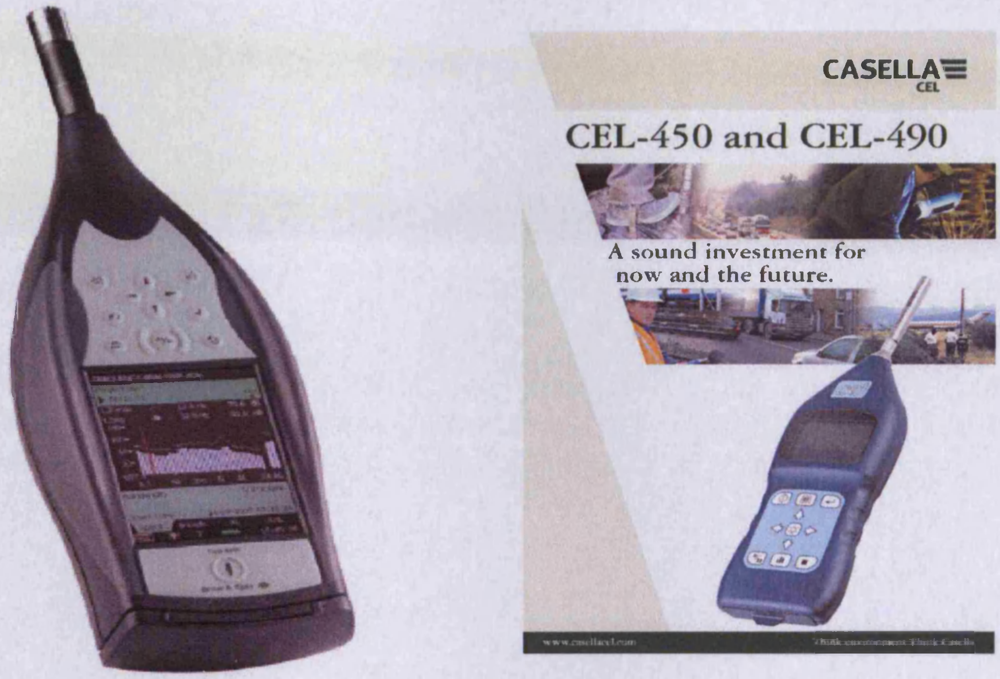


Figure 79: The Bruel & Kjaer 2250 (left) and the CASELLA CEL-490 (right) Sound Level Meters

The presentation of the monitoring program in Piraeus and its outcomes follows in this section in accordance with the structure dictated by the different steps of the generic approach that was presented in the previous paragraph (figure 78). With regard to the objectives of the monitoring program, a differentiation should be noticed between the first and the second year of measurements. In 2005, the program aimed at providing a general overview of noise values in selected locations in and around the port. Due to the fact that limited information was already available within the Port Authority the program aimed to provide actual noise information in selected sensitive spots. The selected spots were spread on both the commercial and the passenger's part of the port, and the city centre of Piraeus (figure 80[30]). The 2006 exercise took place in parallel with a noise mapping exercise in the container terminal (see section 8.6.3). The measurements were more focussed and addressed specifically locations inside and around the container terminal of the port (top left of figure 80). The aim was to follow up on the previous measurements in the terminal, to expand the number of locations, and to gather necessary information that would assist in the analysis and validation of the parallel noise mapping exercise.

Figure 80: Commercial (top left) and Passengers' (lower right) part of the Port of Piraeus

In line with the objectives of the program for both years and in close cooperation with the environmental manager of the Port Authority, the monitoring program was designed and the different parameters were set (Michail 2005-2006b). The following figures 81 and 82 [31] highlight the selected locations were the measurements took place for the commercial, and the passengers' port respectively. As demonstrated in the figures, measurements took place in a total of 11 locations, 7 of which in and around the commercial and 4 in and around the passengers' part of the Port. As explained above the measurements in the commercial port took place in both 2005 and 2006, while the ones in the passengers' port took place only in spring 2005.

[30] Source: Google Earth
[31] Source: Google Earth

Figure 81: Selected monitoring locations in and around the Commercial Port

Figure 82: Selected monitoring locations in and around the Passengers' Port

The following table 81 describes the selected locations and provides information regarding the nature of the dominant noise sources on those locations.

Table 81: Description and noise characteristics of the selected noise monitoring locations

Location	Description	Dominant noise source type

1	At the limits of the commercial port and by the main road access to the container terminal	Road Traffic noise (both lorries and private cars)
2	Truck loading and unloading area inside the Container Terminal	Port operations (loading and unloading, trucks, straddle carriers)
3	At the "head" of the container terminal	Port operations (cranes, straddle carriers, container handling)
4	At Dimokratias Avenue above the commercial port	Road Traffic noise (public road – private cars)
5	Area where the handling and storage of empty containers take place	Port operations (empty container handling, fork lifters operation)
6	At the limits of the commercial port and by the main road access to the container terminal	Road Traffic noise (both lorries and private cars)
7	At the limits of the commercial port and by the main road access to the container terminal	Road Traffic noise and port operations (due to proximity to spot 2)
8	Passengers' Gate E6	Traffic noise and port operations (ships)
9	Passengers' Gate E8	Traffic noise and port operations (ships)
10	Passengers' Gate E9	Traffic noise and port operations (ships)
11	Piraeus city centre, in front of the "Dimotiko" Theatre	Road Traffic noise

(Michail 2005-2006b)

In the commercial port, seven measurement locations were selected in cooperation with the Port Authority. The selection was based on the noise significance of the locations both in geographical (e.g. limits of the port area, proximity to residential areas) and operational terms (e.g. identified main noise sources in and around the container terminal). Spots 1 (figure 83), 6, and 7 are situated by the main road access to the container terminal, which is identified as a major noise source, and in close proximity to the terminal's physical limits. Spot 2 (figure 84) is located at the area of loading and unloading trucks with the assistance of straddle carriers, one of the noisiest operations in the container terminal and the commercial port in general.

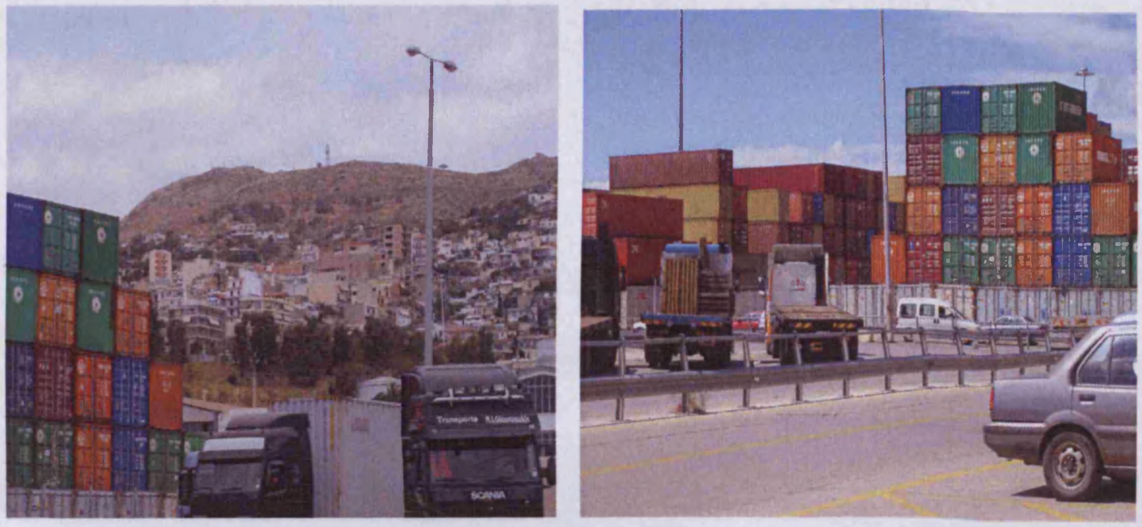


Figure 83: Limits of the Commercial Port of Piraeus (Spot 1)

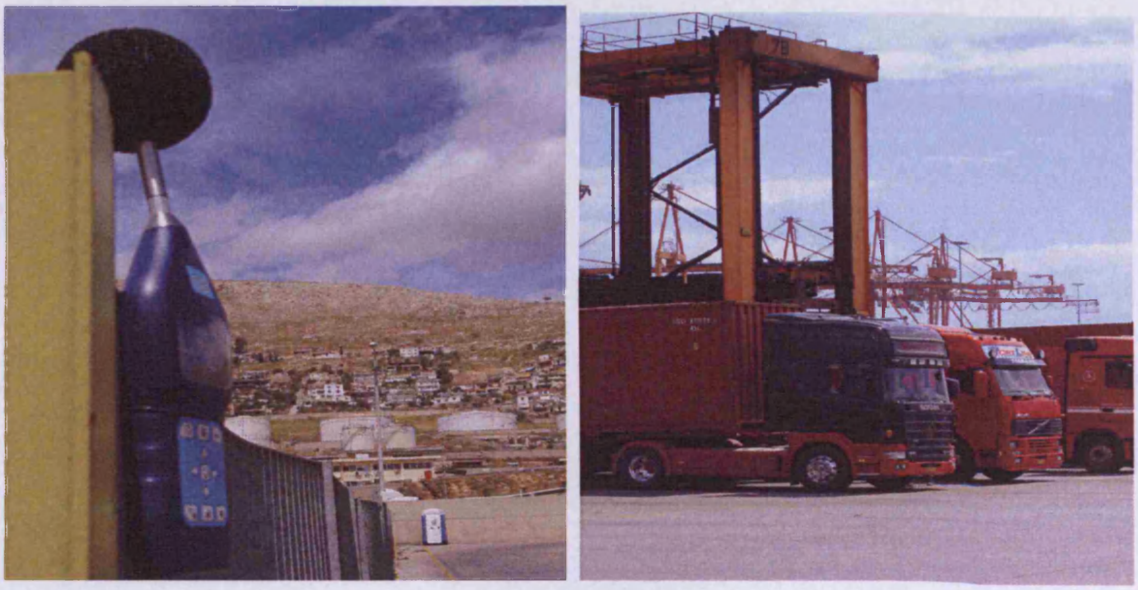


Figure 84: Trucks' loading and unloading area inside the Container Terminal (Spot 2)

Spot 3 (figure 85) is situated at the "head" of the container terminal where loading and unloading of container ships takes place and it reflects typical noise coming from container terminal activities. Spot 5 (figure 87) is located in the handling area for empty containers. The handling of empty containers is identified as a main noise source in the terminal[32] and the operations take place in close proximity to the physical limits of the terminal. Spot 4 (figure 86) is outside the physical limits of the port, by the busy "Dimocratias" Avenue, and in close proximity to the nearest to the port residential area. It was selected in order to investigate how non-port generated

[32] Complaints from residents living around the commercial port were recorded especially for noise coming from empty container handling during evening and night times.

road traffic contributes to the noise situation close to the residential area in comparison with the contribution of port traffic and operations.

Figure 85: Head of the Container Terminal (Spot 3)

Figure 86: View of the terminal from the "Dimokratias" avenue (spot 4)

Figure 87: Empty containers handling area (spot 5)

In the passengers' part of the port 4 locations were selected. Noise significance was again the main criterion guiding the selection process. The passengers' gates E6, E8 (figure 88), and E9 (figure 89) (spots 8, 9, and 10 respectively) are the busiest gates in the Port of Piraeus. Spot 11 is situated at the very centre of the city of Piraeus and in close proximity to the port. It was selected in order to provide means of comparison between noise levels from port activities and city generated noise.

Figure 88: Measurement at the Passengers' Port (Gate E8 – spot 9)

Figure 89: Measurement at the Passengers' Port (Gate E9 – spot 10)

With regard to the number of measurements per selected location, this was subject to the significance of the location under question and the accessibility of it in parallel with the availability of port personnel since that access was restricted especially for the spots inside the Commercial part of the port. All the measurements took place in a total of 7 days, 4 in 2005 (14, 17, 18, and 19 of April), and 3 in 2006 (25 of April, 2 and 4 of May). The following table provides information on the amount of measurements taken per each of the selected locations.

Table 82: Number of measurements per selected location

Location	2005	2006	Total
1	2	4	6
2	2	3	5
3	2	2	4
4	1	0	1
5	0	7	7
6	0	2	2
7	0	1	1
8	2	0	2
9	2	0	2
10	2	0	2
11	3	0	3
Total	16	19	35

(Michail 2005-2006b)

Within the above mentioned limitations it was tried to spread the different measurements for each location in different times during the day in order to get various pictures of the occurring noise levels. Evening measurements took place for some of the spots (1, 2, 5, and 6) in the commercial port in 2006 (4 of May). The majority of the measurements had duration of 20 minutes. In few cases duration of 10 minutes was selected. The instrument kept record of sound level each 5 seconds during the measurement period (sample interval 5 sec). Those values were then logarithmically averaged over the measurement duration in order to produce the measured L_{Aeq} values. The measurements were taken at a height of 1.5 to 2 meters from the ground level.

The outcomes of monitoring are noise values for selected indicators, and noise graphs showing the variations of those indicators over the period of the measurements. The following table 83 summarises the measured L_{Aeq} (dB) noise levels for the total of the 35 measurements in 11 locations.

Table 83: Measured L_{Aeq} (dB) noise levels at the selected locations

Location	2005				2006			
	L_{Aeq} (dB)				L_{Aeq} (dB)			
	14/04	17/04	18/04	19/04	25/04	02/05	04/05	04/05 evening
1	66.6	-	69	-	65.4	69.1	69.8	51.7
2	74.6	-	76	-	-	74.3	72.2	61.3
3	63.1	-	71.6	-	-	72.7	68.8	-
4	76.7	-	-	-	-	-	-	-
5	-	-	-	-	61.1	73.5 62.7	68.2 66.0 68.7	53.8
6	-	-	-	-	-	-	70.7	58
7	-	-	-	-	-	-	70.5	-
8	-	-	71.4	71	-	-	-	-
9	-	65.3	-	74.1	-	-	-	-
10	-	65.6	-	68.2	-	-	-	-
11	-	64.3	68.4	69.1	-	-	-	-

(Michail 2005-2006b)

The following observations can be made from the study of the results:

- Although for certain spots only small variations can be observed between the different measurements (e.g. spots 1 and 2, around 4 dB variations between minimum and maximum measured values, excluding evening measurement), in many cases significant variations occur (e.g. spots 3 and 5 present variations of 10 and 12 dB respectively between minimum and maximum measured values). Those variations can be explained by the changes in the intensity of operations that occur in certain locations between different days or even between different periods during the same day. This applies mainly in spots where the dominant sources of noise are related to port activities (industrial noise) such as in the case of the spots 3 and 5.
- An average value for noise levels typically occurring in container terminals is quoted as 65 to 69 dB (Witte 2007). The average of the 25 measurements in the six spots (1-3 and 5-7) located inside the physical limits of the Piraeus container terminal is calculated to be around 67 dB. This value fits well inside the estimated framework and indicates validity of the overall results.

Selected noise graphs demonstrating the variation of the L_{Aeq} indicator over the measurements' duration are presented and discussed below. The noise graphs were produced by specialised software, compatible with the sound level meters that were used (the CEL-6813 dB23 V1.0 Download, Report and Control Software for the CASELLA, and the Noise Explorer Type 7815 Version 4.11, for the Bruel & Kjaer sound level meters).

Generally, noise graphs of road traffic noise are characterised by larger variations between measured sound levels over time. This is especially the case when intervals in traffic flow are observed. High sound levels are logically recorded when the traffic becomes heavier and low when it is interrupted. Industrial noise tends to present smaller variations between high and low sound level peaks over time. This is due to a generally high level of background noise that occurs in areas where industrial activities take place. In an industrial area, even during the quiet intervals of the nearest to the sound level meter noise sources, overall background noise remains high as the result of various and often intense neighbouring activities. Those general remarks are of course subject to the specific application, type of traffic and industrial operations, and noise characteristics. Another difference in the characteristics of traffic and industrial noise is that usually the peaks in sound levels occur gradually in traffic noise and suddenly in industrial noise. A truck approaching a sound level meter will gradually increase the measured noise value, peak when at the nearest point and will gradually decrease it while getting away from the meter. An industrial sound can often be sudden and unexpected. For example the noise produced while a fork lifter drops a container peaks instantly and then disappears.

Two selected examples of noise graphs produced using the CEL-6813 dB23 V1.0 Download, Report and Control Software in analysing measurements taken with the CASELLA sound level meter (2005) are presented in figures 90 and 91 (Michail 2005-2006b). The graph on figure 90 refers to the measurement in spot 1 (road traffic noise) on 18/04/2005. The one in figure 91 is the L_{Aeq} over time for the measurement in spot 2 (industrial noise) on the same day. A higher level of background noise can be observed in the second graph (spot 2 -industrial noise) in line with the remarks made in the previous paragraph.

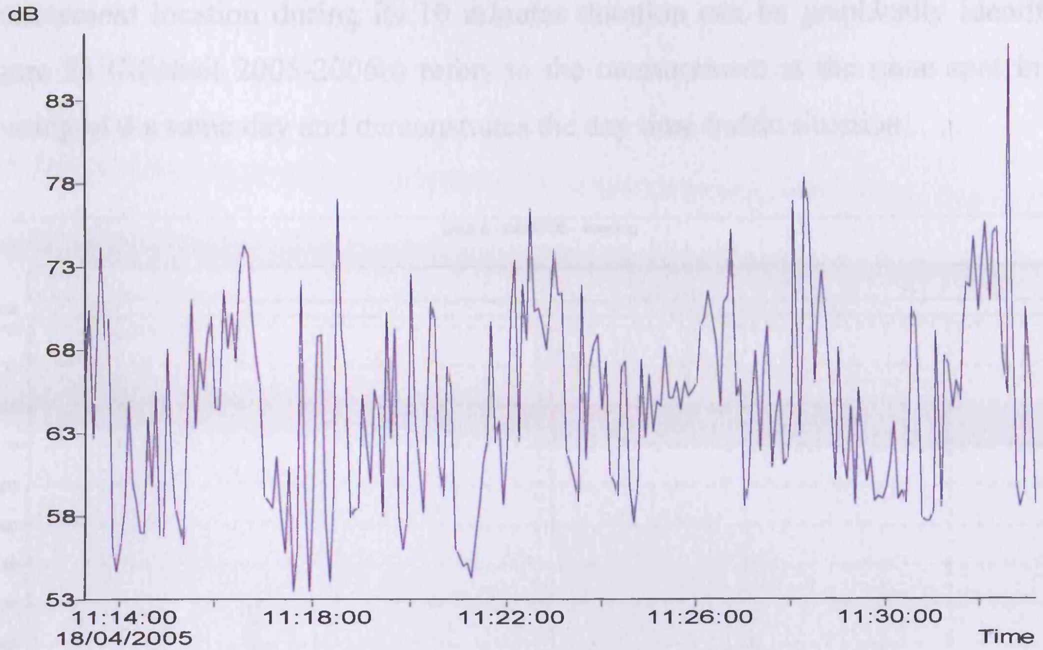


Figure 90: Noise graph (L_{Aeq}) – Spot 1 – 18/04/2005

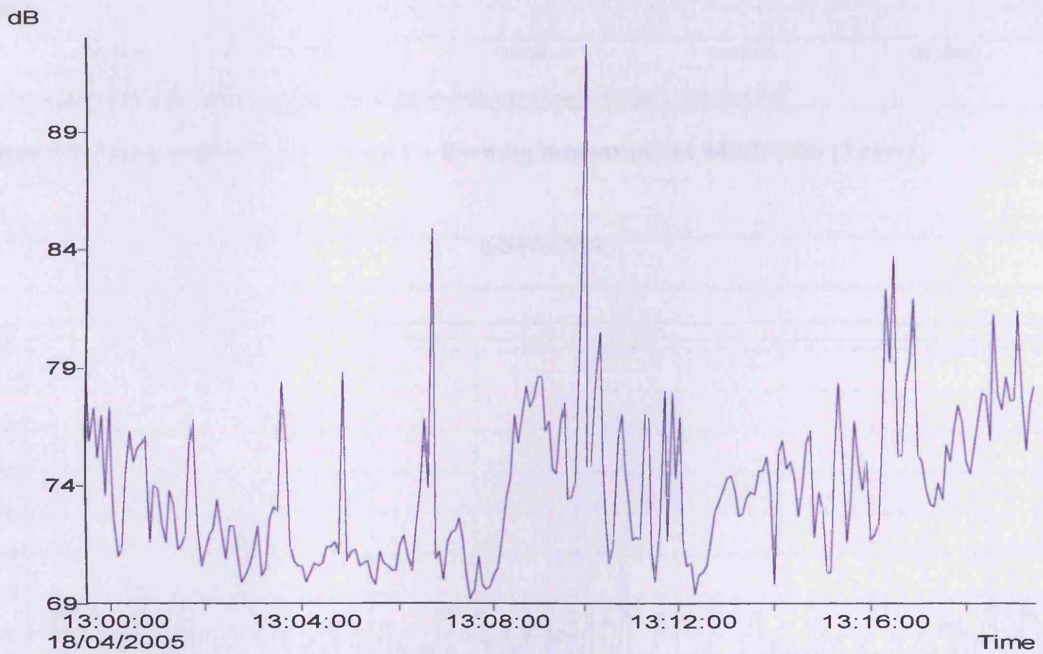


Figure 91: Noise graph (L_{Aeq}) – Spot 2 – 18/04/2005

Some further selected examples of noise graphs produced by the Noise Explorer Type 7815 Version 4.11 software applied for the analysis of data collected with the Bruel & Kjaer sound level meter (2006 exercise) are presented below. Figure 92 (Michail 2005-2006b) refers to the evening measurement in spot 1 (road traffic noise) on 04/05/2006. It is interesting to observe that the 3 cars that passed in front of the measurement location during its 10 minutes duration can be graphically identified. Figure 93 (Michail 2005-2006b) refers to the measurement at the same spot in the morning of the same day and demonstrates the day time traffic situation.

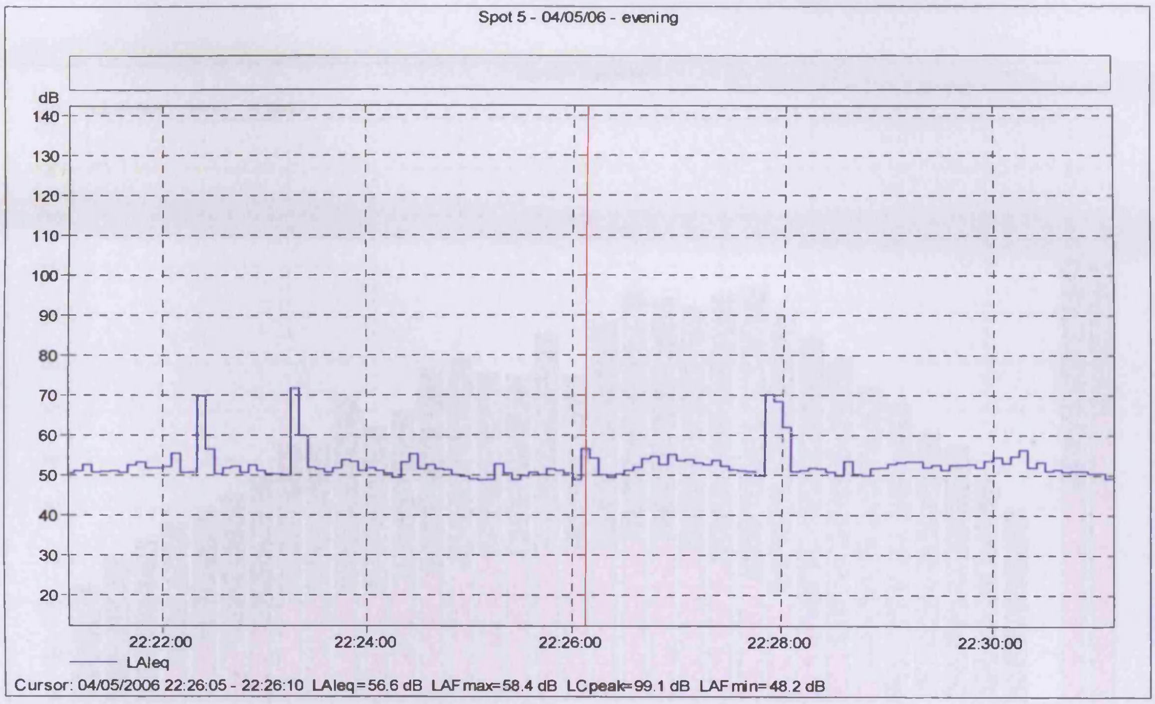


Figure 92: Noise graph (L_{Aeq}) – Spot 1 – Evening measurement 04/05/2006 (3 cars)

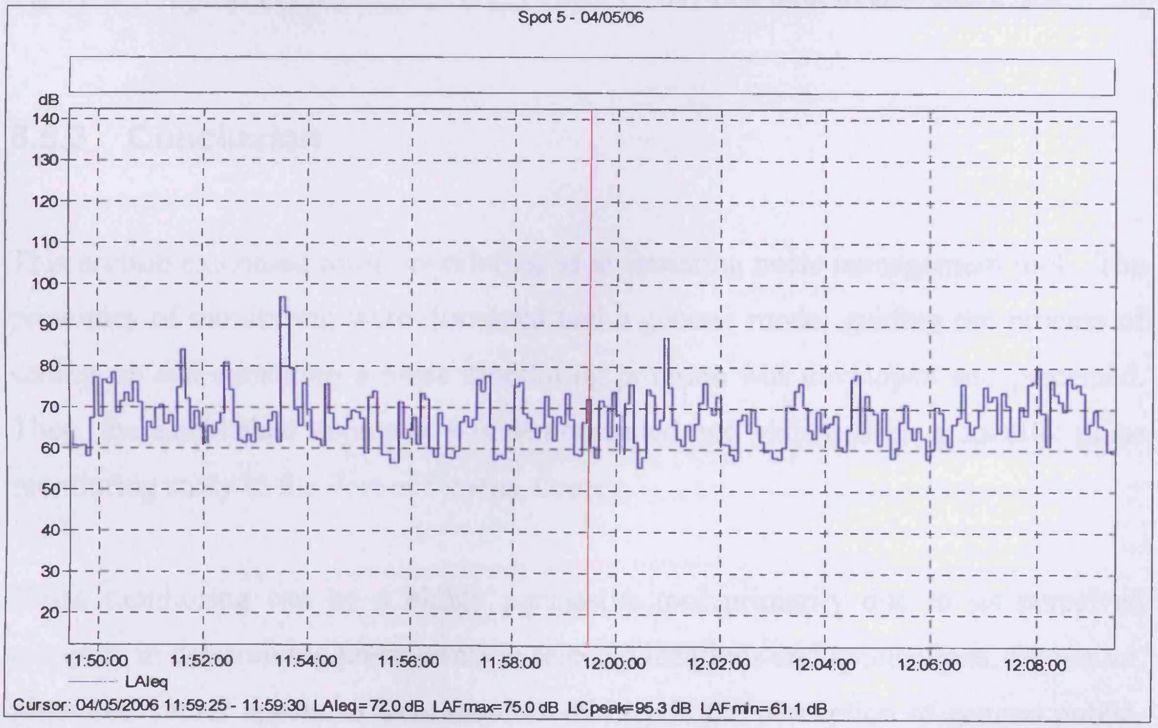


Figure 93: Noise graph (L_{Aeq}) – Spot 1 – Day-time measurement 04/05/2006

In addition to the L_{Aeq} graphs, the Noise Explorer Type 7815 Version 4.11 software produces frequency analysis graphs. An example is provided on figure 94 (Michail 2005-2006b) mainly for display purposes. It refers to the same measurement as figure 93.

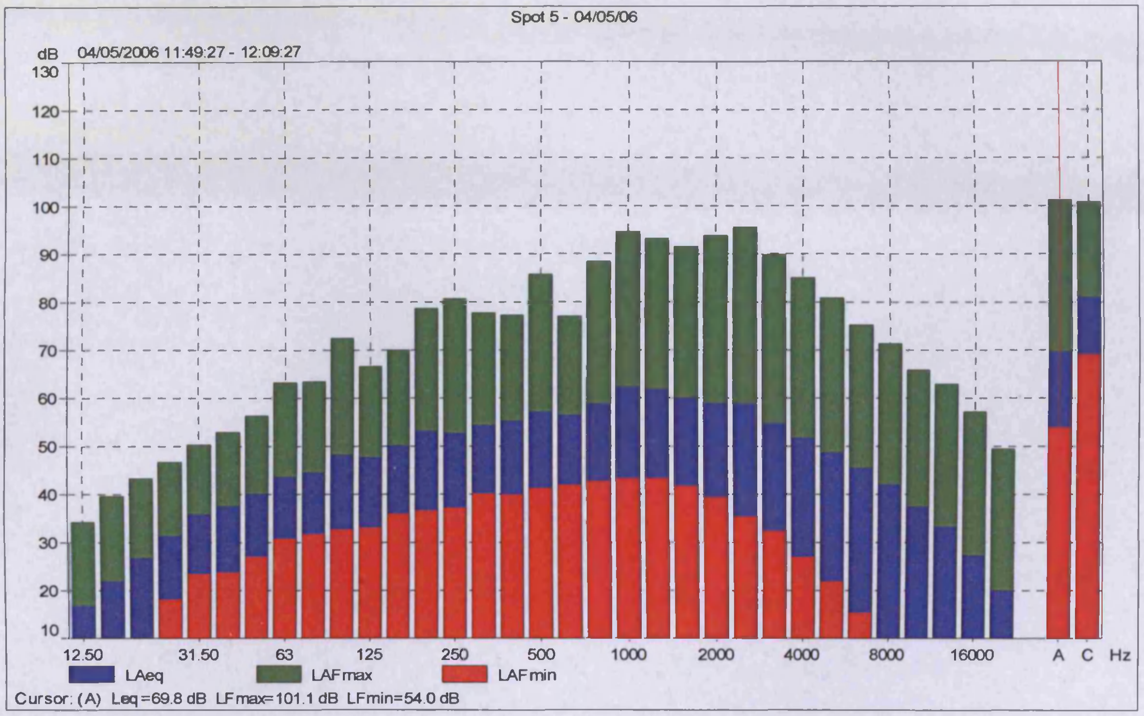


Figure 94: Frequencies analysis graph (L_{Aeq}) – Spot 1 – Day-time measurement 04/05/2006

8.5.3 Conclusion

This section examined noise monitoring as an assisting noise management tool. The principles of monitoring were discussed and a generic model guiding the process of setting up and executing a noise monitoring program was developed and presented. Then, the established approach was demonstrated and validated on a specific noise monitoring study in the Port of Piraeus, Greece.

Noise monitoring can be a highly persuasive tool primarily due to its perceived accuracy in determining noise levels in selected locations and applications. By nature, measured values appear to have more credibility in the perception of general public, regulators and academics. In practice however, accurate noise monitoring can be a challenging exercise. In addition, the qualitative analysis of the monitoring outcomes is often quite complex, especially in areas where traffic and industrial noise sources mix together (e.g. seaport areas). For example, the pure examination of the monitoring outcomes (values and graphs) cannot by itself lead to conclusions regarding the relative contribution of different sources to the measured values. The individual who undertakes the measurements has to do the qualitative assessment regarding the type and nature of noise measured and this often requires a high level of expertise and can still have an objective only output. The overall qualitative analysis of the noise situation in a given area is addressed better by noise mapping as it is demonstrated in the following section 8.6.

8.6 Noise mapping in seaport areas

This section focuses on noise mapping in seaport areas. First, the principles and rationale for noise mapping in seaport areas are discussed and a generic model guiding the process of setting and undertaking a noise mapping study is developed and presented (section 8.6.1). Some technical background information with regard to the function, input requirements, and expected outputs of specialised mapping and prediction software packages is then highlighted in section 8.6.2. By making use of advanced noise mapping software, the established phased approach to noise mapping is demonstrated and tested on a specifically designed noise mapping study in the Port of Piraeus, Greece (section 8.6.3). The process is discussed and the noise maps produced and their implications are presented and analysed. In addition to the Piraeus study, some of the results and major observations from selected similar recent studies in European Ports are highlighted (section 8.6.4). A second case study in cooperation with the Port of Amsterdam that was set in order to investigate the challenge of reducing the calculation time of noise models by means of efficient noise modelling and simulation, is then presented and discussed (section 8.6.5). The section concludes by summarising and synthesising the findings and by concluding on the efficiency and potential of mapping as an assisting tool for integrated seaport area environmental noise management (section 8.6.6).

8.6.1 Generic approach to noise mapping

Noise mapping provides the means for analysing the noise situation in port areas. The outcomes of noise mapping provide the necessary information in order to identify potential hot spots and to analyse the contribution and significance of different noise sources (single or groups) to the overall noise situation in and around the port area. In such way the outcomes of noise mapping can assist in prioritising actions and mitigation measures and can guide through the noise action planning process. The analysis of noise mapping results forms the basis for drawing up action plans in order to minimise and mitigate noise impact. Noise maps provide a potentially valuable planning and decision-making tool because they can be used not only for assessing the current situation but also for predicting future circumstances. The graphic representation of noise values and impacts in 2-D and 3-D images (see examples in sections 8.6.3 and 8.6.4) may be powerfully persuasive documents in the often contentious issues of port expansion and city development. Their strategic value is increasingly recognised in terms of investment, mitigation of impact, stakeholder negotiation and planning consent.

Noise mapping and the resultant action plans derived from their analysis may provide port managers with authoritative, science-based calculations that may be used to demonstrate their environmental credentials and to bring some quantified objectivity to what is often a controversial, and passionate environmental debate. The production, analysis and interpretation of noise maps in conjunction with associated noise management tools can provide the port manager with a suite of useful decision-making options specifically designed to assist with compliance with legislation (noise limits), the mitigation of the impacts of operations and activities, and the delivery of high standards of health and environmental quality through the implementation of best practice solutions.

Figure 95 (Michail 2006c) presents a generic approach to noise mapping in seaport areas. The presented approach reflects the guidelines of recent studies in the field of noise mapping (DEFRA 2004; EC WG-AEN 2007) and is in line with the NoMEPorts project approach and guidelines (NoMEPorts project 2008). The highlighted steps of the generic approach are: (1) Setting noise mapping objectives, (2) Defining the boundaries of the noise mapping application (both geographical and noise sources related boundaries), (3) Creating the noise model, (4) Running noise calculations, and (5) analysing the outcomes of the noise mapping application.

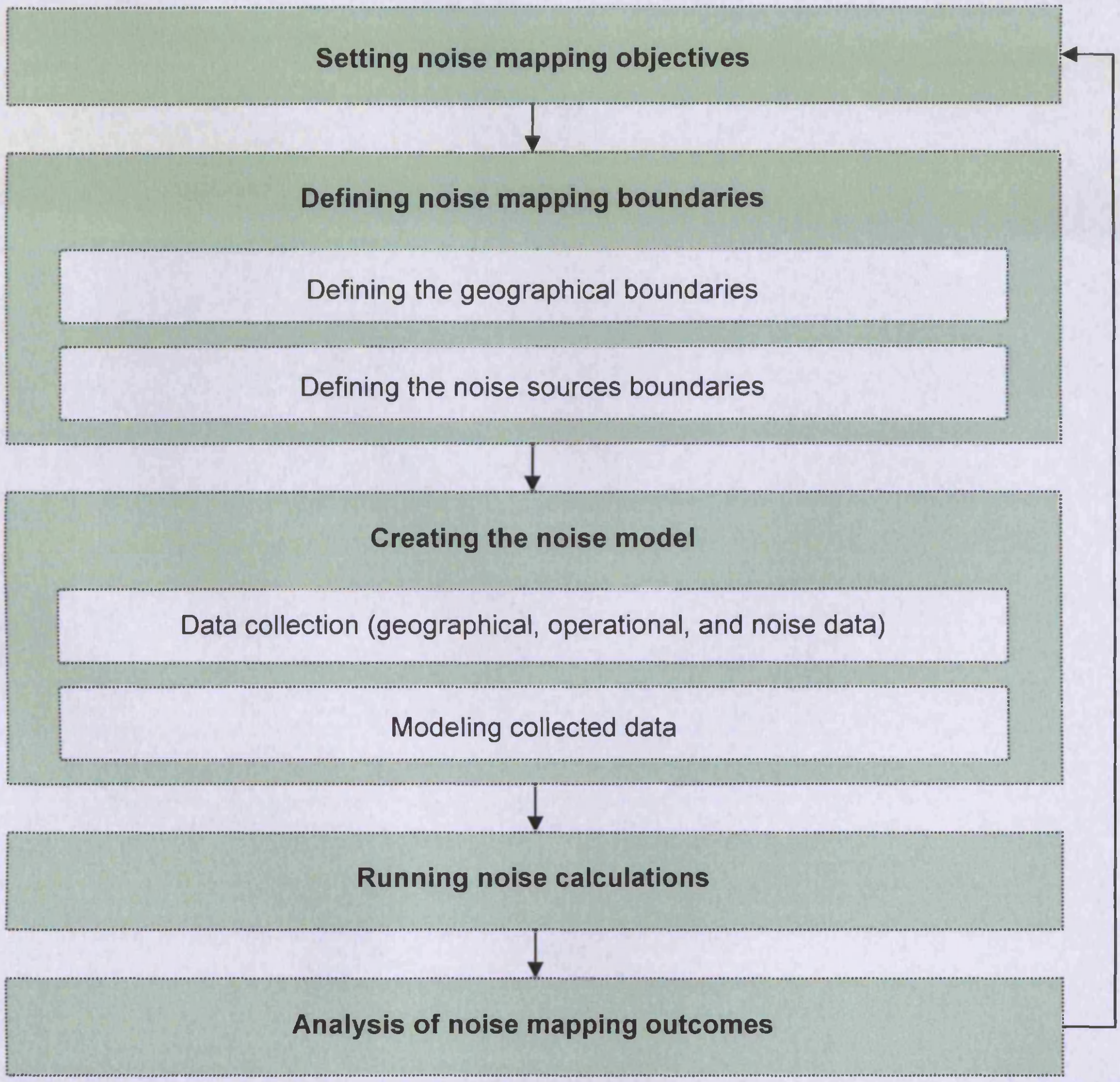


Figure 95: Generic phased approach to seaport area noise mapping

Noise mapping studies may have different objectives according to the case and application. A definition of those objectives would determine certain parameters of the mapping process such as decisions with regard to boundaries to be applied and technical noise modelling aspects. The first step of a mapping study is therefore to set the objectives for the specific application. Objectives of noise mapping studies could be:

- Predicting of noise levels in selected locations in and around the seaport area

- Assessing the relative contribution of different sources, or groups of sources (e.g. road traffic, rail traffic, industry) to the overall noise situation in and around the seaport area
- Assessing future scenarios with regard to the noise situation due to port development plans (e.g. examining the noise impact of options for locating new companies in the port area)
- Assessing the potential effectiveness of certain noise mitigation measures (e.g. introducing a noise barrier in a noise model and estimate potential reduction on noise levels reaching a certain sensitive area)
- Producing strategic noise maps in compliance with the END (Directive 2002/49/EC). In that case specific requirements are applied with regard to boundaries, technical and demonstrational parameters

The second phase of a noise mapping study is the definition of the geographical and noise sources boundaries to be taken into consideration. A common point of debate with regard to seaport area noise management is defining the geographical boundaries of the area to be modelled and studied. Seaport areas have clearly defined geographical limits based on legal designation, but while examining noise, one of the more trans-boundary and multi-source environmental aspects in the logistic chain, the definition of the boundaries of a noise study in line with the port area physical boundaries does not appear to be a sensible approach. Seaport noise, the noise coming from inside the port area, influences the surrounding areas that also need to be taken into consideration. The noise study area may therefore include (1) the seaport area where the noise sources of interest are located, (2) residential and other noise sensitive neighbouring areas influenced by port noise, and (3) areas between the port area sources and the neighbouring noise sensitive areas.

Defining the noise sources to be taken into account is also of significance. Noise sources in port areas can broadly be divided into industrial and traffic noise sources. Examples are provided in tables 84 and 85.

Table 84: Examples of industrial noise sources in port areas

Industrial noise sources:
• Port services and facilities • Terminals (cargo handling, warehousing) • Industrial areas • Machinery, workshop • Vessel repair or maintenance • Shunting yards • Vessels when berthed (engine noise)

Table 85: Traffic related noise sources in port areas

Traffic noise sources:
• Roads • Railways • Vessel movements and manoeuvring • Air traffic

Although there is a broad agreement that industrial noise sources that are located in port areas have to be taken into consideration in noise mapping studies, there is on-going debate as to whether or not traffic related sources should also be considered, and if so, to what physical extent. The main argument for not considering at all, or for partly considering traffic related sources in noise studies, is based on the limited degree of responsibility of port areas for the generated traffic. Although a certain percentage of the traffic is logically port generated, part of it cannot be considered as such. Setting the boundaries of noise sources to be taken into consideration generally depends on the application and its objectives. It should be noticed that the NoMEPorts initiative for seaport area noise mapping suggests that for the needs of strategic noise mapping traffic related sources should be taken into consideration. It is considered significant for a noise study to first provide a representative picture of the general noise situation. The issues of assessing the relative contribution of different groups of sources and then allocating responsibilities are significant, but should be tackled during the analysis of the noise studies and the action planning phases (NoMEPorts project 2008).

After clearly defining the noise mapping objectives and the boundaries to be used, the next step is the actual creation of the noise model. The creation of the noise model is the main and most significant phase in the noise mapping process. The quality of noise maps in terms of accuracy of predictions depends entirely on the quality of the noise models that produced them. The creation of noise models involves collection of geographical, operational and noise data. The geographical data forms the basis of the creation of a 3-dimensional model of the area under study. The operational and noise data assists in attributing noise values while simulating the identified noise sources in the area under study. The creation of a noise model is analytically presented in section 8.6.3 via the noise mapping application in the Port of Piraeus.

After creating the noise model of the area under study the next step is to run the calculations with the assistance of specialised noise predicting software. Several calculation parameters need to be set such as the location of the points were the calculations of noise values will take place (grids and receivers), and meteorological parameters. The outcomes of the prediction software's calculations are estimated noise values in selected locations, and 2-D and 3-D noise maps. The analysis of the outcomes reflects back to the objectives of the noise mapping study. Information obtained from analysing noise maps can assist in formulating noise action plans, prioritise areas of interest, and assessing different mitigation measures and port development plans.

8.6.2 Technical background

Noise mapping is naturally assisted by specialised software packages. The generic schematic function of any noise prediction software is presented in figure 96. The figure highlights the input requirements and the expected outputs of such packages.

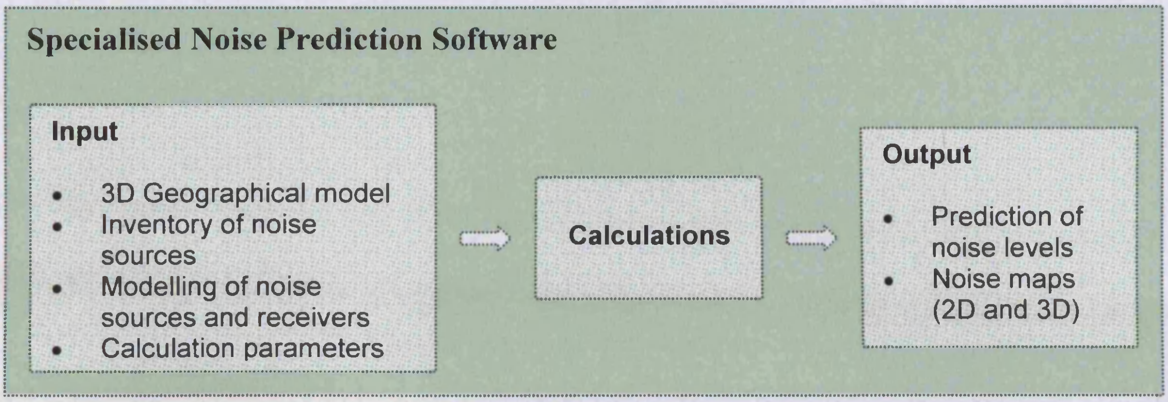


Figure 96: General schematic function of noise prediction software

The software's input requirements include a 3-dimensional physical model (geographical data collection) of the area under examination, the inventory and then modelling (noise and operational data collection) of the main noise sources that occur in the area and finally setting up the calculation parameters (e.g. meteorological data, and locating the calculation points) to be taken into consideration. Output of the software calculations could be prediction of noise levels in specific locations in the area and overall colour coded two and three-dimensional noise maps.

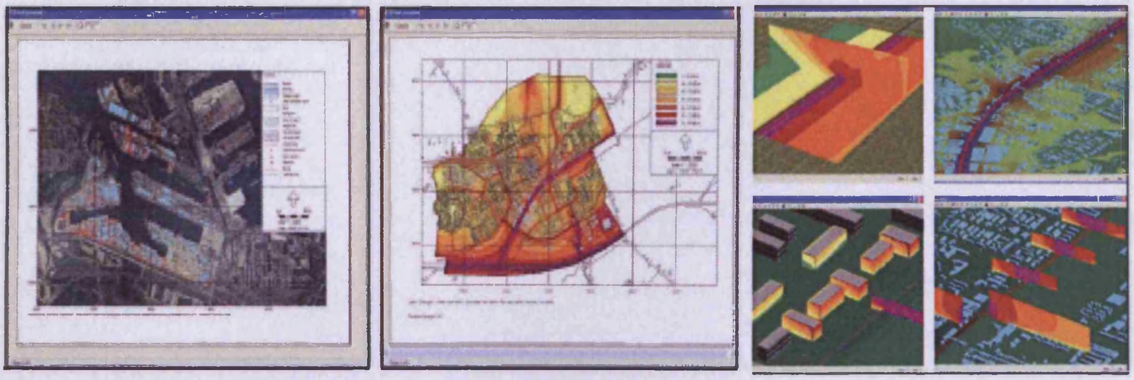


Figure 97: Working and display surfaces of the Predictor software

The software that has been used for the noise mapping case studies that follow on sections 8.6.3-8.6.5 is the Noise Prediction Software Type 7810 Predictor (figure 97), developed by Bruel & Kjaer. The Predictor software is an advanced noise prediction and mapping software and it has been considered as the most appropriate software to use for noise mapping in seaports by the NoMEPorts project. One of the main advantages of Predictor is its ability to combine transportation related noise sources and operational-industrial ones in a single noise map. This is particularly useful in port areas where both types of noise sources are of significance.

The user of any noise mapping software should identify the most appropriate calculation method according to the desired application. The interim calculation methods stated in the END (European Parliament 2002) are:

- ISO 9613-2 (noise propagation) in combination with other ISO standards for source sound power assessment, for industrial sources,
- ECAC Doc. 29 for aircraft,
- NMPB-routes-96 for road traffic, and
- Reken- en meetvoorschrift railverkeerslawaai '96 for rail traffic

In time, the above mentioned interim methods could be replaced by the methods that were delivered by the Harmonoise and Imagine projects (HARMONOISE project 2006; IMAGINE project 2007). These were aimed to produce accurate and reliable methods that represent an important step forward in synthesising the above mentioned Interim Methods. For the case studies that follow (sections 8.6.3 – 8.6.5), the calculation method HARMONOISE/IMAGINE has been used. It is the method that was selected by the NoMEPorts initiative as the most appropriate to be applied for studies in seaport areas. Some selected advantages and disadvantages of the method are presented in the following table:

Table 86: Implications of using the HARMONOISE/IMAGINE calculation method

Positive implications	Negative implications
Advanced calculation method (better results)	Long calculation times, since no optimised computation scheme is yet available
Same noise propagation for all types of sources, same type of modelling data for all sources (e.g. ground impedance, reflections in facades, screening), and ability to combine traffic and industrial noise sources in one model	Locally the results may not be used for strategic noise maps. Depending on national legislation, different calculation methods might be dictated. The input data though is in any case similar and therefore can be reused.
Taking meteorological parameters into consideration	

8.6.3 Case study: Noise mapping of Piraeus container terminal

In order to demonstrate noise mapping in practice a small scale mapping study was set at the Port of Piraeus, Greece (Michail 2006b). The study took place in 2006 and made use of the long established research links between Cardiff University and the Port of Piraeus. The noise mapping study focussed in particular in the Container terminal of the port. The Port of Piraeus is divided in two main areas: the Passengers' Port and the Commercial Port. Major part of the Commercial Port (Lat 35057'28''N; Lon 23036'12''E) is the Container Terminal (figure 98[33]). The terminal handled a total of approximately 1.400.000 TEUs in 2006 (Piraeus Port Authority S.A. 2006).

Figure 98: Views of the container terminal at the port of Piraeus

There is a special interest of the Piraeus Port Authority in examining the noise situation in and around the Container Terminal. The terminal is located in close proximity to the residential area of Perama (figure 99) and there have been recorded complaints for port related noise by the residents of Perama.

---

[33] Source of photos, Piraeus Port Authority (left), Google Earth (right)

Figure 99: The container terminal as seen from the residential area of Perama

The presentation and demonstration of the different phases of the noise mapping study follows the structure of the generic approach that was established in section 8.6.1. It starts by discussing the objectives of the study, and the applied geographical and noise sources related boundaries. The process of creating the noise model of the container terminal is then demonstrated following a phased approach that incorporates relevant data collection and actual modelling techniques. Finally, calculations related aspects are examined and the produced noise maps and predicted noise levels are presented and analysed.

Starting by setting the noise mapping objectives, it should be noticed that the aim of the study was to produce the first noise maps of the Container Terminal of the Port. The Port of Piraeus is located in close proximity to the city of Piraeus (agglomeration of more than 250.000 inhabitants) and therefore falls under the requirements of the END (European Parliament 2002) and has to cooperate with the relevant authorities in the production of strategic noise maps. The mapping study aimed at providing the Port Authority managers with an understanding of approach and data collection requirements that would enable the further development of the current study and the fulfilment of the Directive's requirements. The outcomes of the study presented in this section are not complete strategic noise maps. The study can be seen as a small scale application of principles and approach. Nevertheless, it is in line with the requirements of strategic noise mapping as those are set by the END and by appropriate geographical expansion of the focus area could be developed to produce complete strategic noise maps for the Port.

Next step was the definition of the boundaries to be used for the study both in geographical terms and in noise sources to be taken into consideration. With regard to the geographical boundaries the physical limits of the container terminal were taken into consideration. All the main identified noise sources that were included in the defined study area were taken into consideration. Working in cooperation with the Piraeus Port Authority an inventory of the main noise sources in the Container Terminal was made. The noise sources were divided into two categories: the transportation related ones and the industrial-operational ones, as it is demonstrated in table 87. Figures 100, 101, and 102 highlight examples of identified sources.

Table 87: Identified noise sources

Transportation related noise sources:

- Road access for cars (employees, visitors)
- Road access for trucks
- Internal traffic of vehicles (trucks, straddle carriers, fork lifters)

Industrial-Operational noise sources:

- Loading – unloading container ships using container cranes (figure 108)
- Loading – unloading trucks with straddle carriers (loaded containers) (figure 109)
- Empty containers handling with folk lifters (figure 110)
- Loaded containers handling with straddle carriers (figure 109)

(Michail 2006b)

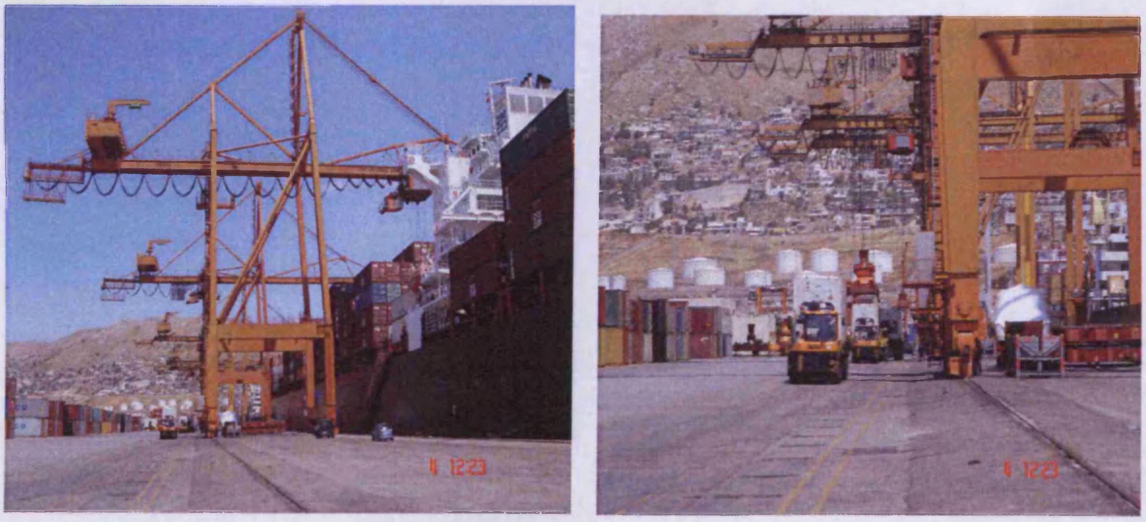


Figure 100: Loading – unloading container ships using container cranes

Figure 101: Loaded containers handling with straddle carriers

Figure 102: Empty containers handling with fork lifters

The creation of the noise model involved geographical, operational and noise data collection. The geographical data assisted in building a 3-D model of the area under study, while the operational and noise data allowed attributing noise values in the process of modelling the identified noise sources on the previously produced 3-D model, transforming it into a noise model.

A three-dimensional model of the area under examination forms the base for inserting the various noise sources and then calculating the noise maps in the Predictor software (and any noise prediction software). The model should include all sorts of morphological and topographical data together with the main structures (buildings, infrastructure) that are present in the area. The geographical data requirements are highlighted in table 88.

Table 88: Geographical data requirements

Geographical information should include:

- Height lines of the study area
- Residential and industrial buildings (including height dimensions)
- Other obstacles in the study area (e.g. containers' formations)
- Location of noise sources: industry, main roads, secondary roads and railways.
- Location of noise sensitive areas (schools, hospitals, recreational areas)

Ideally, such a model would be already available in the port in compatible formats with the Predictor software (e.g. AutoCAD, GIS). In that case the model can easily be imported into the Predictor software following the guidelines of the software's manual. Otherwise, as in the case of Piraeus, such a three-dimensional model needs to be built. One option is building up the physical model using the AutoCAD or GIS software packages and then importing it to the Predictor. The second option which has been followed at the Piraeus case study is building up the model using the features of the Predictor software itself. Although being basic the Predictor working surface is simple, user friendly and does not require a high level of expertise in 3D modelling from the user in order to build a satisfactory model. The data requirements for this approach are summarised in table 89.

Table 89: Data requirements for building up the 3D physical model

Data requirements for building up the 3D physical model	**Justification**
A two-dimensional map of the container terminal (in Bitmap format)	To be imported in the Predictor and be used as a background for building up the three-dimensional model
Detailed topographical data of the area (relative and absolute heights, location and dimensions of buildings and infrastructure)	The core data in order to transform a two-dimensional model into a three-dimensional one
Data concerning the types of material in area surfaces, buildings and infrastructure	Each material has a different behaviour when it comes to noise reflection or

	absorbance and therefore the software requires that kind of information for every surface or structure in the model

(Michail 2006b)

For the Piraeus case study the map appearing in figure 103 has been imported to the Predictor software to be used as a background for building up the 3-D model using the software's features. Importing a file in bitmap format is a quite straight forward procedure following the steps described in the software's manual.

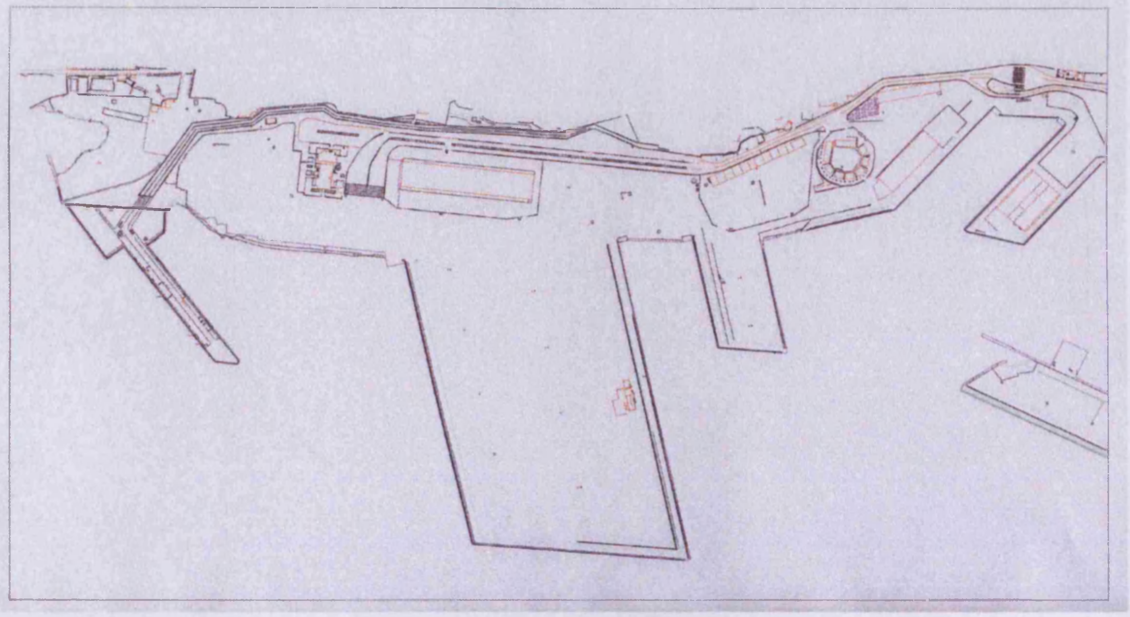


Figure 103: The 2-dimensional map of the container terminal

In cooperation with the Port Authority all the necessary topographical data has been collected as well as the data concerning the types of material for the different surfaces, buildings and other infrastructural assets. The exercise resulted in the model appearing in figure 104 (Michail 2006b) that has been used as the base for modelling the different noise sources as it is explained on the following paragraphs.

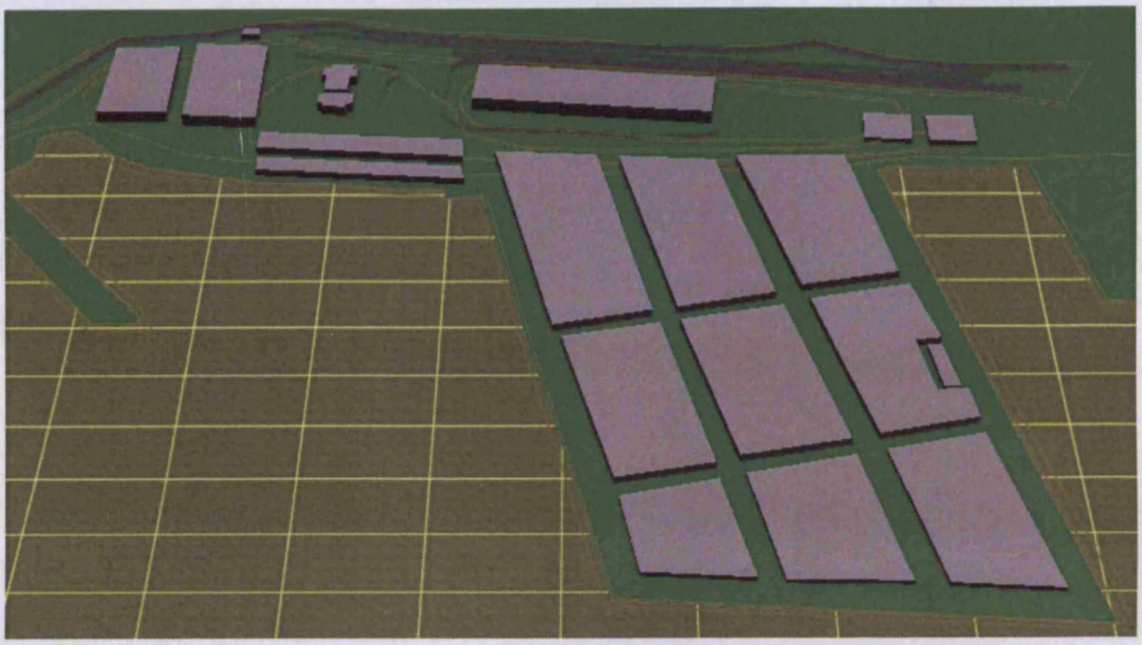


Figure 104: The 3-dimensional model built using the Predictor software

The main challenges that occurred during the selected process of 3D modelling using Predictor's working surfaces are summarised and discussed in the following table 90.

Table 90: Main challenges encountered in 3D modelling with Predictor

Main challenges	Response
Importing the 2D bitmap file to the Predictor: A bitmap's file dimensions are described by a pixels' ratio (3911*2221 for the map we used). Predictor requests from the user during the importing process the file's coordinates. If those are given as they appear in pixels (3911*2221) the software "reads" the pixels as being meters. In other words the software in importing the above map assumed that its dimensions where 3991*2221 meters which was incorrect.	The meters' ratio (2640*1500) of the imported file should be inputted instead of the pixels' one. In an accurate electronic file (not stretched) the actual ratio should be equal in pixels and in meters. In the case of the map we used 3911/2221 (pixels' ratio) equals 2640/1500 (meters' ratio) which are the correct map dimensions in meters.
Creating the morphology of the ground (height lines): Due to the basic modelling functions in the Predictor some complications occurred with regard to the accuracy in entering the different height lines to the model.	Simplified forms were used with regard to the morphology when the differences in height were considered to be insignificant. This was possible in the case of the Piraeus container terminal as there were very small height differences (the absolute morphological heights varied from 2 to 5

	meters all over the modelling area) between different areas.
Dealing with complicated infrastructural forms: Due to the basic modelling functions in the Predictor some complications occurred with regard to the accuracy in building representations of complicated infrastructural forms (balconies, watching tower, covered truck gate, container cranes)	Simplified forms were used in line with the Predictor software's modelling capacity.
Representing the containers' formation in the model: Containers are placed one on another creating stacks (1-2 for filled containers, 1-5 for empty ones) of different heights. At any given time the formation of the containers has got a different shape. The challenge has been finding a way to physically represent those dynamic structures in one single model. This has been considered essential as the containers' formation has a significant influence with regard to the noise dispersion.	It has been decided to make an assumption with regard to the containers' formation based on the average container handling volume throughout a year as a percentage of the total handling capacity of the container terminal. Another option could have been to run a series of calculations using different scenarios for different containers' formations.

(Michail 2006b)

The process of modelling noise sources involves decision making in two levels: first in selecting the appropriate modelling option for each identified source and secondly in collecting the relevant noise data that would allow attributing noise values to each source. The Harmonoise-NoMEPorts calculation method offers a variety of options for modelling noise sources (road, rail, point source, line source, moving source, area source) and the decision is left to the user and depends on the nature of the actual sources. In any case the user has to provide the necessary information that would determine the noise values (sound power levels) for the noise sources under examination. This process involves operational and/or noise data collection. The following tables 91 and 92 summarise some of the data requirements for modelling industrial and traffic related sources respectively.

Table 91: Data requirements for modelling industrial noise sources

Industrial noise sources: • Location of every relevant industrial source (e.g. cargo handling, container handling, cranes, vehicles, auxiliary equipment) including height • Working hours of every source taken into account for day, evening and night period • Sound power level of each industrial source

Table 92: Data requirements for modelling traffic related noise sources

Traffic sources: • Location of roads and road surface (e.g. asphalt, bricks) • Road traffic data: number of vehicles (light, medium or heavy) per hour for each time period (day, evening, night), average speed. • Location of railways • Railway traffic data: number of trains of each category per hour for each time period (day, evening, night), average speed, rail support (e.g. wooden or concrete sleepers) and data on rail track (e.g. joined rail, switches and crossings)

The two-level decision making process for each of the identified noise sources in the Piraeus container terminal is demonstrated and explained on the following paragraphs. The way that the identified sources have been simulated in the Predictor's model and the process of the relevant noise data collection are explained. Two examples of identified sources are analytically discussed, "the main road access for trucks" and the "loading and unloading of ships using dockside container cranes". The information on the modelling process with regard to all the identified noise sources is summarised in table 93 that follows after the two examples.

For the main "road access for trucks" at the Piraeus Container Terminal the "road" modelling option was selected. The road that was drawn on the 3D model is demonstrated in figure 105 (red line) (Michail 2006b). Then, at the properties table of the inserted road, the traffic flow of trucks had to be inserted for the different time periods of the day (day, evening, night). While inserting a "road" item in Predictor the user is requested to provide the following information:

- Traffic in the network (number of vehicles per hour for every type of vehicle for the different periods of the day)
- Types of vehicles (light, medium heavy, heavy)
- Average speed of the vehicles in the network

The information with regard to the traffic flow is used by the software in order to estimate the noise emission of the road. Providing that 1300 trucks (heavy vehicles) in average access the container terminal daily from 07:00 to 19:00 and that their average speed is 30 km/h the properties table has been filled respectively (figure 106 - Michail 2006b).

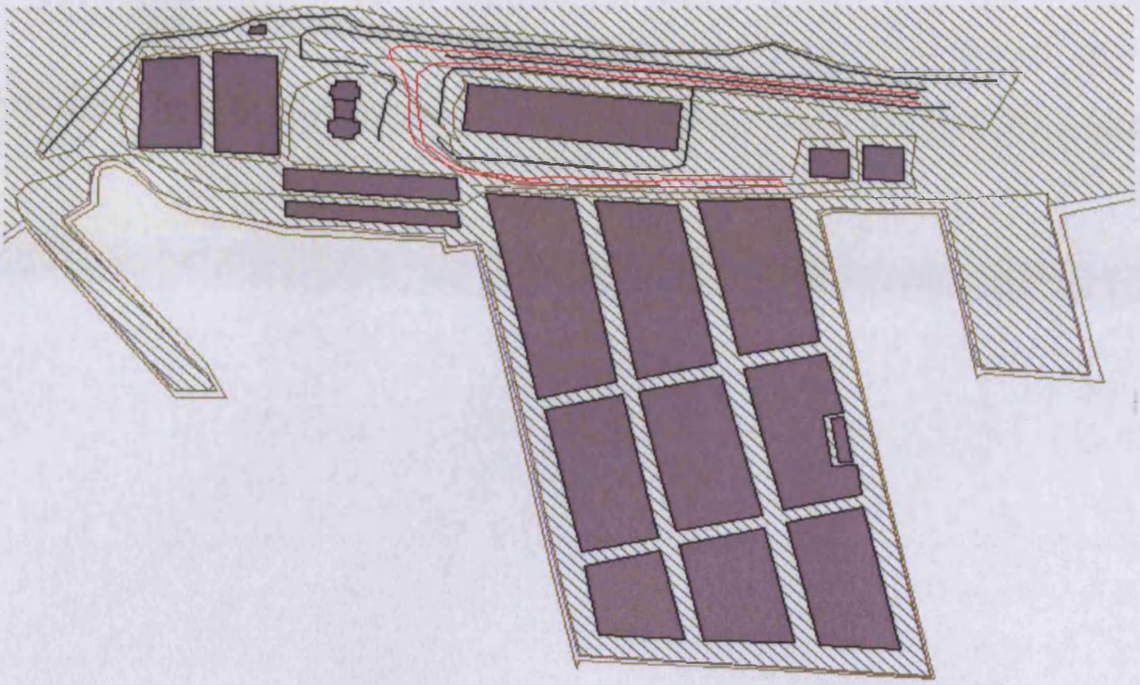


Figure 105: Main road access for trucks (red colour line)

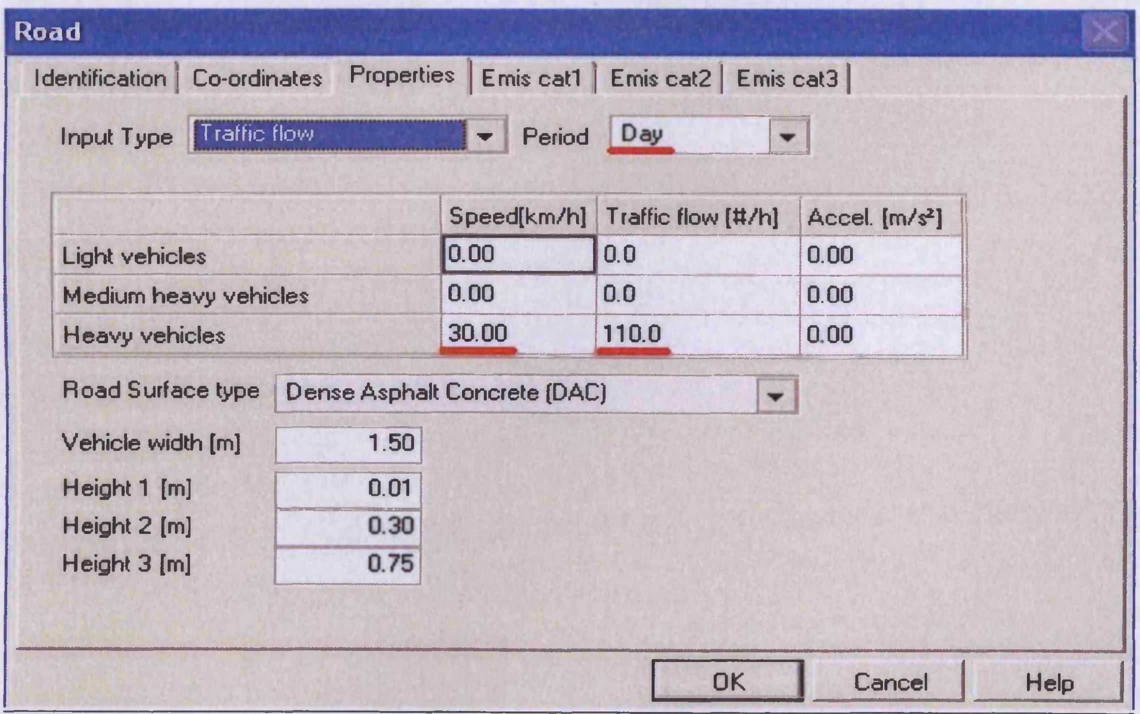


Figure 106: The properties table of the main road access for trucks

In order to model the container cranes that are used for the process of loading and unloading the container ships the "point source" option in Predictor was considered as the most appropriate to use. Twelve point sources were inserted in the model providing a picture of the most likely location of the 12 operating cranes at any time (figure 107 - Michail 2006b).

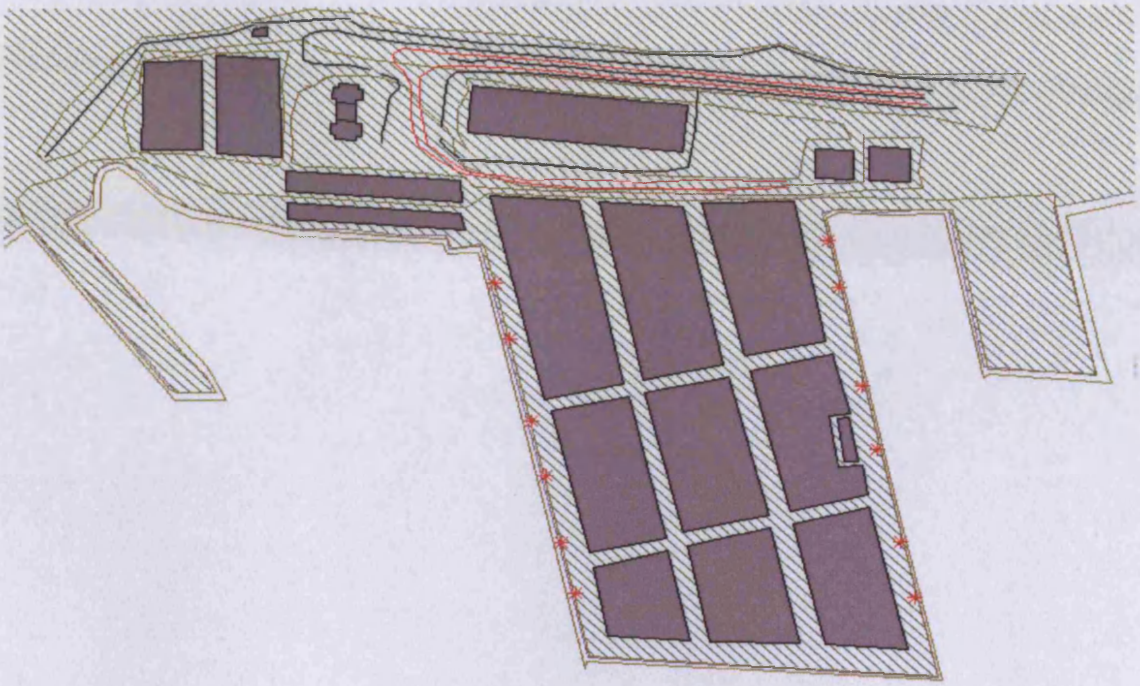


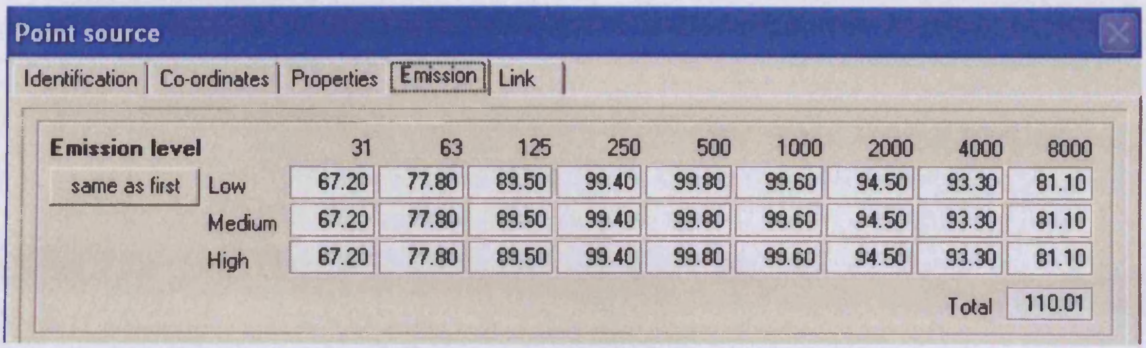
Figure 107: Modelling the container cranes (red dots)

With regard to the properties of those 12 point sources the following remarks can be made:

- The height of the sources has been set to 40 metres as usually applied to that type of container cranes.
- The noise value (sound power level) of each source was set to be 110 db (figure 108). This value was extracted from the SourcedB[34] database (DGMR 2005) since there was no other reliable estimation or measurement available. The entry "dockside cranes" (figure 109) has been selected from the noise database as being the one corresponding to the type of container cranes used in Piraeus.

[34] The SourcedB is an online available database that provides sound power levels estimates for a range of industrial noise sources. It is considered by noise experts a quite reliable source of information.

- The operation of the container cranes at Piraeus is a continuous 24 hours a day process. After communication with the Port Authority, the operational time for each of the cranes was set to be at 80% during day (07.00-19.00) time, 70% during the evening (19.00-23.00) and 60% during the night (23.00-07.00).



Emission level	31	63	125	250	500	1000	2000	4000	8000
Low	67.20	77.80	89.50	99.40	99.80	99.60	94.50	93.30	81.10
Medium	67.20	77.80	89.50	99.40	99.80	99.60	94.50	93.30	81.10
High	67.20	77.80	89.50	99.40	99.80	99.60	94.50	93.30	81.10

Figure 108: Emission value attributed to each of the container cranes

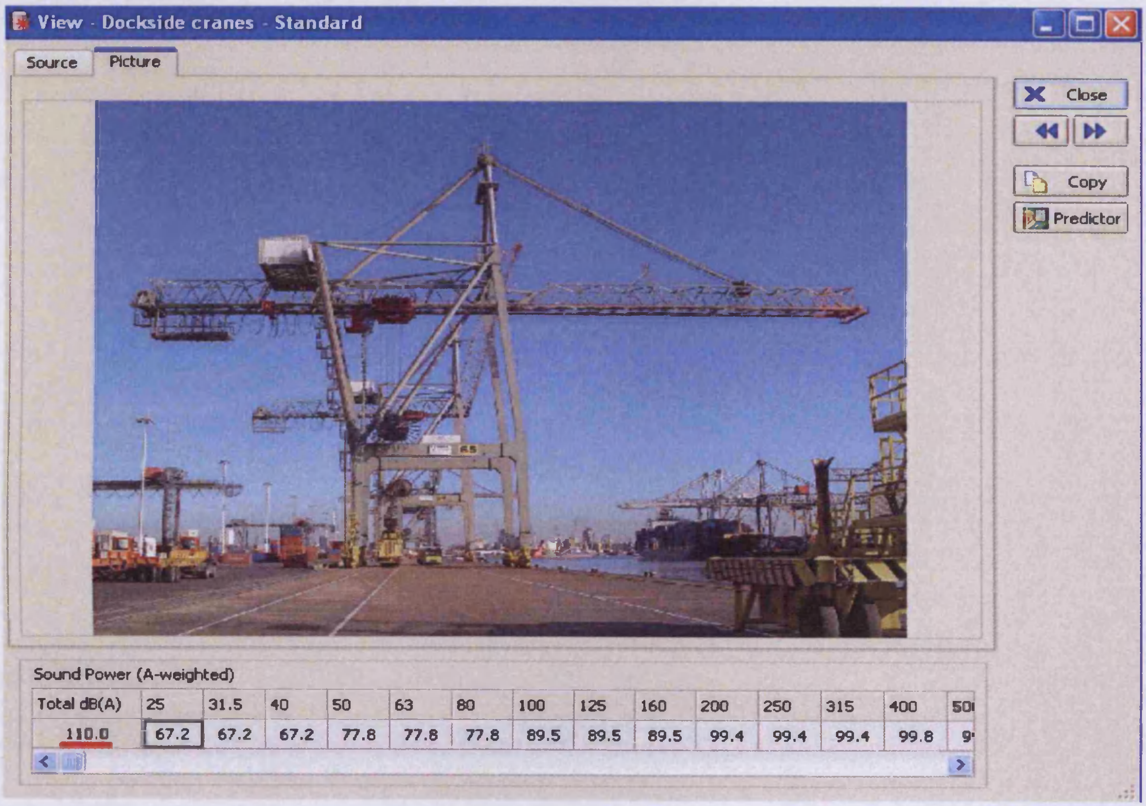


Figure 109: The entry "dockside cranes" at the Imagine Noise Database

Following similar approaches with the presented examples, all the identified sources in the container terminal (traffic and industrial sources) were simulated. The following table 93 summarises the selected modelling option for each of the identified noise sources and describes the associated noise data collection process.

Table 93: Summary of modelling approaches for the identified noise sources

Noise source	Modelling decision	Associated noise data collection
Road access for cars (employees, visitors)	2 "roads" to simulate the two corridors of the main road access for cars.	All the traffic flow related information has been provided by the port and determined the noise emission level of the inserted roads.
Road access for trucks	2 "roads" to simulate the two corridors of the main road access for trucks.	All the traffic flow related information has been provided by the port and determined the noise emission level of the inserted roads.
Loading – unloading container ships using container cranes	Twelve point sources at a height of 40 metres from the ground, one for each container carne in use.	The SourcedB Database has been used to extract the estimation of the sound power level of the cranes. The entry "dockside cranes" has been selected (110 db).
Loading – unloading trucks with straddle carriers (loaded containers)	A network of "point" sources has been selected. The network consisted of 10 point sources referring to the movements of trucks and two point sources referring to the operation of straddle carriers.	The SourcedB Database has been used to extract the estimations of the sound power levels of both the trucks and the straddle carriers. The entries "truck <20km/h" and "straddle carrier" have been respectively selected (106.8 db and 113.82 db).
Empty containers handling with fork lifters	A network of "point" sources has been selected. The network consisted of three point sources referring to the operation of fork lifters and two point sources referring to the associated movement of trucks. The point sources were spread in the empty containers handling area.	The SourcedB Database has been used to extract the estimations of the sound power levels of both the fork lifters and the trucks. The entries "Lifting truck - 16 ton - diesel" and "Trucks - <20km/h" have been respectively selected (106 db and 106.8 db).
Loaded containers handling with straddle carriers	A network of "point" sources has been selected. The network consisted of 8 point sources referring to the operation of the straddle carriers. The point	The SourcedB Database has been used to extract the estimations of the straddle carriers. The entry "straddle carrier" has been selected (113.82 db).

	sources were spread all over the loaded container handling area.	
Container ships	Three point sources have been inserted to the model at a height of 25 meters.	The SourcedB Database has been used to extract an estimation of the sound power level of the container ships. The entry "Ships 10.000 tot 20.000" has been selected (110.63 db).

(Michail 2006b)

Figure 110 (Michail 2006b) demonstrates the emerged noise model of the container terminal.

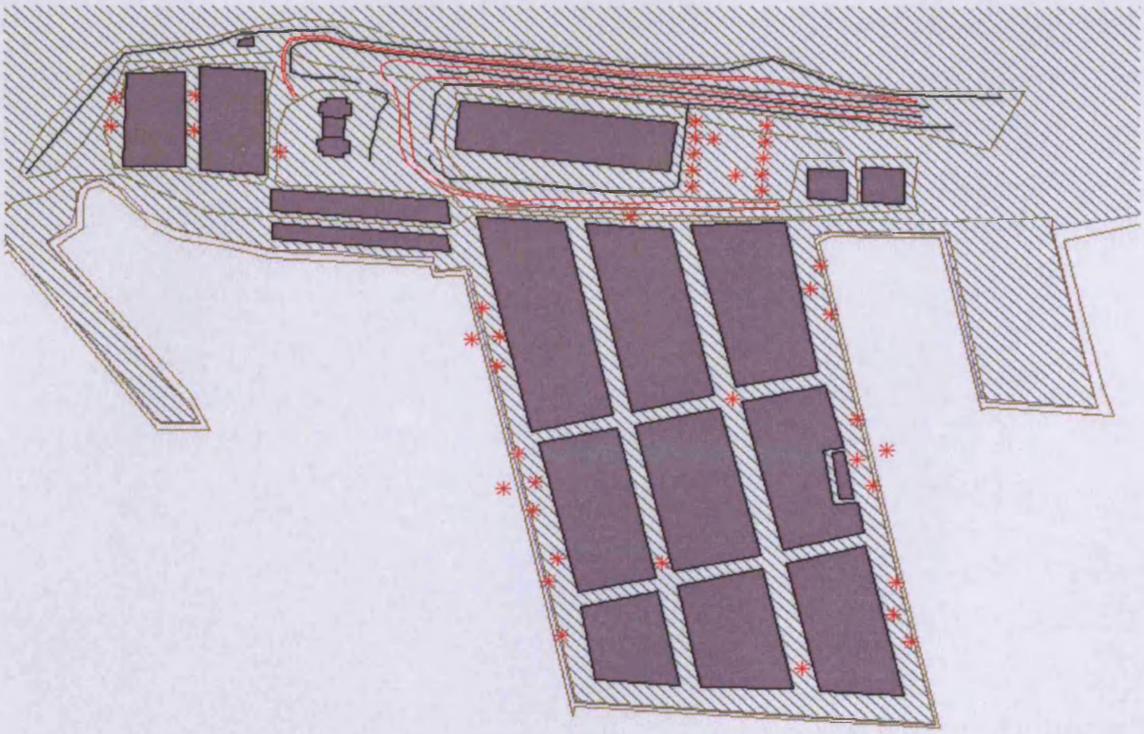


Figure 110: Complete picture of noise modelling in the container terminal

Once the morphology is built and the noise sources are simulated the user of Predictor is asked to locate receivers and grids to the model. The receivers and grids are determining the points where the calculation of the noise levels will take place. The receivers can be placed at single points of noise interest (e.g. limits of the port area, nearest residential area). The grids are horizontal or vertical surfaces that consist of a network of receivers. The colour coding that appears after the calculation of the noise models actually applies to the grid surfaces determined. For the Piraeus study receivers where placed at 6 selected points of interest as presented in figure 111 (Michail 2006b). The selected spots were the same as the ones in the monitoring program that was presented in section 8.5.2. It was considered of interest to compare the measured values with the calculated ones by the Predictor software.

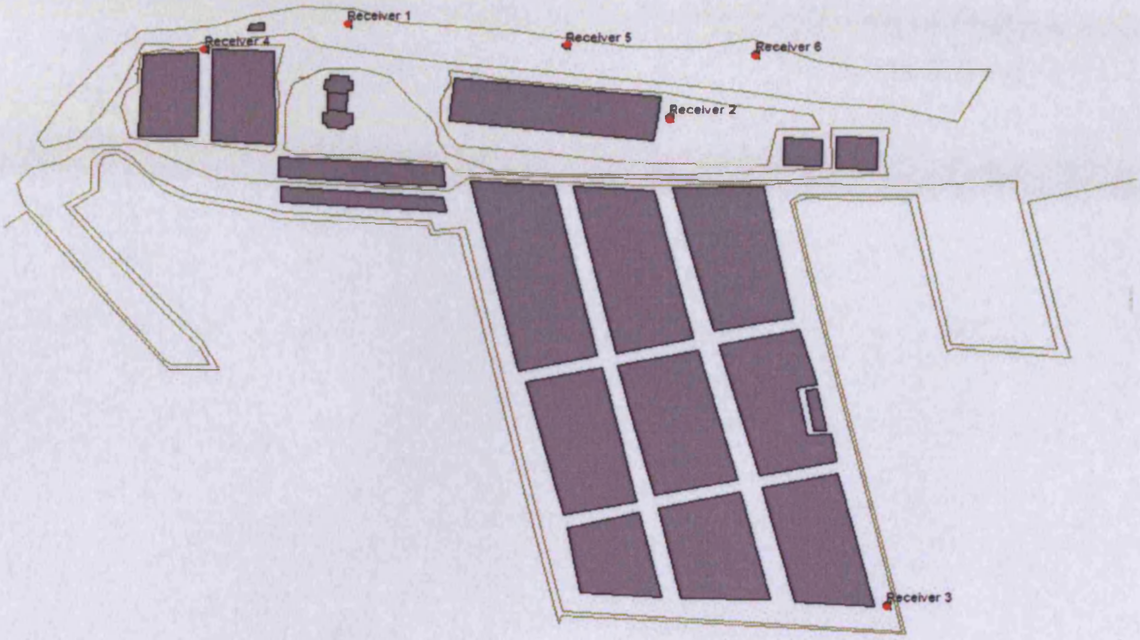


Figure 111: The location of the receivers

Concerning the grids a horizontal one at a height of 4 meters[35] from the ground was considered essential as being representative of the overall noise situation in the terminal. A vertical grid was also placed at the limits of the port area towards the residential area of Perama. The residential area of Perama lies up hill above the container terminal and it has been considered significant to visualise how the noise situation changes with the height towards that direction.

Next step after locating the grids and receivers was to set the calculation parameters. Those mainly include technical information and meteorological data as can be seen in figure 112.

[35] The suggested height according to the END

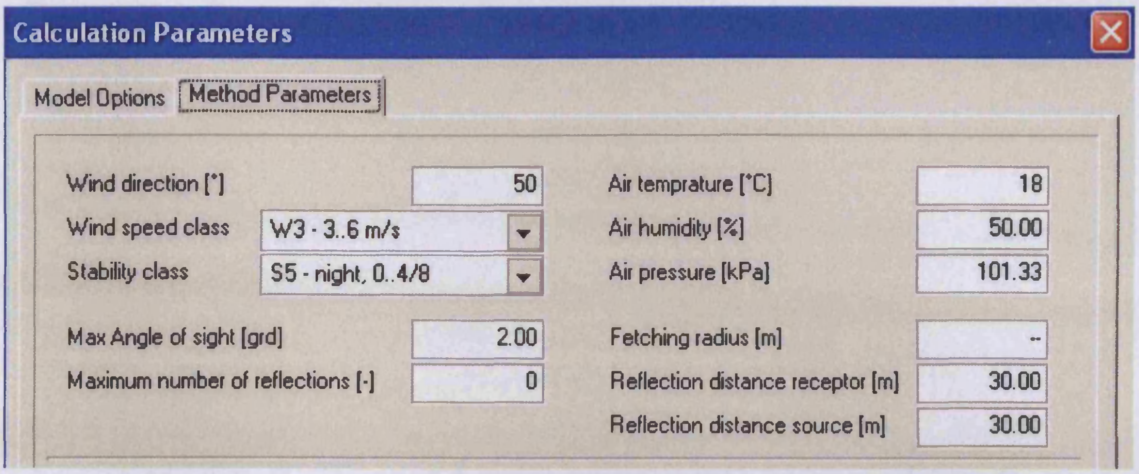


Figure 112: Calculations parameters

The calculation time of the developed noise model was around 2 hours. The model included 51 noise sources and 1065 calculation points (grids and receivers).

The produced two and three dimensional noise maps are presented below (Michail 2006b). Figures 113 and 115 are the two-dimensional colour coded representations of the L_{DEN} and L_{NIGHT} levels respectively throughout the container terminal. Figures 114 and 116 are the three-dimensional views of the same noise maps. An index providing information regarding the colour coding appears on each map.

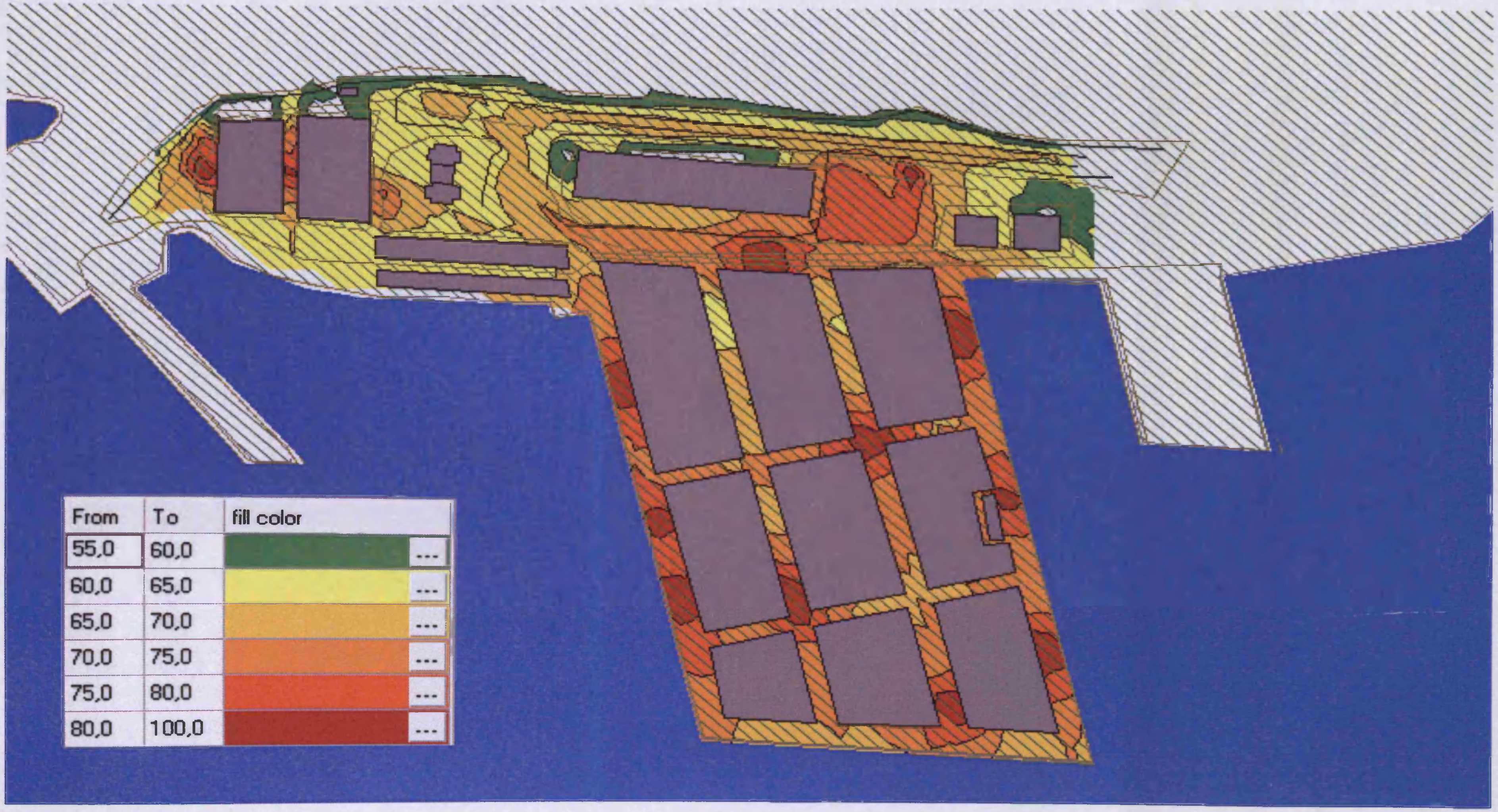


Figure 113: Port of Piraeus Container Terminal - 2D noise map (L_{DEN})

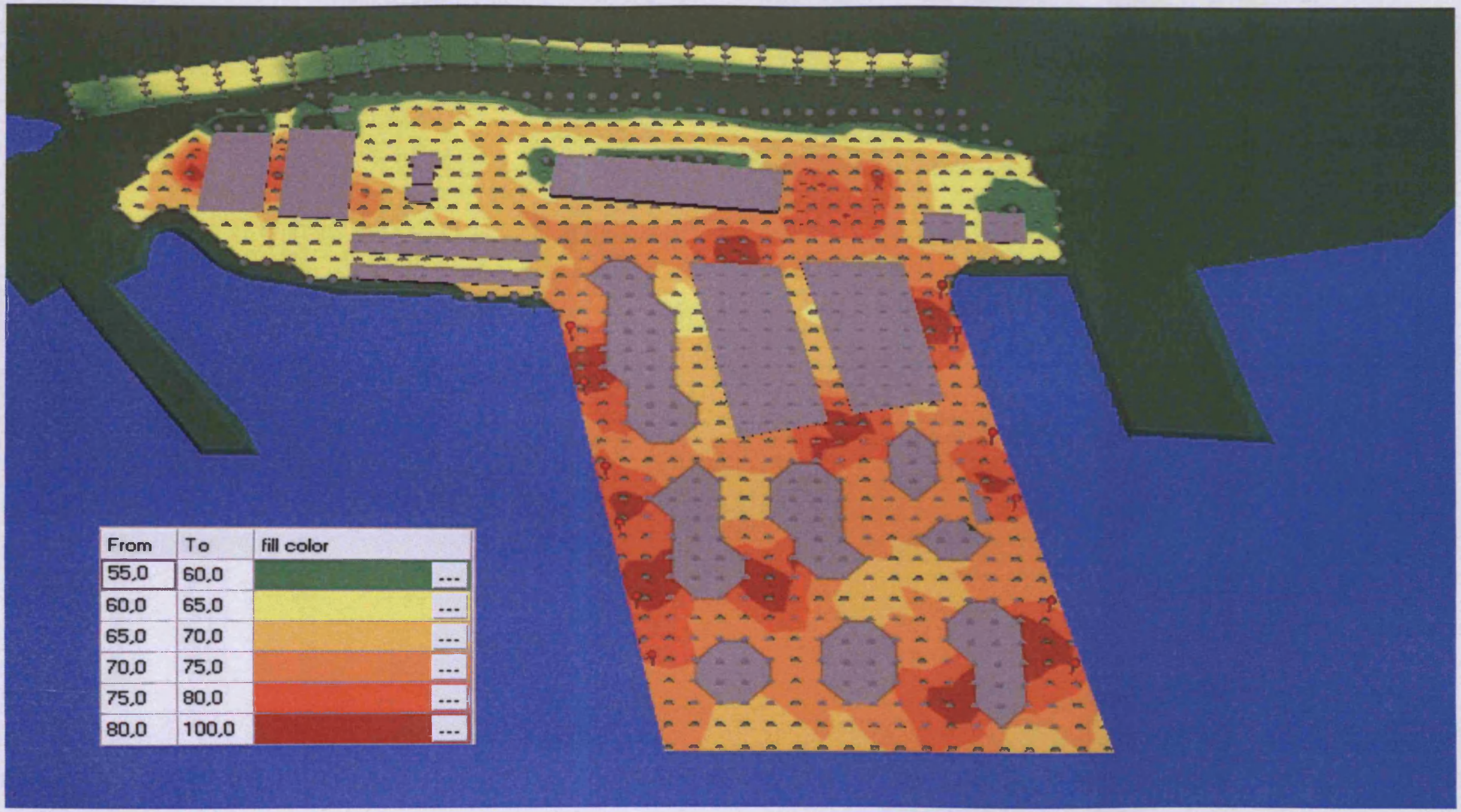


Figure 114: Port of Piraeus Container Terminal - 3D noise map (L_{DEN})

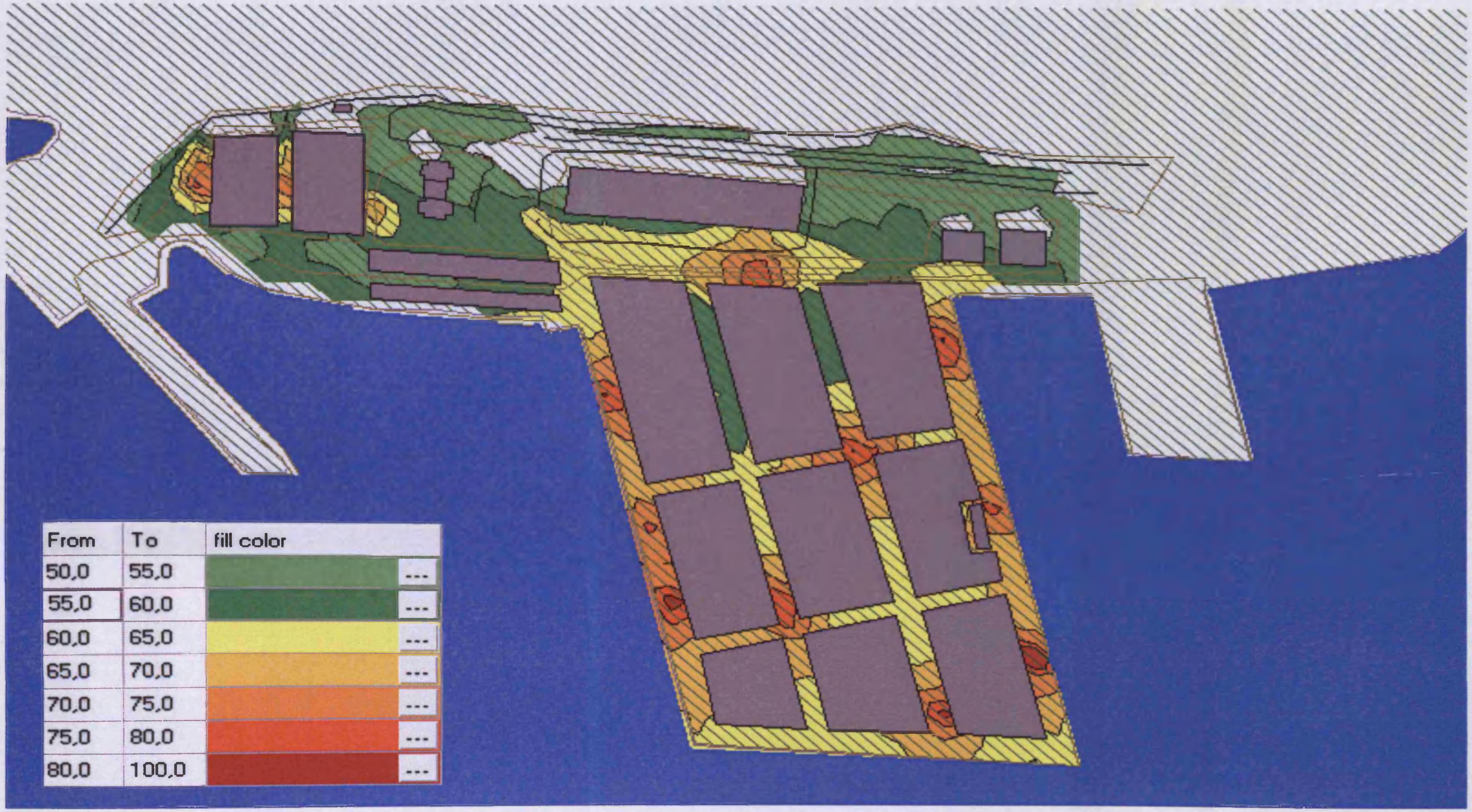


Figure 115: Port of Piraeus Container Terminal - 2D noise map (L_{night})

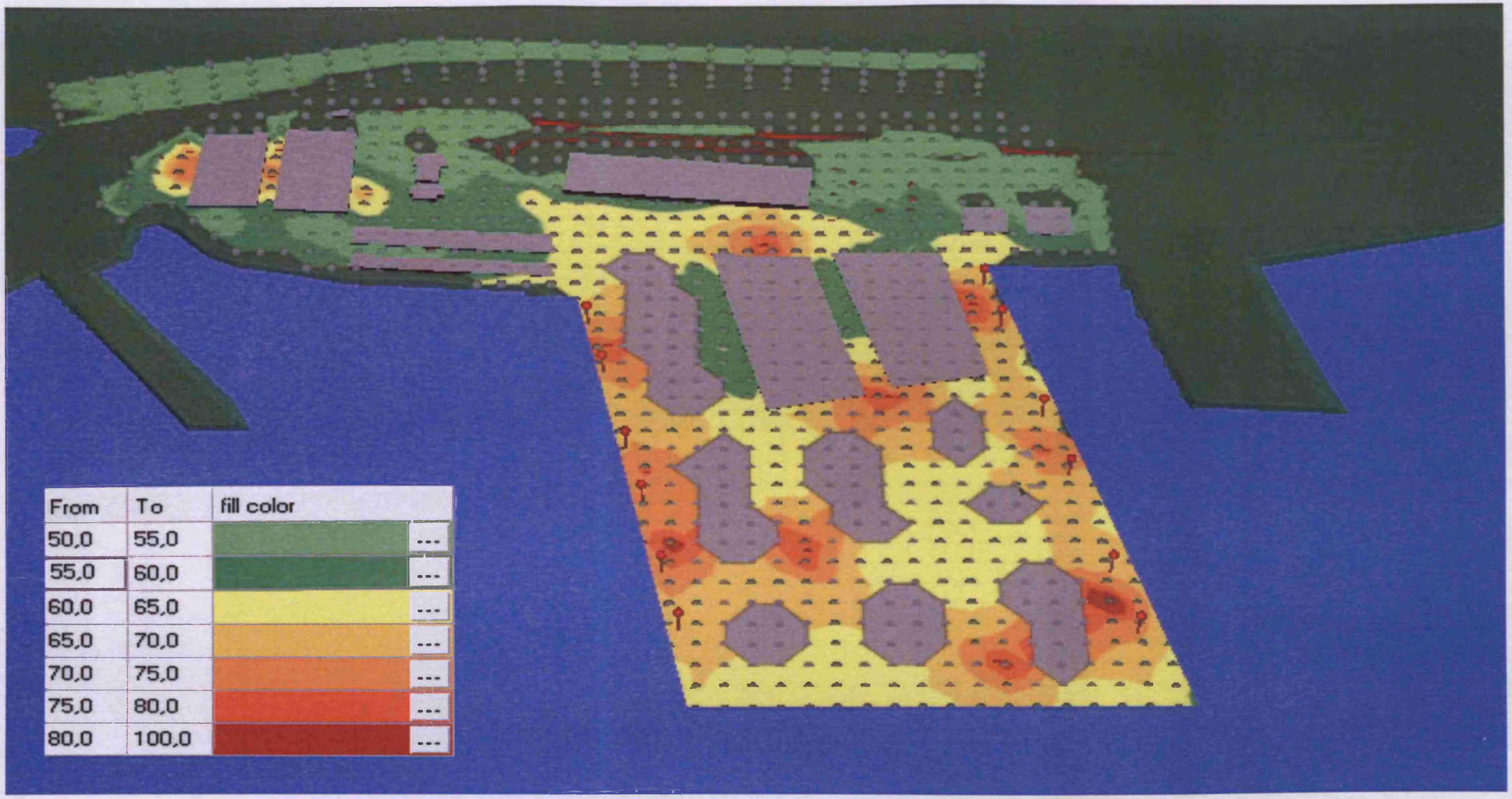


Figure 116: Port of Piraeus Container Terminal - 3D noise map (L_{night})

The noise maps demonstrate the distribution of estimated noise values L_{DEN} and L_{night} throughout the container terminal. The scale of the mapping exercise is such that does not allow the analysis of the impact of port noise to the overall noise situation in the surrounding areas and especially the nearby residential area of Perama. Nevertheless, some observations can be made from the study of the maps:

- An average value for noise levels typically occurring in container terminals is quoted as 65 to 69 dB (Witte 2007). Although predicted values at specific points appear to be higher than 70 dB, the average situation as can be observed on the maps generally seems to fit the given dB framework.
- The predicted noise levels around the physical limits of the terminal do not generally exceed the 65 dB for L_{DEN} and 55 dB for L_{night}. An area where further investigation is suggested is the empty container handling area where the indicators reach and in cases exceed those values.
- The noisiest areas inside the container terminal appear to be those where container cranes and straddle carriers operate, and where the loading and unloading of trucks using straddle carriers takes place.
- The traffic related noise sources (road access for both trucks and private cars) appear to have a modest contribution to the overall noise situation in comparison with the industrial (port operations) related noise sources.
- The visual effect regarding the display of the container stacks in the 3D versions of the maps (figures 114 and 116) can be explained by the interference between the heights of the stacks and the applied horizontal grid. In fact, those heights are both set to be around 4 meters above the ground.

Apart from the noise maps the calculations revealed predicted noise levels at the six selected receiver spots (figure 111). The following table 94 attempts a comparison between the predicted values as occurred from the results of the calculations and the average measured values of the monitoring program that were presented in section 8.5.2.

Table 94: Measured and predicted values in selected locations

Receiver	Spot	Average day measured values (L_{Aeq})	Evening measured values (L_{Aeq})	Predicted values (L_{DEN})	Predicted values (L_{day})	Predicted values ($L_{evening}$)
1	1	67.9 (5)	51.7	64.7	65.2	58.3
2	2	74.3 (4)	61.3	77	79.9	51.8
3	3	69 (4)	-	71.9	67.2	66.2
4	5	66.7 (6)	53.8	66.2	63.9	61.8
5	6	70.7 (1)	58	64.1	64.7	57.7
6	7	70.5 (1)	-	60.9	61.1	54.8

(Michail 2006b)

The "Average day measured values (LAeq)" column provides the average value for the total of measurements during day-time for each of the six locations. The number of measurement that contributed to this average is provided in brackets. For example, the average value of the (5) measurements at spot 1 was 67.9 dB. Only one evening measurement was available per location and it is provided in the 4th column of the table. The "predicted values" columns refer to values that occurred from the Predictor calculations. A comparison can only be eligible between the "Average day measured values (LAeq)" and the "Predicted values (Lday)", and between the "Evening measured values (LAeq)" and the "Predicted values (Levening)". Even between those values the comparison is subject to various assumptions and only general observations can be made.

Inconsistency can be generally observed between the measured and the predicted values. There is no obvious trend that can be identified. In cases the values are quite similar (e.g. spots 1 and 3 for the day time measurements), but in other they differ significantly (e.g. spots 6 and 7 for the day time measurements). In some cases the measured values are higher (e.g. spot 7) and in some other present lower values (e.g. spot 2) than the predicted ones.

8.6.4 Selected results from other studies

Some selected results of noise mapping studies that took place under the umbrella of the NoMEPorts project are highlighted in this section. The aim is to demonstrate the contribution of noise mapping in assessing the noise situation in and around seaport areas and in proving insight with regards to the relative contribution of different groups of sources (e.g. road traffic, rail traffic, industrial noise) to the overall situation. Selected noise maps from the ports of Hamburg, Livorno and Amsterdam are presented. The author had an advising role on those studies as part of Cardiff's University scientific coordination of the NoMEPorts project.

The following three noise maps from the Hamburg seaport area (figures 117, 118, and 119) demonstrate the Lden distribution over the port area from industrial, road traffic, and rail traffic related noise sources respectively. By presenting the noise mapping results in such a way it is possible to identify the relative contribution of different groups of noise sources in different geographical areas of interest. This is of significance while formulating noise action plans in order to mitigate noise.

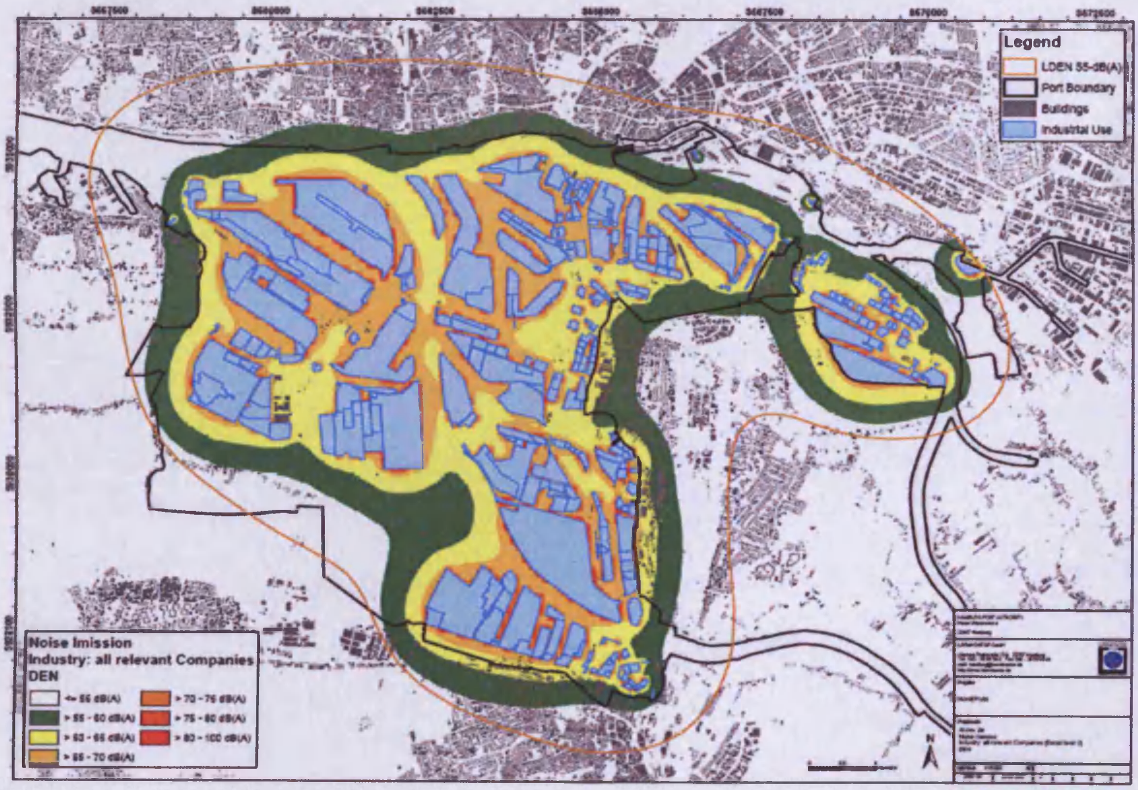


Figure 117: Port of Hamburg – Industrial noise sources (Lden)

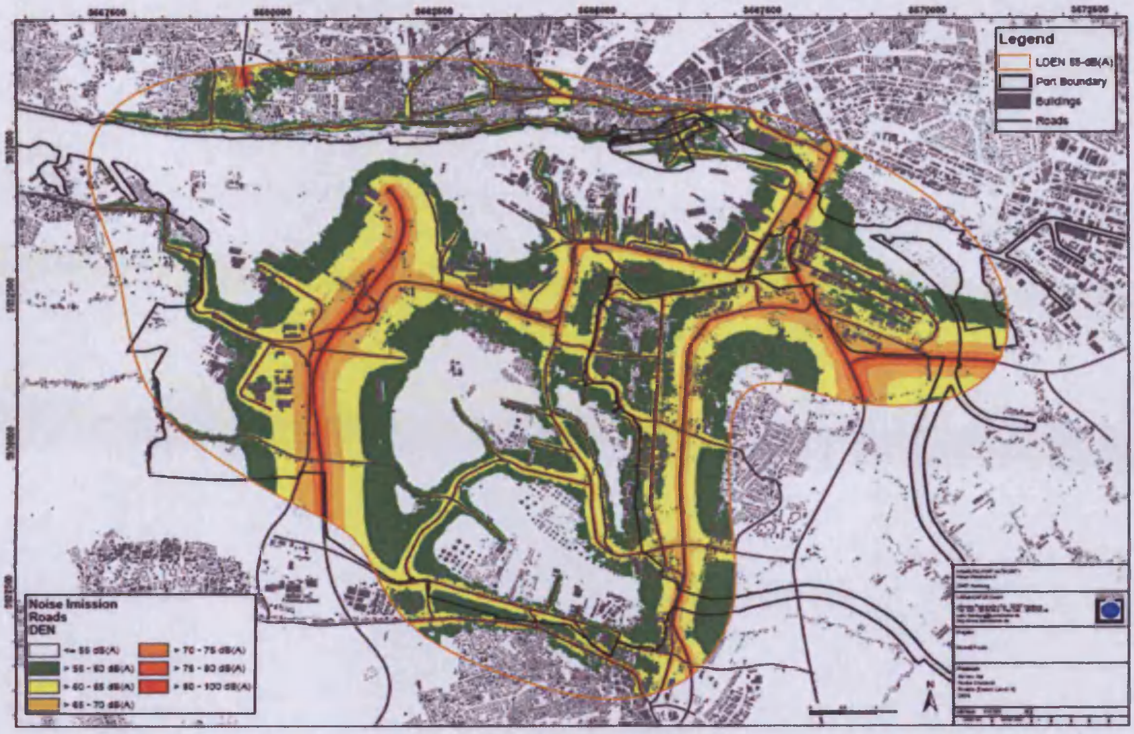


Figure 118: Port of Hamburg – Road traffic noise (Lden)

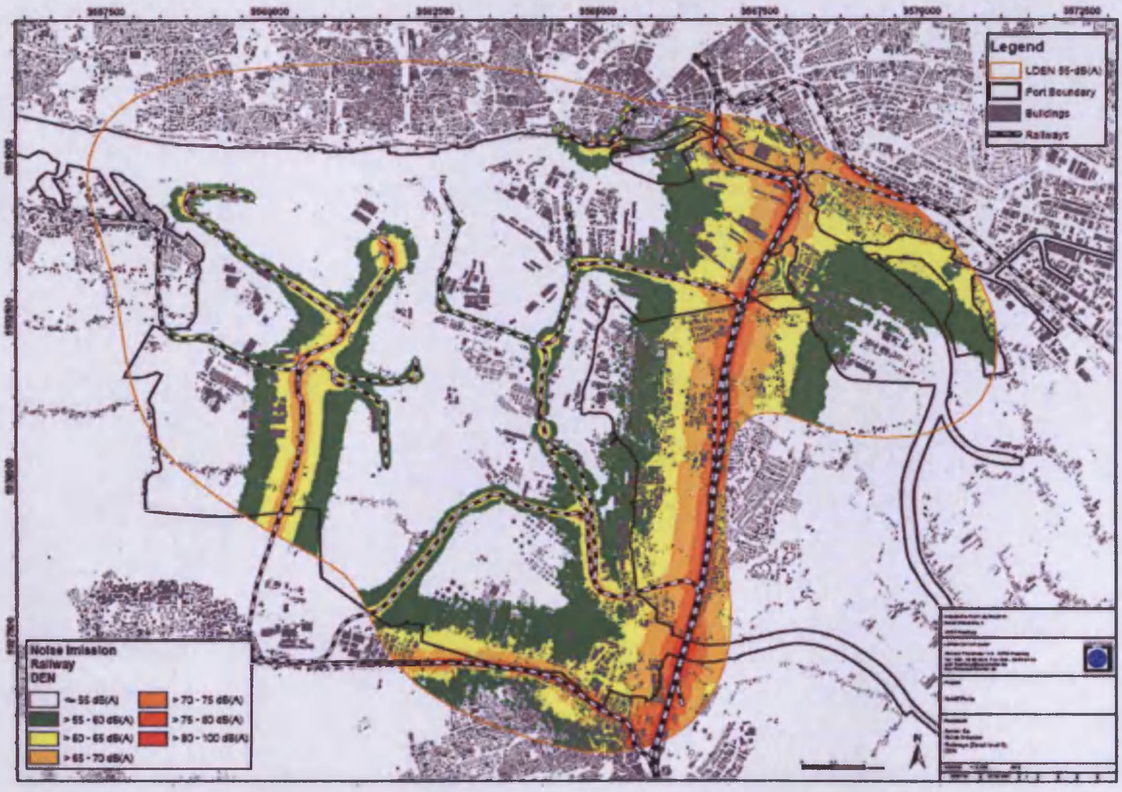


Figure 119: Port of Hamburg – Railway noise (Lden)

The following three noise maps from the Livorvo seaport area (figures 120, 121, and 122) demonstrate the Lden noise contours over the port area for all sources together, road traffic, and rail traffic respectively.

Figure 120: Port of Livorno - All sources (Lden)

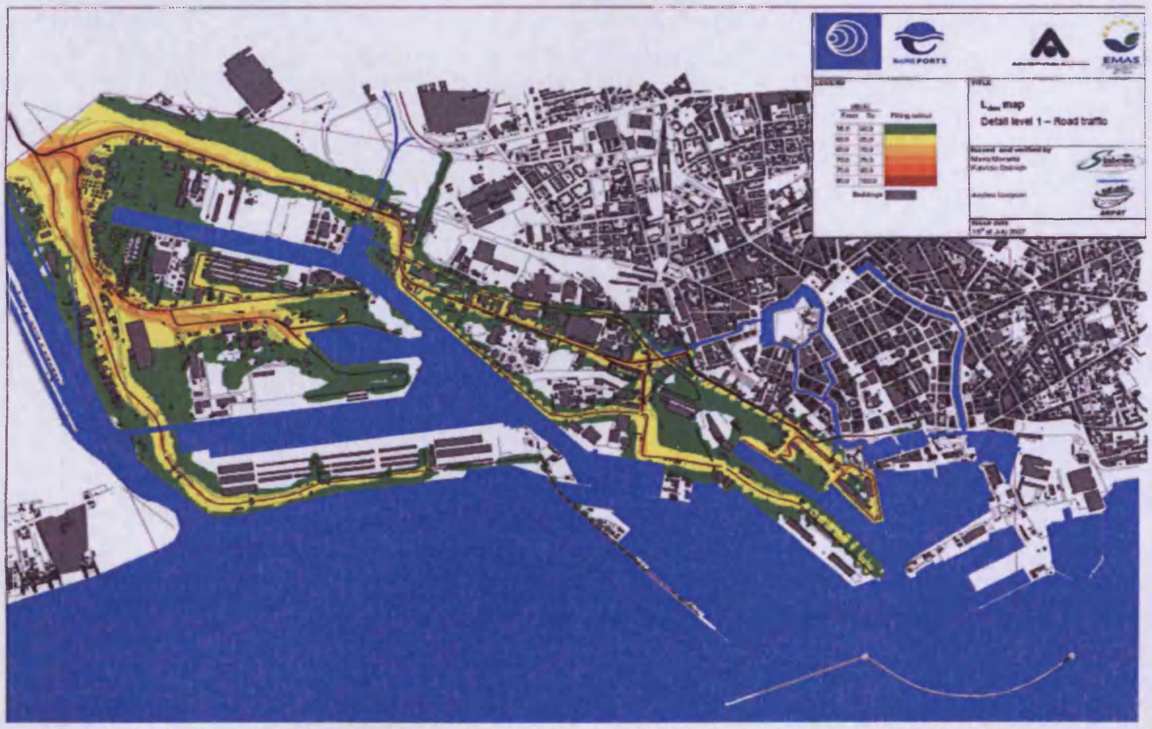


Figure 121: Port of Livorno – Road traffic noise (Lden)

Figure 122: Port of Livorno – Railway traffic noise (Lden)

Similarly, for the Amsterdam seaport area figure 123 maps the overall Lden noise situation, while figures 124, and 125 the road traffic and the railway traffic noise respectively.

Figure 123: Port of Amsterdam - All sources (Lden)

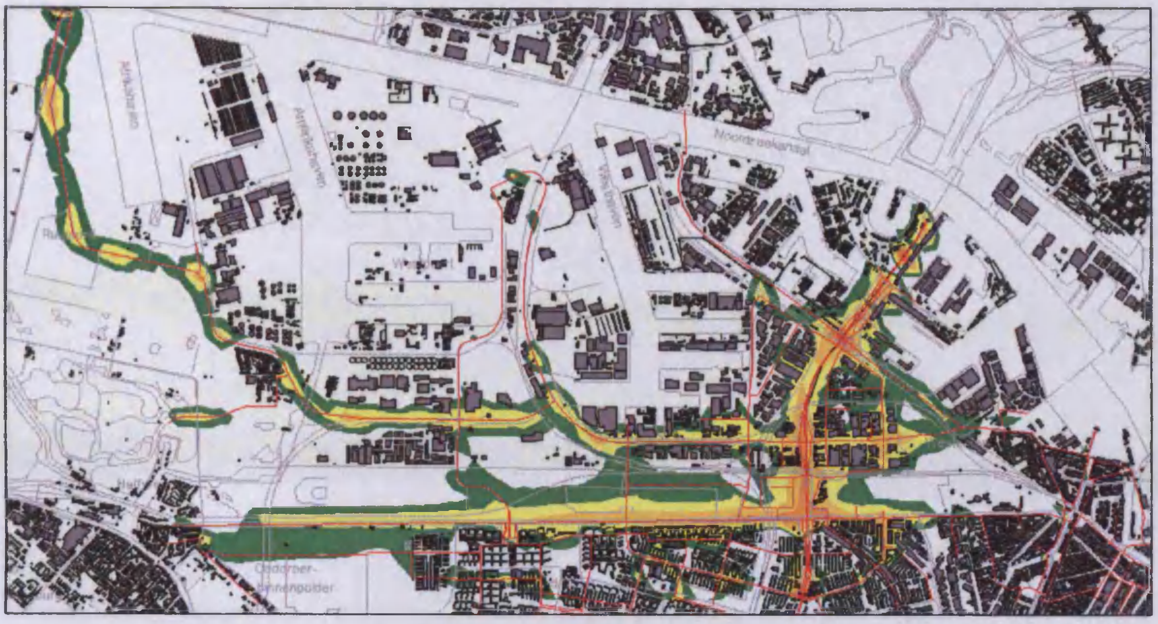


Figure 124: Port of Amsterdam – Road traffic noise (Lden)

Figure 125: Port of Amsterdam – Railway noise (Lden)

From the examples it can be demonstrated that such a display of results (by different groups of sources) can aid decision makers both in analysing noise maps and identifying problem areas as it is demonstrated in section 8.7, and in analysing the impact of different sources on those areas, thus guiding the process of noise action planning as discussed in section 8.8.

8.6.5 Case Study: Efficient simulation of noise sources

One of the commonly identified challenges with regard to noise mapping is the amount of time consumed in the calculations of the models. The calculation time depends on the complexity and level of detail of the geographical and topographical information and on the amount of noise sources and receivers that are introduced to the model. In order to investigate potential ways for reducing the calculation time of noise models and thus increasing efficiency and user friendliness of noise mapping, a case study was set aiming to reduce the calculation time at given noise models (Michail 2006d). For that purpose the initial noise model of the Port of Amsterdam that was produced under the umbrella of the NoMEPorts project has been selected.

The noise sources in the industrial area of the Port of Amsterdam were simulated by a complex network of "point source" items that was provided by the companies in the area for the needs of previous noise studies. It was considered that the total amount of sources that were included in the model of the industrial area was too big and the main reason behind the long duration of noise calculations. A case study was then designed in order to investigate options for reducing the amount of sources in the model of the industrial area without though losing significant noise information. The aim was a more flexible and simplified approach to the simulation of the identified noise sources that would not have a significant impact in altering the results of the noise mapping calculations.

The initial model of the industrial area in the Port of Amsterdam can be seen in figure 126. Every single red dot in the model corresponds to a "point source" item. The plethora of those items can be clearly demonstrated in the figure. In that initial version of the model an amount of point sources close to 6000 were introduced. The total calculation time of that initial model reached a time framework of 9 hours making any alterations, re-calculations, or investigation of different scenarios time consuming and often impracticable. Therefore, the managers of the port decided to investigate ways of modifying this initial model so that the amount of sources is reduced without this having a significant impact on the noise mapping results as those were expressed by the initially calculated noise values and noise contours. The methodology described below aimed to respond to that challenge. Additionally, and apart from the specific application, the exercise aimed to demonstrate the principles and approach that could also be applicable in other cases where there is an interest to reduce the amount of sources in noise models.

Figure 126: Initial noise model of the industrial area in the Port of Amsterdam

The encircled area in the model (figure 126) was selected for the case study. Specifically, the focus was placed on one single company (sewage plant). It was considered that if the reduction of noise sources at one company is feasible and effective, then the derived principles and approach could be transferable to the rest of the companies in the industrial area. The selected company for investigation and the way it was initially simulated are presented in figure 127.

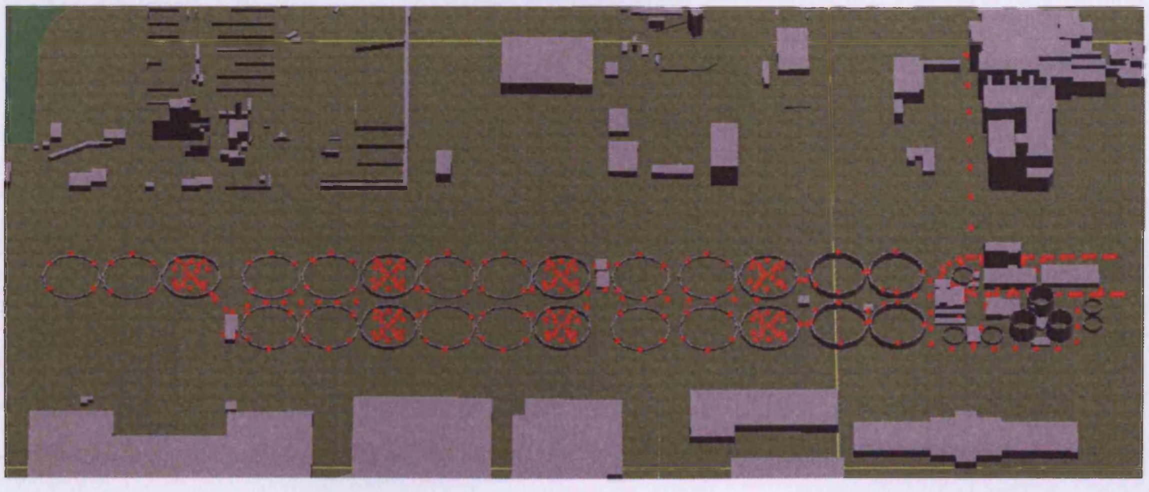


Figure 127: The selected waste water treatment facility in the Port of Amsterdam

The noise sources simulating the sewage plant's operations formulated initially a network of 373 point sources as seen in figure 127 (red dots). It was considered that this amount of sources could be reduced without any significant variations between the new and the initially calculated noise levels. Attention was paid on the way that the noise produced by the waste water treatment facilities (cylindrical features in the model) was simulated. The cylindrical features in the initial model were attributed 5 or 19 point source items as it can be demonstrated in figure 128.

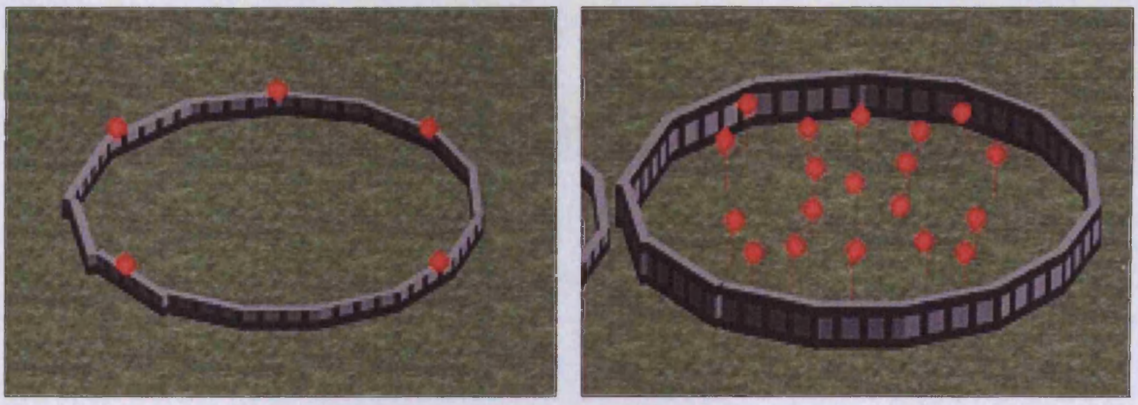


Figure 128: Initial approach to the simulation of two different types of waste water treatment facilities

That level of detail in noise simulation was selected by the given company for the needs of previous noise studies. For the strategic noise mapping of the whole area of the Port of Amsterdam though, it was considered that such a detailed analysis would only affect the calculation time without really adding to the accuracy of the results. A methodology was designed in order to reduce the amount of point sources by replacing the 5 or 19 source initial networks by single point sources positioned at the centre of the waste water treatment facilities (cylindrical features). Graphically, the envisioned transformation is presented in figure 129.

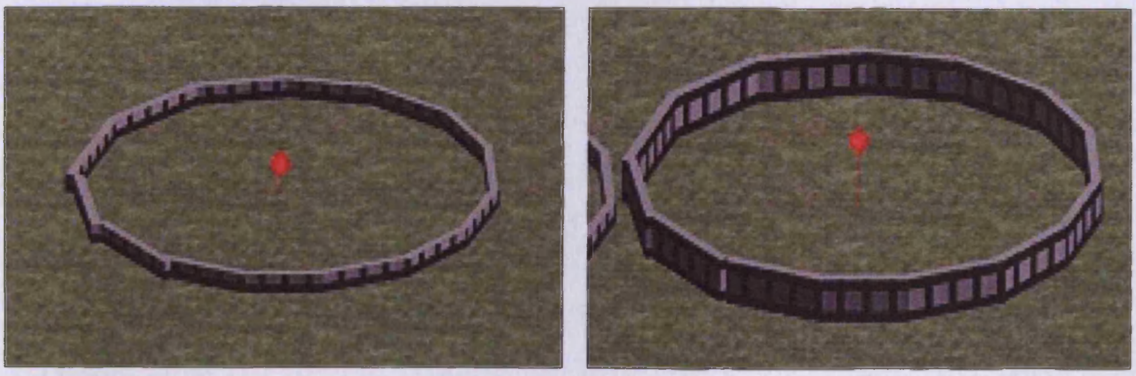


Figure 129: Suggested approach to the simulation of the waste water treatment facilities

In that way, the network of sources simulating the noise produced by the operation of the Sewage plant would be reduced to 175 point source items, thus achieving a reduction of about 53%. The methodology that was followed is presented on table 95. It consisted of developing and calculating 6 noise models and then comparing their results.

Table 95: Approach to reducing the amount of noise sources

Case study methodology:

1. Model 1: Isolate the sewage plant company as initially simulated. Insert a network of receivers (see table 97) in selected distances and towards the four compass points (North, South, East, and West). Calculate the values at the receiver points.
2. Model 2: Copy "Model 1". Erase all receivers and all noise sources apart from the ones applied to one of the cylindrical features simulated by 5 sources. Insert a new network of receivers in selected distances and towards the four (N, S, E, W) compass points. Calculate the model (values at receiver points).
3. Model 3: Copy "Model 2". Keep the same network of receivers and replace the five noise sources by only one in the centre of the cylindrical feature. Attribute to the new source a noise value increased by around 7 dB[36] in comparison with the previous common value of the 5 sources that were replaced. Calculate the model (values at receiver points). Compare the results with the ones from "model 2". Decide whether to accept or not the replacement. If not adapt the noise value and recalculate the model up to the point that the new results can be considered acceptable[37].
4. Model 4: Copy "Model 1". Erase all receivers and all sources apart from the ones applied to one of the cylindrical features simulated by 19 sources. Insert a network of receivers in selected distances and towards the four (N, S, E, W) compass points. Calculate the model (values at receiver points).
5. Model 5: Copy "Model 4". Keep the same network of receivers and replace the 19 noise sources by only one in the centre of the cylindrical feature. Attribute an estimated value (see footnote 45). Calculate the model (values at receiver points). Compare the results with the ones from "Model 4". Decide whether to accept or not the replacement. If not adapt the noise value and recalculate the model up to the point that the new results are "acceptable" (see footnote 46).

---

[36] The value was selected after consulting Mr Rob Witte, noise consultant at DGMR, on adding up and replacing noise sources

[37] The acceptable variation thresholds were set after consulting Mr. Ton van Breemen, Environmental manager and noise expert in the Port of Amsterdam, and Mr. Rob Witte, noise consultant at DGMR, Netherlands.

6. Model 6: Copy "Model 1". Keep the same network of receivers (see table 97). Replace the five sources cylindrical features by single source ones using the accepted values as occurred in "Model 3". Replace the 19 sources cylindrical features by single source ones using the accepted values as occurred in "Model 5". Calculate the model. Compare the results with the ones from "Model 1".

(Michail 2006d)

The modified model that emerged from the above process is presented in figure 130. The model consists of 175 point sources instead of 373 in the initial one, thus reduces the amount of sources by around 53%.

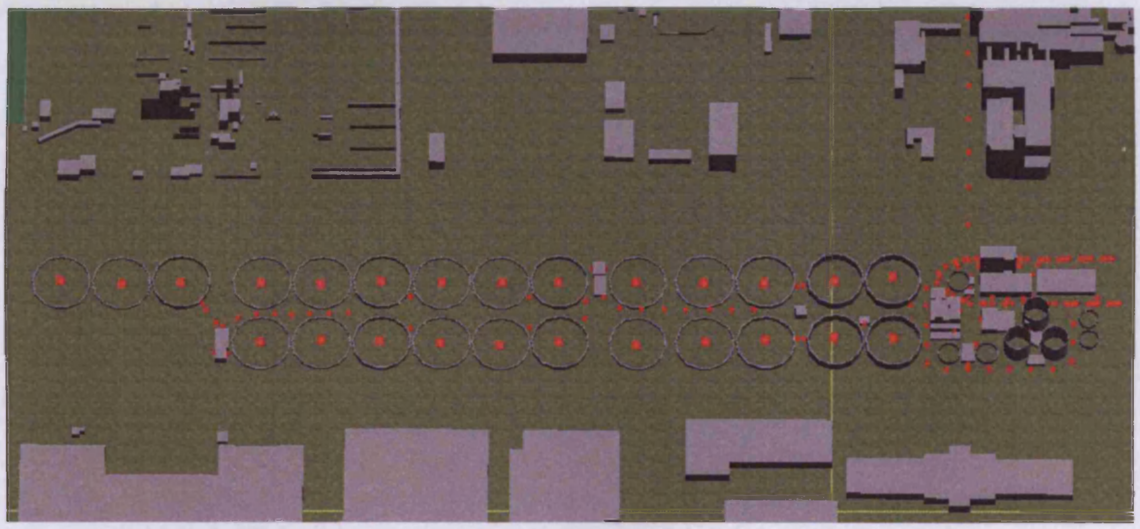


Figure 130: The suggested new model (53% reduction in the number of introduced noise sources)

The following table 96 presents information on the location of the receiver points for the Models 1 and 6.

Table 96: Network of receivers for comparing the results of Models 1 and 6

Receivers:

- North (N1, 2, 3, 4, 5 – 200m, 500m, 750m, 1000m, 1500m from the 9th cylindrical feature (top of it) from the left)
- South (S1, 2, 3, 4, 5 - 200m, 500m, 750m, 1000m, 1500m from the 9th cylindrical feature (bottom of the feature underneath it) from the left)
- West (W1, 2, 3, 4, 5 – 600m, 900m, 1150m, 1400m, 1900m from the vertical line between the two previous points of reference)
- East (E1, 2, 3, 4, 5 - 600m, 900m, 1150m, 1400m, 1900m from the vertical line between the two previous points of reference)

(Michail 2006d)

The comparative results on the set receiver points between the calculations of the initial Model 1 and the new Model 6 are presented in table 97.

Table 97: Results and variations at receiver points between the initial and the modified model

Receivers	373 sources (dB)	175 sources (dB)	Variations (dB)
N1	52.1	52.1	0
N2	45.8	45.8	0
N3	39.1	39.1	0
N4	35.1	35.4	0.3
N5	29.7	30.3	0.6
S1	24.8	25.7	0.9
S2	42.2	42.2	0
S3	22.8	24	1.2
S4	34.7	35.2	0.5
S5	29.3	29.9	0.6
W1	54	54	0
W2	43.2	43.5	0.3
W3	37.4	37.7	0.3
W4	31.9	32.7	0.8
W5	26.3	27.4	1.1
E1	43.1	43.2	0.1
E2	40.4	40.6	0.2
E3	36	36.4	0.4
E4	30.4	31	0.6
E5	3.3	5.8	2.5

(Michail 2006d)

In order for the alterations to be considered acceptable a threshold of 0.5 dB was initially set. The green colour appears on table 25 to indicate the cases were this criterion was met (variations less or equal to 0.5 dB); while the red colour indicates that higher variations occurred while examining the values at the relevant receiver. The initial scepticism (due to the red parts of the table) that occurred from the primary analysis of the results was surpassed while examining the identified problem areas (red receivers). It was realised that the problem areas (red receivers) were characterised by extremities regarding various aspects. For example in some cases tall buildings were interfering between sources and receivers (e.g. receiver E5) influencing the propagation in multiple ways.

The principles with regard to the approach to noise sources reduction that were established in the case study were further developed and finally applied by the Amsterdam Port Authority in order to effectively simplify the initial model. The Port of Amsterdam succeeded to reduce the amount of noise sources in the industrial area by 55% with insignificant variations between the initial and new calculated noise values and contours.

8.6.6 Conclusion

This section examined noise mapping as an assisting tool to noise management. The principles of mapping were discussed and a generic model guiding the process of setting up and undertaking a noise mapping program was developed and presented. Then, the established approach was demonstrated and validated in a series of selected studies. It was demonstrated that the graphic representation of noise values and impacts in 2-D and 3-D images may be powerfully persuasive documents in communicating noise related information and in negotiating with stakeholders. Noise mapping provides port managers with authoritative, science-based calculations that may be used to demonstrate their environmental credentials and to bring some quantified objectivity to what is often a controversial, and passionate environmental debate. The production, analysis and interpretation of noise maps in conjunction with associated noise management tools can provide the port manager with a suite of useful decision-making options. The analysis of noise maps and the formulation of noise action plans are further discussed in sections 8.7 and 8.8 that follow

8.7 Analysis of noise maps

In this section the process of analysing the outcomes of noise mapping is discussed. The analysis of the noise mapping outcomes is of significance and could offer decision makers the necessary decision support tools in order to formulate and justify the noise action planning (figure 131). The analysis embraces three main components: (1) the identification of the most significant noise sources (both group and individual sources), (2) the identification of hot spots and problem areas of interest, and (3) the estimation of the number of people exposed in certain noise classes for L_{DEN} and L_{Night} (by groups of noise sources and/or overall). For each of these components, generic methodologies and relevant guidelines are presented below. Examples of good practices are highlighted were necessary.

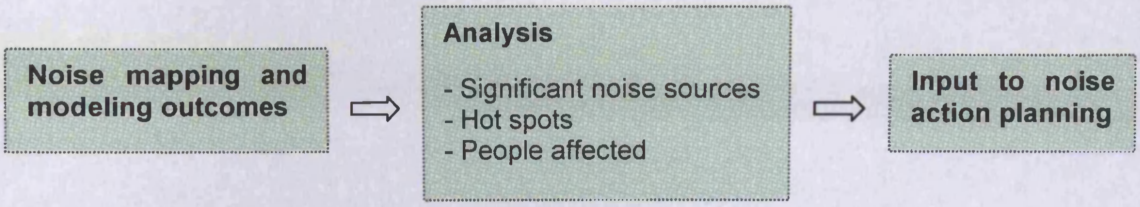


Figure 131: Analysis of noise mapping outcomes

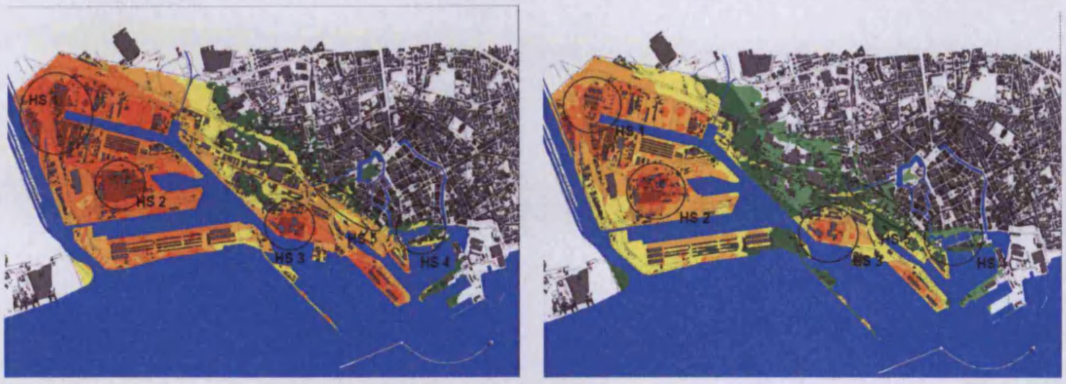
(1) Screening for noise sources significance - The process of screening for noise sources significance refers both to the identification of the relative importance of groups of noise sources (industry, port terminals, roads, railways and ship movements) and the identification of single sources significance (e.g. individual company, specific activity, specific road). As "significant noise sources" can be defined the sources that contribute highly on the environmental noise (both on L_{DEN} and L_{Night}) levels, on a number of positioned sensitive receivers. The significant sources can be identified by examining the resulted noise levels at those receivers. Receivers can be placed near housing areas around the industrial area, where the highest noise levels occur. For these receivers the group results can be displayed as well as the individual sources. This will give the information on the noise source significance. These results might also be visualised by displaying contours.

(2) Hot spots and problem areas - It can be argued that the identification of hot spots is port area specific. It requires a good knowledge of the peculiarities of the area under study and a sensitiveness analysis of the included sub-areas. A hot spot can be broadly defined as a critical point where noise indicators reach the highest values and/or the effect of noise on sensible receptors is significant. Identifying hot spots requires combining information on noise levels and on the number of people that are affected. There is an ongoing scientific debate (Witte 2007) on the evaluation of the combined data. Is it worse having 10 people exposed to 70 dB or 100 people exposed to 60dB?

An example[38] of hot spots' identification in the Port of Livorno is highlighted below.

Identification of hot spots – Livorno port area example

The figures below present the L_{DEN} (left figure) and L_{Night} (right figure) noise maps of the Livorno port area highlighting the five identified potential hot spots.



The potential hot spots were identified based on two criteria; (1) areas were noise indicators reach their highest values (spots 1, 2 and 3), and (2) sensitive areas where significant noise levels are observed (spots 4 and 5). The following remarks can be further made on the significance of each of the identified spots:

- The noise situation in spots 1 and 2 is related to noise emissions from industries, liquid terminal and heavy traffic. Despite the high noise values that can be observed, both spots are very distant from the urban context and their contribution to the acoustic situation in residential areas is very small. The noise levels at spot 3 are mainly influenced by terminal activities (solid bulk and forestry products).
- Spot 4 is particularly interesting because of the presence of port activities in close proximity to urban areas of the city. The main sources contributing are ships at berth and road traffic. The spot is also of interest because of its L_{Night} observed values (50-55 dB) that reach the noise limit (55 dB) which is imposed by the present Italian legislation.
- Noise values at spot 5 are almost entirely dependent on road traffic. The traffic in that zone consists of light traffic to and from the passenger station, and light traffic related to accessing and getting out of the city centre.
- Summarizing, spots 4 and 5 can be identified as "hot spots" in the sense that they both present high noise values, and that those values may affect residents and/or put at risk the port's compliance with the applied legislation.

Figure 132: Example of hot spots identification in the Port of Livorno

[38] Source: NoMEPorts project

(3) Number of people affected - The calculation of the number of people affected by noise in a port area usually requires the use of specialised software or general software such as GIS, that has the ability to synthesise the results of the noise mapping process with information regarding the number of inhabitants in different areas on the noise maps. The general picture in terms of input requirements and output of such software is presented in the following figure.

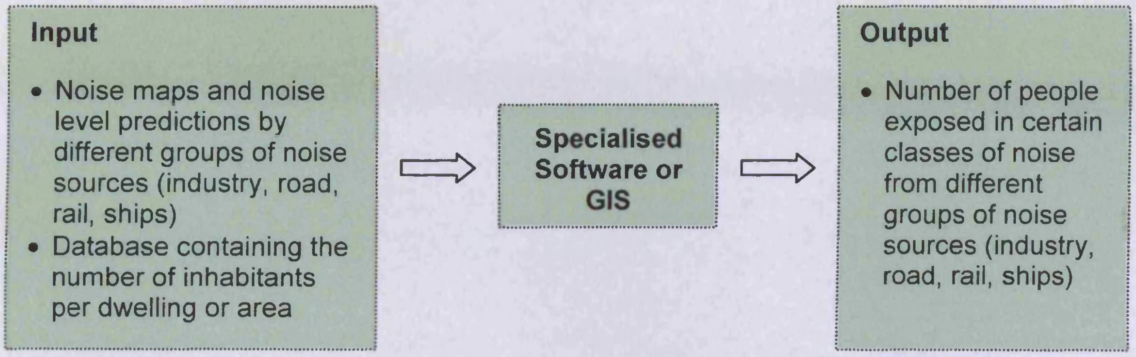


Figure 133: Schematic function of software for estimating the number of people affected

The examples that follow demonstrate different display options of the results regarding the estimated number of people that are exposed in certain noise classes. The examples are taken from noise studies undertaken under the umbrella of the NoMEPorts project in the ports of Livorno and Amsterdam.

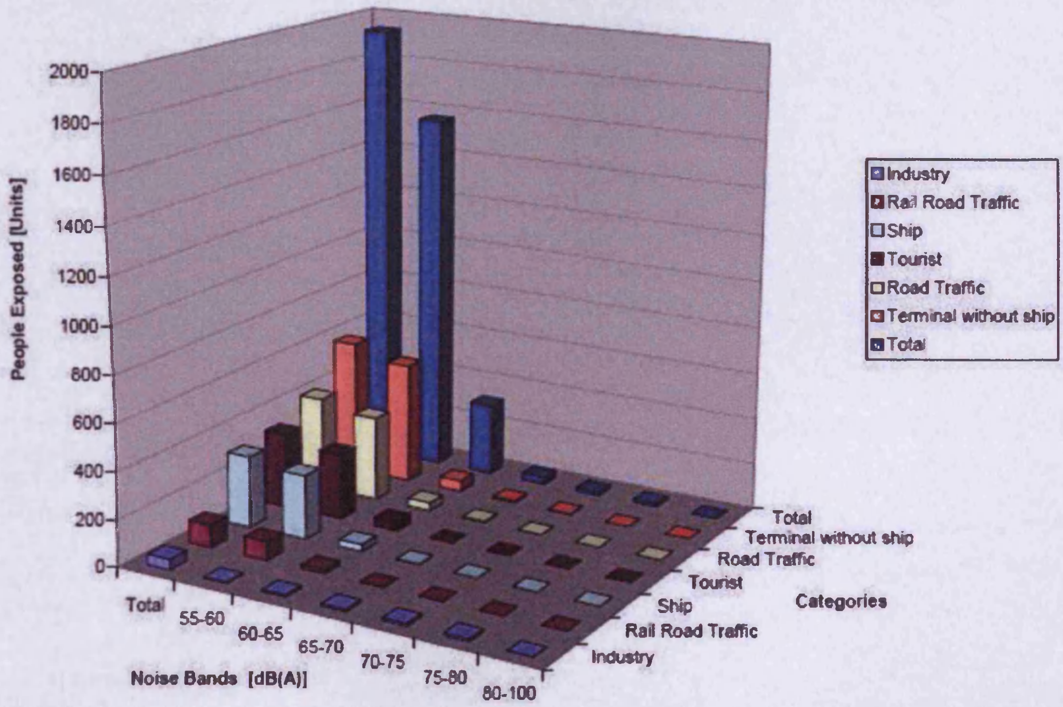


Figure 134: Port of Livorno – Display of the number of people exposed to different noise classes

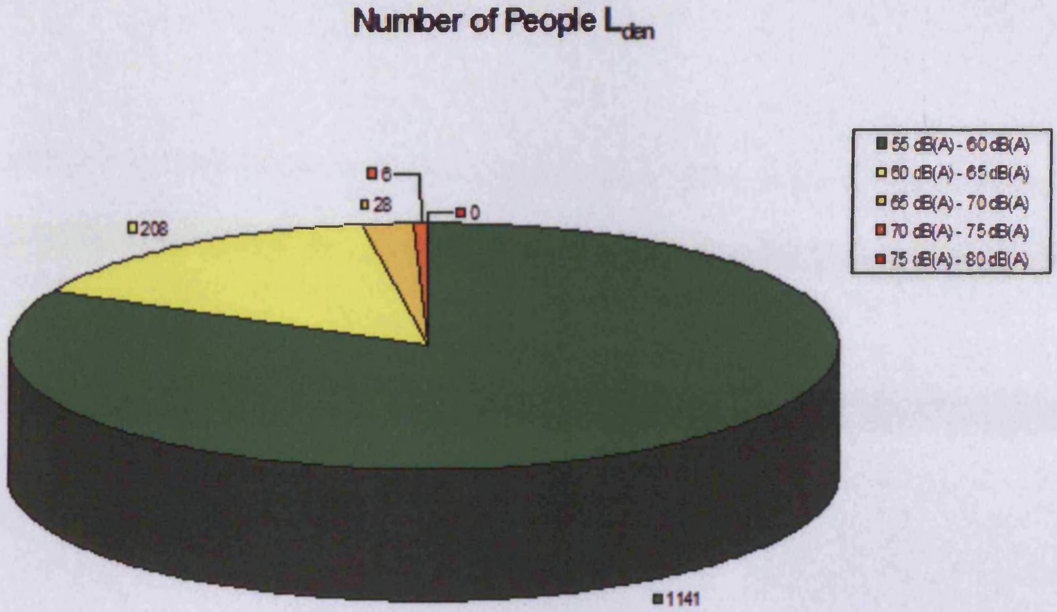


Figure 135: Port of Amsterdam - Number of people exposed to different noise classes

8.8 Noise action planning

Action planning is an important instrument within the noise management system and it targets the reduction of noise exposure and associated impacts to the physical and psychological health of humans and other living organisms. Noise action plans are designed to manage and control noise impacts and to reduce noise exposure where considered necessary. Noise mitigating measures are to be implemented in order to tackle the significant challenges as those are identified and established by the application and analysis of outcomes of tools such as noise monitoring, predicting, and mapping. Mitigation measures address priority areas (hot spots) which may be identified by the analysis of noise maps as seen in the previous section, and in line with the study of the applied legal framework and stakeholders' interest.

In the EU, and in the context of the Environmental Noise Directive (2002/49/EC), action plans have to be drawn as the outcome of producing, and analysing strategic noise maps. END provides that the noise action plans shall be reviewed and revised if necessary, when a major development occurs affecting the existing noise situation, and at least every five years after the date of their approval. The public shall be consulted about proposals for action plans, given early and effective opportunities to participate in the preparation and review of those. Noise action planning is a cross-sectional task. For the development and implementation of action planning, many different sources of knowledge and interests have to be considered and coordinated. Those could include; the analysis of noise monitoring and mapping outcomes, the results of consulting with the public, the applied legal and regulative framework, the study of recorded complaints from citizens, and the analysis of the efficiency of different mitigating response options. The following table 98 summarises the key components of a noise action plan.

Table 98: Components of a noise action plan

Components of a noise action plan:

- a description of the area and the noise sources taken into account,
- the authority responsible,
- the legal context (e.g. any applied limit values in place),
- the evidence on which decision making was based (e.g. analysis of noise monitoring and/or mapping outcomes),
- an evaluation of the estimated number of people exposed to noise,
- identification of problems and situations that need to be improved,
- record of the public consultations,
- any noise-reduction measures already in force and any projects in preparation,
- actions which the competent authorities intend to take in the next five years, including any measures to preserve quiet areas,
- estimates in terms of the reduction of the number of people affected (annoyed, sleep-disturbed, or other),
- long-term strategies,
- financial information (if available): budgets, cost-effectiveness assessment, cost-benefit assessment, and
- procedures for evaluating the implementation and the results of the action plan.

Source: NoMEPorts project

Noise mitigation can be approached under four headings (Nelson 1987), which are complementary rather than mutually exclusive. In order to achieve desired reduction of noise exposure, a combination of different mitigation measures, rather than individual ones, may be considered as more effective. Maximum mitigation will be obtained only if all are incorporated in an overall approach (Hunter, Farrington et al. 1998).

The four categories of noise mitigation measures are:

- Measures targeting the reduction of noise at source. For example, vehicle design, silent technologies, traffic management and speed limits, covering of sound intensive components with insulation, silent exhaust pipes, and softer ground material where allowed by the operations.
- Measures to control noise along its transmission path (propagation): These consist mainly of barriers such as fences and embankments, and the use of buildings as noise barriers. For example, a two-storey building may reduce noise on the "lee" side by about 13 dB(A) (Nelson 1987)
- Measures to protect the observer from noise at the point of hearing. Buildings can be designed to reduce noise impacts on their occupants. For instance, double or triple glazing and acoustic insulation can have significant benefits.
- Land-use planning and zoning: This approach is the most effective in reducing noise levels at the larger scale, because it targets the location of residential areas and workplaces further away from noise sources.

For all the above categories, mitigation measures can be technical, structural, formative and/or organisational in their nature.

One of the main political messages that can be derived from the NoMEPorts project is the suggestion that the Port Authorities could take the lead with regard to noise action planning in port areas (NoMEPorts project 2008). Although the message might seem logical at first hearing, it demonstrates a significant step of progress. Port authorities themselves recognise their role as coordinators of the efforts to manage and control the environmental impacts of the whole port area.

8.9 Conclusions

This chapter demonstrated noise management response options throughout the logistic chain and in seaport areas in particular. It broadly identified the chain related activities and operations that impact on the noise situation and it discussed management options, tools and methods that are applied in order to assess, control, and mitigate the impact where needed. Then, focusing on seaport areas a phased approach to integrated noise management was established and its components were demonstrated. Selected case studies of noise monitoring and mapping were presented and analysed. The studies applied, tested and validated principles and approach. The chapter established that integrated management of environmental noise, one of the major and more complex to control logistic chain aspects, is feasible and practicable in seaport areas and in the whole logistic chain. The technologies required (e.g. sound level meters, prediction software packages) are available, scientifically proven and effective. The research in seaport areas demonstrated that although the administrative and liability issues are often of a challenging nature, the identification of mutual interest and advantage can, through collaboration between the interested parties, overcome such concerns.

The above findings are of significance for the overall aims of the thesis, the feasibility assessment of establishing an EMS for the logistic chain and the contribution towards its development. It can be argued that if integrated noise management is feasible in both technical and organisational/administrative terms, then the management of other, often easier to control environmental aspects of transport related operations, may also considered feasible. In addition, the identification of mutual interest and advantage between different parties regarding the environmental management of the logistic chain is of high relevance in the development process of an integrated EMS. Those implications are further discussed in the next chapter that synthesises the concepts and findings throughout the thesis in order to assess the feasibility and practicability of integrated logistic chain environmental management and to establish the guiding principles of a system or framework towards that direction.

9 Conclusions: Integrated Environmental Management of the logistic chain

This chapter, the concluding of the thesis, synthesises the findings of all the previous chapters in order to address the overall research aims. The aims were (1) to assess the feasibility and practicability of a framework or system for the integrated environmental management of the logistic chain, (2) to derive the principles and preconditions that would allow the establishment of such a framework, and (3) to provide the main axes of such a system in the form of a generic model that could be applied.

The discussion on the feasibility and practicability of an environmental management framework is discussed in section 9.1 where the findings of the different sub-areas of the research and the major observations are summarised and synthesised in order to address both the technical feasibility and the organisational framework of integrated environmental management of the logistic chain. Section 9.2 focuses on establishing the principles and preconditions of an environmental management framework specifically designed to deliver continuous improvement of environmental performance of the logistic chain. Section 9.3 uses again the major findings and observations of the thesis in order to filter and adapt the generic over-arching environmental management framework that was introduced in chapter 4 (section 4.6) in line with the organisational and operational characteristics of the logistic chain. The outcome is a proposed model that establishes the principles and guides the development and implementation of an EMS that delivers continuous environmental improvement of logistic chain operations. Then, in section 9.4 selected tools and methodologies that could assist in the different phases of the presented generic model are summarised and their contribution is highlighted. Finally, section 9.5 draws the final conclusions, and makes suggestions and recommendations with regard to further research in the field and potential applications of the presented generic model.

9.1 Feasibility and practicability

In order to assess feasibility and practicability several parameters need to be examined, in particular, technical and organisational requirements. Major questions are; (1) is integrated environmental management of the logistic chain technically feasible?, and (2) is it possible to overcome the organisational and administrational challenges? Those can be addressed in line with the main findings of the different study areas in the thesis.

9.1.1 Major observations

The following table 99 highlights selected results arising from the research pathway. Specific attention is paid to those elements that allow the drawing of conclusions with regard to the feasibility and practicability of an integrated environmental management scheme for the logistic chain.

Table 99: Major observations and implications of research pathway components

Component of the research pathway	Major observations	Conclusions and Results
Function, format and organisation of the logistic chain (chapter 3)	The logistic chain is a highly dynamic, interrelated, multi-actor and complex system, already in what concerns its primary function which is to efficiently respond to the freight mobility needs	The development of a realistic model for an environmental management framework that addresses such a complex system is equally complex and challenging. The identified organisational challenges, and the leadership and liability issues are some of the main areas that need to be addressed
Interaction between the chain and the environment (chapter 4)	Humanity is faced with the challenge of reducing transport's irreversible damage to the environment and health, without losing the benefits to society and economies	An integrated environmental management framework or system for the logistic chain has the potential to ensure continual environmental improvement and to respond to the sustainability

		challenge. Such a framework needs to address the specific administrative and operational characteristics of the logistic chain
Significant environmental aspects (chapter 5)	The significant environmental aspects of the logistic chain operations can be identified by following a structured environmental management based methodology	It is feasible to identify the elements of activities, products, and services of logistic chain operations that need to be addressed by environmental management
Major players' response to the challenge of sustainability (chapter 6)	Good practice examples of major players' practices demonstrate potential for improving the environmental performance of the logistic chain. Common practice is acknowledged to be suboptimal but it can be argued that good practices demonstrate trends towards future common practices	The major players in the logistic chain increasingly consider freight transport related environmental considerations in the scope of their environmental policies and management efforts. Voluntary self regulating response to societal forcing mechanisms appears to be the more efficient and promising framework for the operation of greener logistic chains.
Environmental management of logistic nodes (chapter 7)	Within the European port sector, there has been a steady progress over the last fifteen years towards the direction of integrated seaport area environmental management.	The integrative trends from point to area focussed approaches in seaports' environmental management justifies an optimistic standpoint towards assessing the potential for further integration in the logistic chain
Environmental management response options (chapter 8)	It can be demonstrated that integrated management of environmental noise, one of the major and more complex to control logistic chain aspects, is technically feasible and practicable in both seaport areas and in the whole chain.	The integrated environmental management of other, often simpler and easier to control, environmental aspects can also be considered technically feasible and practicable

Although of a complex and challenging nature, a framework for integrated environmental management of the logistic chain has the potential to deliver continuous environmental improvement and to respond to the challenge of sustainability. Components of such a framework, including the identification of the significant environmental aspects to be addressed, can be considered feasible and practicable. The increased interest demonstrated from the main players in the logistic chain towards such a direction, the integrative trends in the field of seaport area environmental management, and the demonstration of integrated environmental noise management justify an overall optimism while assessing the potential for integrated logistic chain management.

9.1.2 Technical feasibility

Technical feasibility requires access to, and application of appropriate, cost-effective and proven tools and systems. Such technical means and requirements could include for example advanced IT platforms that enable and facilitate the communication and information exchange between different chain players on environmental grounds, and appropriate equipment and software packages that could be applied for the collection and analysis of relevant environmental data and for providing evidence of progress and effects of the actions taken and solutions implemented.

The availability of such systems has been highlighted in a series of examples. For instance, the IT platforms of systems such as PRIOS in the Port and Municipality of Hamburg and PortInfolink in the Port of Rotterdam that were discussed in section (7.5.2) demonstrate that different parties interfaces could be linked to one system enabling the efficient exchange of information that appears to be a precondition in the case of integrated environmental management of the multi-actor logistic chains. In addition, many advanced IT systems are already applicable for the facilitation of the information exchange between supply chain partners in order to increase efficiency of operations. Current information and communication technology provides new possibilities to support the complex chain coordination and control (Bontekoning, Macharis et al. 2004).

With regard to the availability of equipment and software for collecting and analysing environmental data (thus enabling evidence-based environmental management), chapter 8 of the thesis demonstrated that such technical systems are available. In the case of noise, one of the most complex environmental aspects to control, data can be collected and analysed with the use of advanced noise monitoring equipment and noise prediction and mapping software. Acknowledging the high degree of complexity in controlling noise, it may be suggested that for the control of most environmental aspects appropriate and proven technical means are reasonably expected to be available and applicable. Nevertheless, in order to fully support the statement above the detailed study of all the major aspects of chain operations would be required.

It is well established that industry requires technology to be cost-effective, robust, reliable and compatible between the range of players involved. The main constraints in applying the available systems and tools could include financial considerations and overall effort requirements including the need for trained and designated users. In fact though, advanced IT systems are already in place in the big majority of firms involved in freight transportation. Such systems are imposed by efficiency requirements with regard to the communication of operational information between the different parties in the transport chain. In addition, as highlighted in chapter 6, the environmental and economic imperatives are not mutual exclusive and environmental efficiency is in several cases linked to economic benefits. The application of appropriate tools and systems should then be considered feasible and practicable.

9.1.3 Organisational framework

The organisational and administrational challenges are arguably more complex than the technical ones. Throughout the thesis and especially in chapters 3 and 6 those challenges were highlighted. Integrated environmental management requires a well defined organisational structure with roles and responsibilities clearly defined for all players. For example, all environmental management systems refer to an "organisation", a functional entity, which develops policy, defines objectives and targets, appoints and documents responsibilities, decides on and takes necessary measures, assesses impact, and periodically reviews the entire process in order to enable continual environmental improvement. Such a functional entity implies an administrative structure to ensure that strategic commitments towards specific environmental objectives are communicated throughout the different functional elements and components, and that appropriate actions are taken.

The organisational feasibility of integrated environmental management of the logistic chain could therefore be addressed by examining whether or not the logistic chain can be seen as a functional entity with an established administrative structure. Although well established on its physical manifestation, function and format, the logistic chain was considered throughout the thesis in its generic context, implying the interconnected networks of the global freight transport systems. This holistic overall chain consists of a plethora of smaller networks that can be attributed to, influenced and/or controlled by a specific country, product chain, or even single company. While examining the organisational and administrative framework of the logistic chain, it is important to examine not only the general but also selected specific expressions of the logistic chain concept. This can be achieved by considering various scenarios involving different administrational and organisational challenges.

Two main scenarios are selected for further examination on the following paragraphs:

- Scenario 1: Large shipper acting as a chain leader
- Scenario 2: Players of equal market power identify interdependence and mutual interest

Scenario 1 - Large shipper acting as a chain leader

In examining the example of a chain where a large shipper acts as the chain leader the following assumptions and implications can be made:

- The shipper has such a market power that allows him to impose its targets towards environmental improvement to its outsourced transport related services.
- The shipper receives attention from regulators, NGOs and general public with regard to its environmental performance
- Reacting to this attention, the shipper commits to the environmental management of its operations and those of its subcontracted services that it can influence.
- Recognising the significant contribution of its generated transport to its overall environmental footprint, the shipper exercises its customer-driven influence towards its contracted transport providers and operators imposing specific environmental requirements (e.g. better performing trucks for its road transport services). Meeting standards and requirements is established as a precondition for being awarded a transport service (e.g. carriage) contract.
- Transport providers and operators comply with the standards set in order to stay in business with the large client.
- The environmental performance of the logistic chain is improving in line with the targets and requirements set by the large shipper.
- Transport providers are now able to offer environmentally improved services to other clients and therefore there is a further improvement in the environmental performance of other chains and overall.

The administrational structure of the logistic chain in this case is quite clear. The large shipper is the chain leader and its environmental management decisions and practices are upheld throughout the chain and influence its environmental performance. The level of resulting improvement is dependent on the chain leader's policy, objectives and targets. The shipper in this case can generate the green multiplier effect that was discussed in section 6.2.3. It can be seen as a "soloist" and the emerging model for the organisation and administration of the chain is graphically represented on the following figure 136.

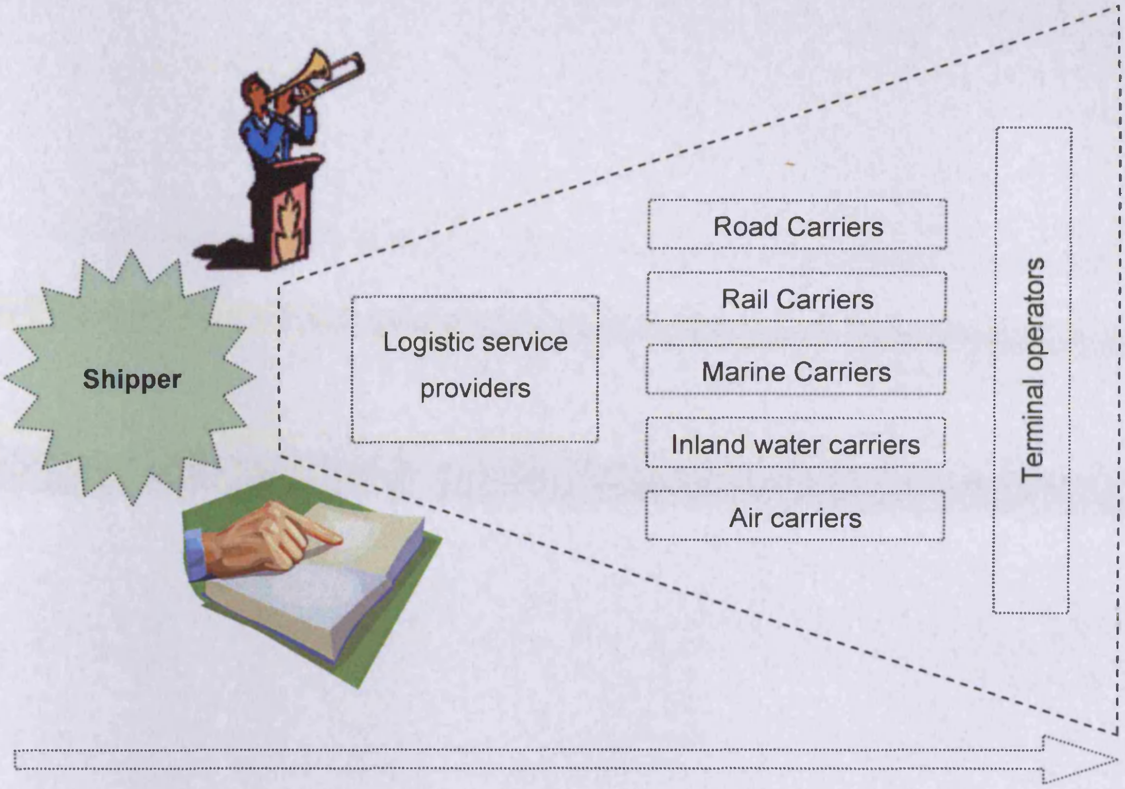


Figure 136: Clear chain leadership - The "soloist" model

It should be noticed that not only large shippers, but also large carriers can undertake a clear leadership in the logistic chain (e.g. Ocean mega carriers in the international chain as discussed in section 3.3.2). In all scenarios where one of the chain players undertakes the overall chain leadership, the administrative structure of the chain is clear. In those cases, the organisational challenges, seen as an obstacle to integrated environmental management, may be considered only marginal. In chapter 3, while examining leadership issues in the logistic chain, the research highlighted that in general no single actor can fulfil the role of the chain leader. The "soloist" model, although applicable in several cases, is not the most commonly encountered one.

The second scenario, where players of equal market power are partners in a given logistic chain and voluntarily commit towards its environmental management, is probably more challenging in terms of organisation and administration.

Scenario 2 – Interdependence and mutual interest

The following assumptions and implications can be made in a case were players of equal market power identify interdependence and common interest, and voluntarily commit towards the environmental management of a given logistic chain:

- A major logistic node, a seaport area, is located in proximity to a major city
- Within the seaport area shippers, carriers, logistic service providers and terminal operators run their businesses.
- The Port Authority may be the landlord but the overall market power dynamics between the operating parties do not allow any of the players to undertake a leading role in influencing the overall operating practices
- All parties have a mutual interest on the efficient operation of the logistic node and this depends, within other factors, on the harmonic relationship between the Port and the City, which is particularly sensitive on the environmental aspects of port operations.
- The mutual interest leads to mutual commitment towards the environmental management of the port node operations.
- A consortium is formulated including representatives of the different partners, challenges are identified, specific environmental objectives and targets are set, and responsibilities are appropriately divided between the players.
- The orchestrated efforts, including measures implemented and changes in operational practices, lead eventually to environmental performance improvements for the port-node overall, and for the single players.

In the scenario 2 example, it is the interdependence between the stakeholders and the identified mutual interest that drive their commitment towards integrated environmental management. The resulting collaborative approach delivers environmental improvement by a fundamentally different mechanism than in the case described by the scenario 1. The mutual commitment of the different players to a common management framework and approach can be pictured as an "orchestra" as opposing to the "soloist" model. The "orchestra" model is graphically presented in figure 137.

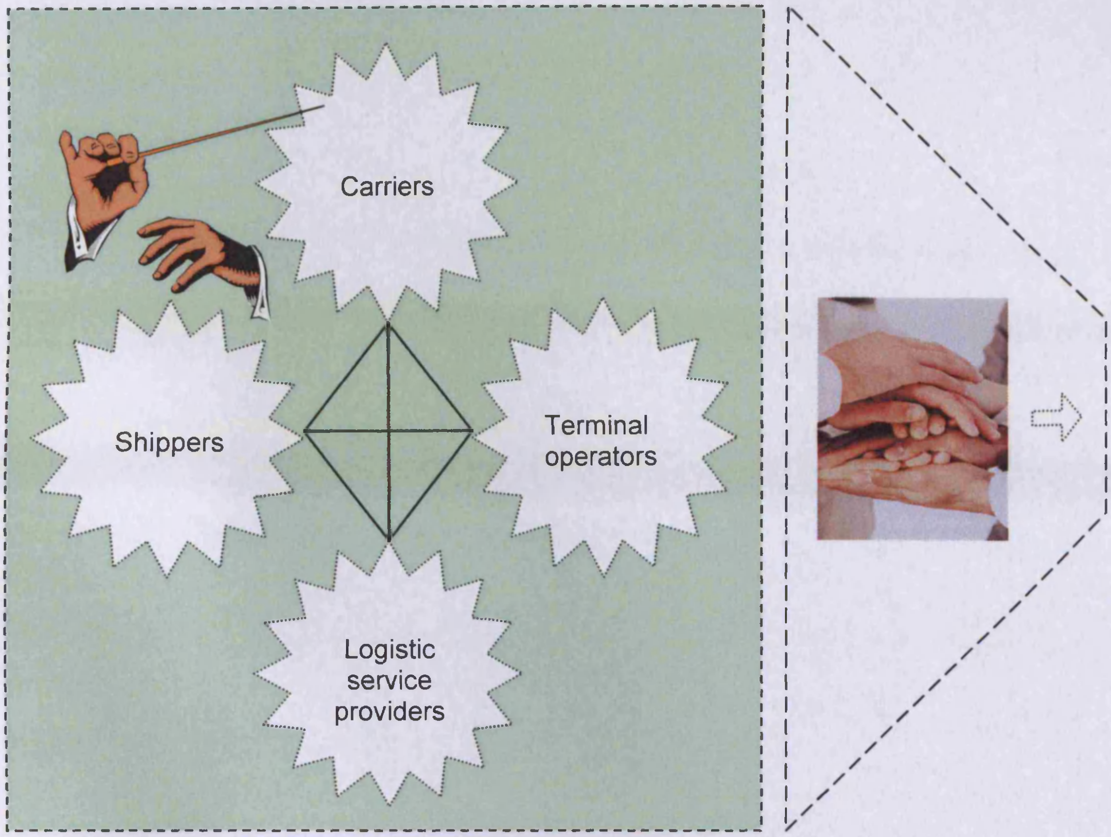


Figure 137: Interdependence and mutual interest - The "orchestra" model

Precondition for the applicability of the orchestra model in examining the environmental management of the logistic chain is the identification of mutual interest between the players involved. Apart from the logistic nodes, where such an interest is clearly identifiable, other examples demonstrating mutual commitment of different players towards common environmental objectives can be demonstrated in specific industry sectors initiatives (e.g. chemical industry – Responsible Care). The administrative structure in logistic chains where the orchestra model is applied is case specific but generally involves synthesis of the multi-actor interests in the decision making process and a clear definition of players' responsibilities.

Bontekoning and Macharis (2004) noted that chain orchestrated coordination can be a challenging process, raising questions in the grounds of specific decision making (e.g. how are decisions taken about issues such as ICT?), costs and benefits redistribution (e.g. how can costs and benefits of changes be redistributed when this does not take place automatically via market mechanisms?), and autonomy of players involved (e.g. what are the consequences for individual organisations when they have to give up some autonomy for the sake of chain objectives?). The application of the orchestra model is therefore challenging, dependent on the identification of mutual interest, and subject to establishing an administrational structure that enables the logistic chain to function as an entity.

9.2 Principles and preconditions

According to its ISO definition, an Environmental Management System is the part of the overall management system that includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy. The principles and preconditions enabling the establishment of an EMS for the logistic chain arise from its definition and components.

A precondition is the willingness of the major players in the logistic chain to factor in environmental parameters in their freight transport related decision making process. Such willingness could be triggered by forcing mechanisms and influence exercised from stakeholders such as governments, regulators, trade associations, insurers, NGO's, and general public. The interest of the major players towards this direction is increasing as it was demonstrated by the outcomes of chapter 6.

In synthesising single players' interests into chain structures and practices the issues of organisation, administration and then environmental liability and responsibility emerge. The previous section examined selected administrative expressions of the logistic chain highlighting that the organisational complexities are often challenging but should not be considered insuperable. Roth and Kaberger (2002) argue that the matter of liability in environmental related topics should be approached with a supply chain – logistic chain perspective. Apart from the interests of single companies, the interaction between the players and particularly between transport buyers and transport providers is a vital part in this context. As the supply chain perspective is customer-shipper orientated, this stresses the responsibility of the transport buyer in steering chain environmental performance as seen in the example of the "soloist" model. The liability for the environmental impacts of transport can then be regulated as part of the business agreements. With an increased explicit contractual assignment of liability for environmental aspects, awareness increases, improving the conditions for conscientious management of environmental aspects.

The opinion expressed by Bokdam, Lloyds Register (*pers.comm.*), when he was consulted by the ECOPORTS project experts' panel researching the role of ports in the logistic chain on the potential for establishing an EMS for the whole chain, was that such a system may be feasible but main issues that require clarification are (1) the determination of what needs to be managed, (2) setting specific environmental objectives and targets, and (3) allocating and documenting responsibilities between partners. Those principles and preconditions have to be met in order for an EMS for the logistic chain to be considered applicable. The following section takes into consideration those requirements in order to propose a model that can be applied for integrated environmental management of the logistic chain.

9.3 Generic EMS model

Taking into account the operational, environmental and administrative characteristics of the multiple expressions that a logistic chain might have this section focuses at developing and proposing an EMS model for the whole chain. This is done by adapting the generic framework that was introduced in chapter 4 (section 4.6) to the chain characteristics as those were established by the different components of the research pathway. The methodology for such an attempt is presented on figure 138. Starting point is the generic over-arching framework that was initially introduced. This framework is then filtered to fit the specific characteristics of the logistic chain system. Those have been examined and highlighted throughout the thesis as demonstrated on the figure (lessons from the various studies). In this way the generic framework is shaped and adapted so that it can take the form of a framework applicable to the complex logistic chain system.

For example, as it was established in chapters 3, 6 and the previous sections of this chapter, the logistic chain can have various specific expressions in terms of operations, organization and administration. Therefore, an EMS for the logistic chain should first establish in detail the system that it is referred to both in terms of its physical manifestation (e.g. transport links, modes, nodes, pathway from point A to point B), and its administrative and organisational characteristics (e.g. players involved, dynamics of their interrelationship, administrative formula that would transform the chain from separate and fragmented links to a functional entity).

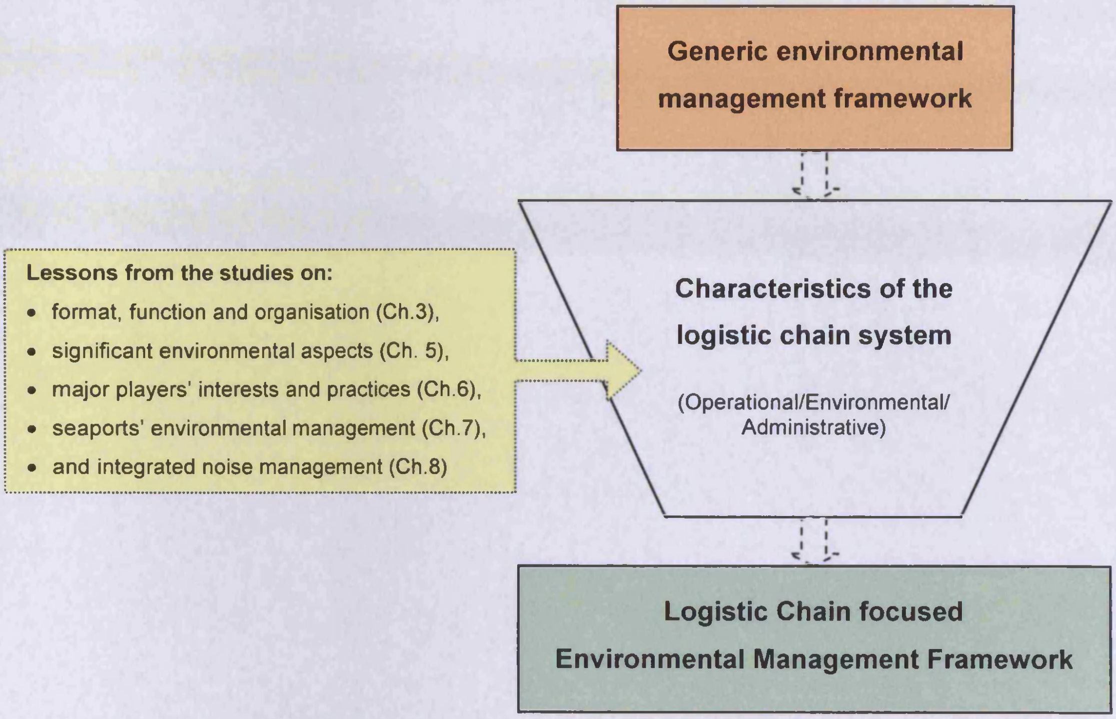


Figure 138: Methodology for developing the EMS model for the logistic chain

The exercise resulted in the development of the logistic chain focused environmental management framework that is presented on figure 139. The model consists of four phases; (1) Function, format and administration, (2) Policy, objectives and targets, (3) Action planning and implementation, and (4) Evaluation and review.

Phase 1 involves the definition of the physical manifestation and boundaries of the chain under question, including the specific modal structures and the characteristics of the cargo flows, and the definition of the players involved and the dynamics between them (e.g. market power, degree of influence). The output of phase 1 includes a definition of the structure and operations that need to be managed and the set up of an appropriate administrative structure for guiding the management process in terms of decision making and allocation of responsibilities between the chain partners.

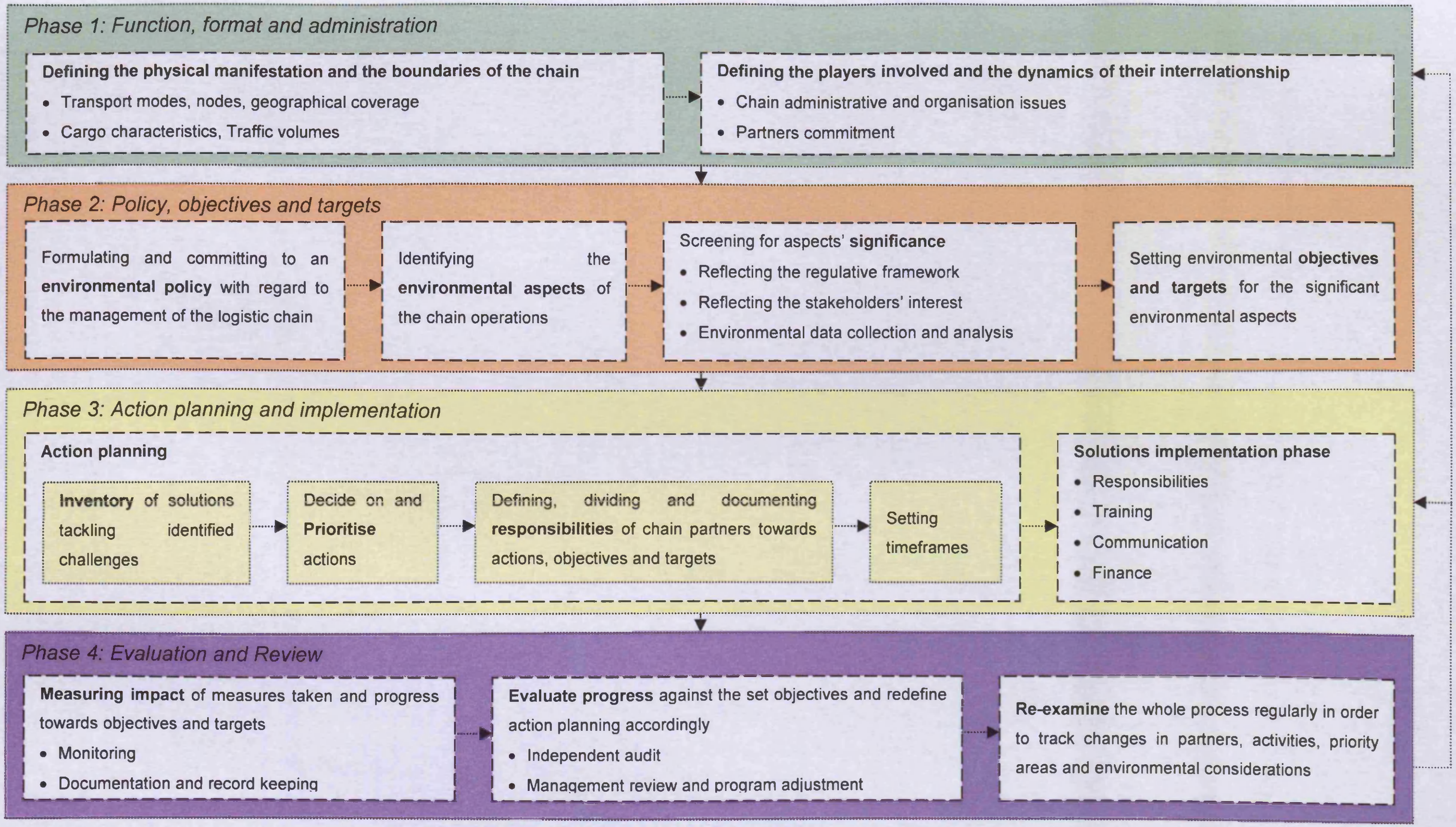


Figure 139: Generic logistic chain environmental management framework

Phase 2 presents a four step phased methodology consisting of developing an environmental policy, identifying the environmental aspects of chain operations, screening for significance and prioritising between the aspects, and setting specific environmental objectives and targets in line with the prioritised challenges.

Phase 3 consists of the action planning and implementation processes. Action planning involves an inventory of available solutions in order to tackle the environmental challenges, the application of a method in order to decide and prioritise between different management response options (e.g. decision support system), and the allocation and documentation of the responsibilities of partners towards the decided actions to be taken, including timeframes. Solutions implementation is unlikely to be an instant process and involves the allocation of resources, responsibilities within the partners, communication and potentially training.

Phase 4 embeds the evaluation of the impact of the selected response options in line with the previously set objectives and targets and the re-adaptation of the action planning process accordingly. It also involves the periodical review of the whole system (from phase 1) in order to track possible changes in partners, activities, priority areas and environmental considerations. The evaluation and review phase is enabling the continual improvement of the chain environmental performance.

9.4 Tools and methodologies for implementation

Several tools and methodologies that were developed, demonstrated and/or discussed in different parts of the thesis contributed to the developments of, and can further assist in the phased approach of the proposed EMS model. Table 100 links selected components of the management system with tools and methodologies that can be applied to assist their implementation.

The identification of the significant environmental aspects can be assisted by the approach that was demonstrated in producing the matrices of chapter 5. As suggested in the conclusion of the chapter, the matrices can be adapted to fit the specific logistic chain requirements. Given a known logistic chain from point A to point B via a network of successive links between transport modes and logistic nodes, applicable information from the matrices can be isolated and an overview of chain-specific environmental aspects would emerge. Cargo-specific related considerations may also be taken into account in complementing the scope of the matrices. Operational and maintenance aspects of the transport modes and infrastructure can be given priority over production and construction phase related environmental aspects.

Table 100: Tools and methodologies for the implementation of EMS components

Components of the management system	Tools and methodologies for implementation	Remarks
Identifying environmental aspects	SEAs Matrices (chapter 5)	Through further application specific adaptation
Screening for aspects' significance	SOSEA, SDM (section 7.4.3.2) Generic noise management tool (section 8.3.4.1) Noise monitoring and mapping (sections 8.5 and 8.6).)	Reflecting legislation, stakeholders' interest, and gathering and analysis of environmental data
Setting objectives and targets	Backcasting	In line with policy and identified priorities
Inventory of solutions tackling identified challenges	ECOPORTS online database (section 7.4.3.2) Generic noise management tool (section 8.3.4.1)	Examples of assisting tools with reference to seaport area and noise management
Prioritise actions	DSS (section 7.4.3.2)	In line with set objectives and targets
Allocating responsibilities	The "soloist" and "orchestra" models can be applied (section 9.1.3)	Reflecting liabilities and contribution of different parties to overall impact
Solutions implementation	PRIOS example (section 7.5.2)	Success factors for implementation

The process of screening for aspects' significance reflects on applied legislative and regulative framework, interest of stakeholders, and on the gathering and analysis of environmental data. A significant environmental aspect is an aspect that can have a significant environmental impact. In seaport areas, the SOSEA and SDM methodologies (see section 7.4.3.2) can be applied. In the example of noise the generic management tool presented in section 8.3.4.1 can link identified activities and operations to applied regulations, thus providing information regarding their significance. Environmental data gathering and analysis tools (e.g. noise monitoring and mapping) can assess magnitude of impact, thus enabling the overall evaluation of aspects' (e.g. noise) significance. Other components of the EMS model can be addressed by tools, approaches, and examples discussed throughout the thesis as seen in table 100.

Of particular interest is the EMS component of the setting of objectives and targets as it implies a philosophical approach to transport related sustainability issues. Roth and Kaberger (2002) examined and argued in favour of backcasting as a philosophical approach to sustainable transport systems. While forecasting is a way of predicting a likely future state of affairs, backcasting is a way of constructing a desirable future. A desirable future is the starting point when constructing the strategy in a backcasting process. Backcasting is a way of discovering a possible path from the present into the envisioned desirable future. Studies (Robinson 1990; Holmberg 1998) provide detailed instructions on how to carry out a backcasting process. The following four steps methodology is suggested: (1) Definition of long term sustainability criteria, (2) Analysis of current situation in comparison with the sustainability criteria, (3) Definition of the envisioned "successful company" in the future sustainable society, and (4) Creative design of the pathway from the present situation to the desired future one

Dreborg (1996) formulated some criteria in order to define cases where the method of backcasting could be applied. In his view, backcasting is particularly useful when: The problem studied is complex, affecting many sectors and levels of society; there is a need for a major change; dominant trends are part of the problem; one of the reasons for the problem is externalities (problems that the market does not treat properly); and the time perspective is long enough to allow deliberate choices (Dreborg 1996). Roth and Kaberger (2002) argue that transport related environmental problems, especially carbon dioxide emissions and climate change, are well suited to be handled by backcasting, and that backcasting may be useful at the sector level as well as within individual companies involved in substantial transport activities. "Steering the transport sector towards sustainability is an example where backcasting may be a suitable tool" (Roth and Kaberger 2002).

The backcasting process compared with the marginal improvement process presents some advantages especially when the transport sector is concerned. For example, taking a transport provider's perspective it may be that long-term sustainability criteria will require completely different transport modes and fuel options. If that is the case, then it can be argued that efforts towards marginal improvements of existing systems may be of no, or of low value. On the other hand, in view of the long term vision of the company, an immediate redirection of the business strategy may place the company ahead of its competitors and open new markets, in the development that will be followed by all in a given timescale. Apart from its potential application at the single company level, and due to the importance of coordinated efforts in the logistic chain, Roth and Kaberger (2002) conclude that a common backcasting exercise involving all the actors of a logistic chain may be even more constructive.

9.5 Final conclusions and recommendations

The thesis discussed the environmental management of the logistic chain. It established that the chain is a highly dynamic, interrelated, complex multi-actor system, already in what concerns its primary function which is to efficiently respond to the freight mobility needs. Whilst humanity is faced with the challenge of reducing transport's environmental impact, without losing the benefits to society and economies, the holistic approach to the environmental management of the logistic chain emerges as a necessity.

The thesis demonstrated that it is feasible to identify the elements of activities, products, and services of logistic chain operations that interact with the environment in an undesired manner and thus need to be addressed by environmental management. It established that the major players (transport buyers, providers and operators) increasingly embrace freight transport related environmental considerations in the scope of their environmental policies and management efforts. It identified voluntary self regulating industry response to societal forcing mechanisms as a proven (e.g. major players good practice examples, and port sector's approach) and efficient framework in delivering environmental improvement and greener logistic chain operations. The thesis examined the evolution and trends in logistic nodes management and seaport areas in particular. The established integrative trends confirm the feasibility of integrated logistic node area management and justify an optimistic outlook in assessing the potential for further integration in the logistic chain. In addition, the thesis demonstrated that integrated management of environmental noise, one of the major and more complex to control logistic chain aspects, is technically feasible and practicable in both major logistic nodes (e.g. seaport areas) and in the whole chain. The derived implication is that integrated environmental management of other, often simpler and easier to control, environmental aspects can also be considered technically feasible and practicable.

Synthesising on the above in order to address its three overall research aims, the thesis;

(1) Established that an EMS specifically designed to deliver integrated environmental management of the logistic chain is technically feasible and practicable. Its development and implementation is primarily subject to the overcoming of organisational and administrative complexities that although often challenging, should not be considered insuperable.

(2) Identified the preconditions that would enable the application of such a system. Those include; (a) a clear definition of the elements that need to be managed, (b) a commitment of the involved parties under an organisationally functional entity (identification of mutual interest and advantage might be required, e.g. where the presented "orchestra" model is applied)), (c) setting clear objectives and targets, and (d) defining and allocating responsibilities between the parties involved.

(3) Developed a EMS model that can guide the development and establishment of a framework that delivers integrated chain environmental management and continual improvement of environmental performance.

It should be noticed that the proposed EMS model, by the way it has been developed, was validated through the findings of the different components of the research pathway. Nevertheless its overall applicability remains still uncertain in the sense that not all the components (transport modes, nodes, and environmental aspects) have been examined in the same level of detail within the thesis. The focus was primarily placed on seaport areas as major logistic nodes and environmental noise as a major environmental aspect. Through the research findings on those areas the proposed model appears to be applicable but this can not ensure its overall applicability for all the expressions of the logistic chain system. Further research is needed in the fields of all nodes and modes and all major environmental aspects in order to derive conclusions regarding the overall applicability of such an EMS model. Further research on those fields may use the approach of the analytical studies presented on chapters 7 and 8 of the thesis as blueprints, complementing those and further adding to the conclusions.

As the concept of environmental management of the logistic chain evolves, there is likely to be growing awareness between all the stakeholders involved that increased collaboration based on the free exchange of information and experience will produce mutual benefit in terms of cost and risk reduction, and evidence that the goals of environmental protection and profitable commercial activities are not necessarily mutually exclusive. Effective environmental management of the logistic chain has the potential to deliver credible sustainable development in practice.

Roth and Kaberger recommended that the most important contribution in the field of transport environmental management is not to add further to the academic literature, but to present the results in such a format that they can be applied. In this context, the developed generic EMS model together with other supported tools that were produced and demonstrated (the matrices of chapter 5 and the generic noise management tool of section 8.3.4.1) can be of particular interest. It is believed that through further research, refinement and adaptation to case-specific requirements those tools can be eligible for pilot applications. The framework for application could be provided for example under an EU research and development project umbrella. Professional feedback obtained during participation on research and development initiatives (e.g. ECOPORTS, NoMEPorts) highlighted a broad interest of both port and logistic chain industry sector (transport buyers, providers and operators).

LIST OF REFERENCES

ABP Research (1999). Good practice guidelines for ports and harbours operating within or near UK European marine sites, English Nature, UK Marine SACs project: 120.

Ackerman, K. B. and A. M. Brewer (2001). Warehousing: A key link in the supply chain. Handbook of logistics and supply chain management. A. M. Brewer, K. J. Button and D. A. Hensher. Amsterdam, Pergamon: 225-237.

American Chemistry Council. (2005). "Responsible Care." Retrieved May, 2005, from http://www.americanchemistry.com/s_responsiblecare/.

Anon (2003). "Chemical industry sets first ever environmental targets." ENDS Report **336**: 3-4.

Archer, L. J. (1993). Aircraft emissions and the environment: CO_X, SO_X, HO_X, and NO_X. Oxford, Institute for Energy studies.

Armstrong, F. W. (2001). "Environmental effects of aviation." Air & Space Europe **3**(3): page 234.

Asariotis, R. (1998). Intermodal transportation and carrier liability. Towards improved intermodal freight transport in Europe and the United States: Next steps. Report of an ENO transportation foundation policy forum. Munich: 33-40.

Azar, C. (1998). "The timing of CO2 emissions reductions: the debate revisited." International Journal of Environmental Pollution **10**: 508-521.

Azar, C. and H. Rodhe (1997). "Targets for stabilisation of atmospheric CO2." Science **276**: 1818-1819.

B&Q. (2005). "Website." Retrieved 25/02/05, 2005, from http://www.diy.com/diy/jsp/bq/templates/contentlookup.jsp?content=%2Faboutbandq.

Berends, M., D. P. Cavalcoli, et al. (2005). Evaluation Of Environmental Performance Indicators For European Ports & Impacts Of The ECOPORTS Project. Amsterdam, EPCEM: 197.

Beresford, A. K. C., B. M. Gardner, et al. (2004). "The UNCTAD and WORKPORT models of port development: evolution or revolution?" Maritime Policy & Management **31**(2): 93-107.

Berg, T. (1998). Survey shows 'good news' for high-tech carriers. Transport Topics: 10-11.

Berry, M. A. and D. A. Rondinelli (1998). "Proactive corporate environmental management: A new industrial revolution " The Academy of Management Executive **12**: 38-50.

Bichou, K. and R. Gray (2005). "A critical review of conventional terminology for classifying seaports." Transportation Research Part A **39**: 75-92.

Black, W. R. (1996). "Sustainable transportation: a US perspective." Journal of Transport Geography **4**: 151-159.

Black, W. R. (1998). Sustainability of transport. Modern transport geography. B. Hoyle and R. Knowles. Chichester, John Wiley & Sons: 374.

BLICC (2004). Report 3: Establishing Actions. Amsterdam and London, Respect Business Leaders Initiative on Climate Change. **3**: 44.

BLICC (2005). Report 4: Engaging in Actions. Amsterdam and London, Respect Business Leaders Initiative on Climate Change. **4:** 32.
Bonnafous, A. and C. Raux (2003). Transport energy and emissions: Rail. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier Ltd. **4:** 293-307.
Bontekoning, Y. M., C. Macharis, et al. (2004). "Is a new applied transportation research field emerging? - A review of intermodal rail-truck freight transport literature." Transportation Research Part A **38**: 1-34.
Boske, L. B. (1998). Multimodal/Intermodal Transportation in the United States, Western Europe, and Latin America: Governmental Policies, Plans and Programs. Austin, L.B. Johnson School of Public Affairs, University of Texas: 592.
Brooks, M. R. (1999). "Performance evaluation of carriers by North American logistics service firms." Transport Reviews **19**(3): 273-283.
Brooks, M. R. (2000). "Performance evaluation of carriers by North American companies." Transport Reviews **20**(2): 205-218.
Brooks, M. R. and G. Fraser (2001). Maritime logistics. Handbook of logistics and supply chain management. A. M. Brewer, K. J. Button and D. A. Hensher. Amsterdam, Pergamon: 419-430.
Business for Social Responsibility - BSR. (2005). "Website." Retrieved 01/03/05, 2005, from http://www.bsr.org/CSRResources/WGO/CC-GF/index.cfm.
Button, K. J. (1993). Transport Economics. Aldershot, Edward Elgar.
Carpenter, T. G. (1994). The Environmental Impact of Railways Chichester, John Wiley & Sons Ltd.
Cerwenka, P. (1990). Traffic management for European long-distance traffic focused on international goods transport. Transport policy and the environment. European Conference of Ministers of Transport. Paris, ECMT - OECD Publications Services: 95-107.
Chemical Industries Association. (2005). "Responsible Care." Retrieved May, 2005, from http://www.cia.org.uk/.
Christopher, M. (1998). Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service. Edinburgh, Pearson Education Limited.
Cooper, J., M. Peters, et al. (1995). Supply Chain Dynamics and the Environment: A Study of Six Industry Sectors. Bedford, Cranfield Centre for Logistics and Transportation (CCLT), Cranfield University.
Council of Logistics Management. (2004). ""The CLM definition of logistics"." Retrieved 01/09/2004, 2004, from http://clm1.org/Website/AboutCLM/Definitions/Definitions.asp.
Coyle, J. J., E. J. Bardi, et al. (1996). The management of business logistics. New York, West Publishing Company.
CPRE (1992). Transport and the environment; CPRE's Submission to the Royal Commission on Environmental Pollution. London, Council for the Protection of Rural England 47.
Croner Transport News. (2006). "Commission challenged over EU Transport White Paper (18 May 2006)." Retrieved May, 2006, from www.croner.co.uk/croner/jsp/.
Cuthbert, J. (2007). Outsourcing Logistics - logically speaking. Times (Media Planet: Power of Logistics, 30/01/07). London: 12.

D'Agosto, M. and S. K. Ribeiro (2004). "Eco-efficiency management program (EEMP) - a model for road fleet operation." Transportation Research Part D **9**: 497-511.

D'Este, G. (1996). "An event-based approach to modelling intermodal freight systems." International Journal of Physical Distribution & Logistics Management **26**: 4-15.

Daly, H. (1990). "Towards some operational principles of sustainable development." Ecological economics **2**: 1-6.

Darbra, R. M., A. Ronza, et al. (2004). "The self diagnosis method: A new methodology to assess environmental management in sea ports." Marine Pollution Bulletin **48**(5-6): 420-428.

Darbra, R. M., A. Ronza, et al. (2005). "A procedure for identifying significant environmental aspects in sea ports." Marine Pollution Bulletin **50**: 866-874.

Davies, M. (1995). "On the radar: Measuring the environmental impact of logistics strategies. Malory Davies looks at the recent report from the Cranfield Centre and its conclusions." Global Transport(Summer): 66-69.

DEFRA (2004). Noise Mapping England - The London Road Traffic Noise Map. London, Department for Environment, Food and Rural Affairs (Defra),: 31.

Delfmann, W., S. Albers, et al. (2002). "The impact of electronic commerce on logistics service providers." International Journal of Physical Distribution & Logistics **32**(3): 203-222.

Dewes, W., R. Cottington, et al. (2000). "The AERONET Network - Emissions, Atmospheric Impact and Regulations." AIR & SPACE EUROPE **2**(3): 24-28.

Dey, P. K. (2002). "An integrated assessment model for cross-country pipelines." Environmental Impact Assessment Review **22**: 703-721.

Dey, P. K., S. O. Ogunlana, et al. (1998). "A risk based maintenance model for cross-country pipelines." Cost Engineering **40**(4): 24-31.

DGMR. (2005). "SourcedB Database (online available noise source database)." Retrieved January, 2006, from http://www.dgmr.nl/software/downloadsdb.htm.

Diment, H., G. Gibbs, et al. (2005). Field visit at the Freightliner terminal at Cardiff and semi structured interview with managers. Cardiff.

Dings, D. and W. Dijkstra (1997). Specific energy consumption and emissions of freight transport. Delft, CE.

Dreborg, K. H. (1996). "Essence of backcasting." Futures **28**(9): 813-828.

Easterby-Smith, M., R. Thorpe, et al. (1991). Management research : an introduction. London, Sage Publications.

EC DG-TREN (2003). Energy and transport in figures: Statistical pocketbook 2003. Brussels, European Commission Directorate-General for Energy and Transport,: 198.

EC DG-TREN (2006 d). Energy & Transport in figures, European Commission Directorate-General for Energy and Transport in cooperation with Eurostat.

EC DG-TREN. (2007 a). "Rail transport." Retrieved March, 2007, from <http://ec.europa.eu/transport/rail/overview/current_en.htm>.

EC DG-TREN. (2007 b). "Maritime transport." Retrieved March, 2007, from <http://ec.europa.eu/transport/maritime/index_en.htm>.

EC DG-TREN. (2007 c). "Inland Waterway transport." Retrieved March, 2007, from <http://ec.europa.eu/transport/iw/index_en.htm>.

EC DG-TREN. (2007 d). "Air transport." Retrieved March, 2007, from <http://ec.europa.eu/transport/air_portal/traffic_management/index_en.htm>.

EC DG-TREN. (2007 e). "Road transport." Retrieved March, 2007, from <http://ec.europa.eu/transport/road/index_en.htm>.
EC DG Environment. (2007 a). "Noise - Existing directives relating to noise sources (website section)." Retrieved December, 2007, from http://ec.europa.eu/environment/noise/sources.htm.
EC DG Environment. (2007 b). "Noise - Activities linked to the Environmental Noise Directive (website section)." Retrieved December, 2007, from http://ec.europa.eu/environment/noise/.
EC WG-AEN (2007). Position Paper - Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure - Version 2, European Commission Working Group Assessment of Exposure to Noise (WG-AEN),: 129.
ECO-Information (1999). ECO-Information in European Ports. Brussels, Final report, ESPO.
ECOPORTS project (2003). Self Diagnosis Method Version 3. Amsterdam, ECOPORTS Foundation.
ECOPORTS project (2005 a). Strategic Overview of Significant Environmental Aspects (SOSEA). Amsterdam, ECOPORTS Foundation.
ECOPORTS project (2005 b). Decision Support System. Amsterdam, ECOPORTS Foundation.
ECOPORTS project (2005 c). D6a: Basic conseptual set-up for mobile environmental information module for commercial visitors in port areas. Amsterdam, ECOPORTS foundation: 54.
ECOPORTS project (2005 e). D23a: Short feasibility study on how to integrate these new modalities in the ECOPORTS project. Amsterdam, ECOPORTS Foundation: 64.
EEA. (2007 a). "Online glossary of terms." Retrieved December, 2007, from http://glossary.eea.europa.eu/EEAGlossary.
EN ISO 14001 (1996). The International Organization for Standardization, text of International Standard.
Eriksson, E., M. Blinge, et al. (1996). "Life cycle assessment of the road transport sector." The Science of the Total Environment **189/190**: 69-76.
ESPO (2003). Environmental Code of Practice. Brussels, ESPO.
ESPO. (2005). "ESPO Environmental Survey 2004: Review of European Performance in Port Environmental Management (Summary)." Retrieved June, 2005, from http://www.espo.be/downloads/archive/36f31a9e-e902-40c1-85ef-a9826324f6d5.pdf.
ESPO. (2007). "Website - Home page." Retrieved December 2007, 2007, from http://www.espo.be/Home.aspx.
ESPO & EPF (2004). Port Environmnetal Management: European Sea Ports Organisation's Review of European Benchmark Performance in collaboration with the EcoPorts Foundation (ESPO survey questionnaire), ESPO and EPF: 10.
European Commission (2001). Freight Intermodality: Results from the transport research programme. Directorate-General for Energy and Transport, European Communities: 20.
European Commission (2001 a). White Paper - European transport policy for 2010: time to decide. Luxemburg, European Communities: 1-119.

European Commission (2001 b). The economic impact of carrier liability on intermodal freight transport - Final Report. London, European Commission: 1-43.
European Commission (2001 c). The economic impact of carrier liability on intermodal freight transport - Executive Summary. London, European Commission: 5.
European Commission (2003 a). Freight Integrator Action Plan "Supporting the organisers of intermodal freight transport", European Commission, Directorate General for Energy and Transport, Directorate for Maritime and intermodality - G4.
European Commission (2003 b). Consultation Paper: "Supporting the organisers of intermodal freight transport". Brussels, Directorate - General for Energy and Transport: 18.
European Commission (2004). Transport research in the European research area. A guide to European, international and national programmes and other research activities. Directorate-General for Energy and Transport, European Communities: 78.
European Environment Agency (2003). Europe's environment: the third assessment. Copenhagen, European environment agency: 344.
European Environment Agency (2007). Europe's environment: the forth assessment. Copenhagen, European Environment Agency: 452.
European Environment Agency (2007). Europe's environment: the fourth assessment. Copenhagen, European Environment Agency: 452.
European Environmental Agency (2003). Europe's environment: the third assessment. Copenhagen, European environmental agency: 344.
European Parliament (2002). DIRECTIVE 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise, Official Journal of the European Communities. **2002/49/EC**: 14.
European Parliament and Council (1994). Directive 94/62/EC of 20 December 1994 on packaging and packaging waste. European Commission. **94/62/EC**.
Eye for Transport. (2004). "Transport Glossary." Retrieved August, 2004, from http://www.eyefortransport.com.
Faulks, R. W. (1999). International Transport: An introduction to current practices and future trends. London, Kogan Page Limited.
Frankel, E. (1999). "Intermodal integration." Lloyd's Shipping Economist **21**: 10-11.
Freight Forward International. (2004). "What is a Freight Forwarder?" Retrieved May, 2004, from http://www.freightforwardinternational.org.
FreightForward International. (2004). "What is a Freight Forwarder?" Retrieved 01/05/2004, 2004, from http://www.freightforwardinternational.org.
Fridell, E. (2006). The environmnetal performance of shipping and possible improvements. RoRo 2006, Ghent.
Fridell, E. (2006b). "The environmental performance of shipping and possible improvements (presentation - RoRo 2006 conference)." Retrieved August, 2006, from www.roroex.com/speakerpapers.
Gordon, D. (1991). Steering a new course: transportation, energy and the environment Washington DC, Island Press.
Gordon, D. (1995). Sustainable transportation: What do we mean and how do we get there? Transportation and energy: strategies for a sustainable transportation

system. D. Sperling and S. A. Shaheen. Washington DC, American Council for an energy efficient economy.
Graham, B. (1998). International air transport. Modern transport geography. B. Hoyle and R. Knowles. Chichester, John Wiley & Sons: 311-336.
Greene, D. L. and M. Wegener (1997). "Sustainable transport." Journal of Transport Geography **5**(3): 177-190.
Gwilliam, K. M. (1991). The Importance and Adverse Effects of Freight Transport. Freight Transport and the Environment. European Conference of Ministers of Transport (ECMT). Paris, ECMT: 15-38.
Hagelaar, G. J. L. F. and J. G. A. J. van der Vorst (2002). "Environmental supply chain management: using life cycle assessment to structure supply chains." International Food and Agribusiness Management Review **4**: 399-412.
Hall, D. and A. Braithwaite (2001). The development of thinking in strategic supply chain and logistics management. Handbook of Logistics and Supply Chain Management. A. M. Brewer, K. J. Button and D. A. Hensher. Amsterdam, Pergamon Press: 81-98.
Hamburg Port Authority (2005). Im Focus dynamischer Waachstumsmarkte. Hamburg: 73.
Hamer, M. (1992). "Polluting planes top the greenhouse league." New scientist(25 July 1992).
Handfield, R. and E. L. Nichols (1999). Introduction to Supply Chain Management. Upper Saddle River, NJ, Prentice Hall.
Handfield, R., R. Sroufe, et al. (2005). "Integrating Environmental Management and Supply Chain Strategies." Business Strategy and the Environment **14**: 1-19.
Handy, S. (2003). Amenity and severance. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier Ltd. **4**: 117-140.
HARMONOISE project. (2006). "Why "Harmonoise" ? (website section)." Retrieved May, 2006, from http://www.harmonoise.org/why.asp.
Hayuth, Y. (1987). Intermodality: Concept and Practice: Structural changes in the Ocean Freight Transport Industry. London, Lloyds of London Press.
Hensher, D. A. and K. J. Button (2003). Introduction. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier. **4**: 1-6.
Hewlett Packard (2003). 2003 Global Citizenship Report: 80.
Hewlett Packard. (2005). "Website." Retrieved 01/02/05, 2005, from www.hp.com.
Holmberg, J. (1998). "Backcasting: a natural step in operationalising sustainable development." Greener Management International **Autumn**(23): 30.
Holmen, B. A. and D. A. Niemeier (2003). Air quality. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier Ltd. **4**: 61-79.
Houghton, J. (1996). Sustainable transport: how the Royal Commission sees the future. Transport and the Environment. The Linacre Lectures 1994-5. B. Cartledge. Oxford, Oxford University Press: 23-44.
Hubner, P. (2000). "The action programme of UIC, CER and UIP "Abatement of railway noise emissions on goods trains"." Journal of Sound and Vibration **231**(3): 511-517.
Hunter, C., J. Farrington, et al. (1998). Transport and the environment. Modern transport geography. B. Hoyle and R. Knowles. Chichester, John Wiley & Sons: 374.

ICCA. (2005). "Product Stewardship Guidelines, Responsible Care®." Retrieved May, 2005, from www.icca-chem.org.
IKEA (2004). IKEA - social and environmental responsibility Report 2003, Inter IKEA Systems B.V. 2004: 88.
IKEA. (2005). "Website." Retrieved 01/02/05, 2005, from www.ikea.com.
IMAGINE project. (2007). "Website." Retrieved February, 2007, from www.imagine-project.org.
International Navigation Association (1999). Environmental Management Framework for Ports and Related Industries. Report of working group 4 of the Permanent Environmental Commission. Brussels, International Navigation Association (PIANC): 38.
IPCC (1995). IPCC second assessment synthesis of scientific-technical information relevant to interpreting Article 2 of the UN Framework Convention on Climate Change. Bracknell, Intergovernmental Panel on Climate Change.
IPCC (1999). Aviation and the Global Atmosphere: Summary for policy makers. Geneva, Intergovernmental Panel on Climate Change: 23.
IPCC (2001). Climate change 2001: the scientific basis. Contributions of Working Group I to the Third Assessment Report of the IPCC. J. T. Houghton. Cambridge, Cabridge University Press.
IPCC (2007). Climate Change - Fourth Assessment Report, Intergovermental Panel on Climate Change.
IPPC (2007). Climate Change - Fourth Assessment report, Intergovernmental Panel on Climate Change.
Irish Ships. (2004). "A History of Roll on - Roll off in Dublin port." Retrieved September, 2004, from http://www.irishships.com/a_history_of_roll_on.htm.
ISO (1996). ISO 14001 Environmental management systems - specification with guidance for use. Brussels, CEN.
Ivarsson, T. (2003). IKEA's Environmental demands when purchasing transport services (conference presentation). First Ecoports Conference, Barcelona, unpublished.
Johnston, H. (2006). "Every little helps... Tesco takes the plunge into rail." Rail(549): 6-7.
Jones, W. B., C. R. Cassady, et al. (2000). Developing a standard definition of intermodal transportation, Department of Industrial Engineering, Mississipi State University.
Joumard, R. (2005). "The stakes of air pollution in the transport sector, from the French case." Atmospheric Environment **39**: 2491-2497.
Journée, H. and C. F. Wooldridge (2005). "Developments in the management of environmental risk: "Foundation" for the future." Port Technology International **27th edition**(Autumn 2005): 28-30.
Journée, H. and C. F. Wooldridge (2007). "Environmental evolution: logical development of stakeholder response in the port sector." Port Technology International **33rd edition**(Spring 2007): 39-41.
Karamitsos, F. (2004). European policy on Intermodality and Logistics (Presentation). TEDIM Jubilee Seminar, Helsinki, unpublished.
Knoepfel, I. H. (1996). "A framework for environmental impact assessment of long-distance energy transport systems." Energy **21**(7/8): 693-702.
Konings, J. W. (1996). "Integrated centres for the transshipment, storage, collection and distribution of goods." Transport Policy **3**(1/2): 3-11.
Koukoumelis, D. (2004). Sarlis Container Services S.A. Athens.

KPMG (2005). KPMG International Survey of Corporate Responsibility Reporting 2005, KPMG and University of Amsterdam: 49.
Lai, K. (2004). "Service capability and performance of logistics service providers." Transportation Research Part E **40**: 385-399.
Lambert, D. M. (2001). The supply chain management and logistics controversy. Hanbook of logistics and supply-chain management. A. M. Brewer, K. J. Button and D. A. Hensher. Amsterdam, Pergamon: 99-126.
Lamure, C. (1990). Environmental considerations in transport investment. Transport policy and the environment. European Conference of Ministers of Transport. Paris, ECMT - OECD Publications Service: 108-146.
Lang, J. (1986). Assessment of noise impact on the urban environment. Copenhagen, Report to WHO.
Lenzen, M., C. Dey, et al. (2003). Climate change. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier Ltd. **4**: 37-60.
Levitt, M. (2006). Ports and terminals: EU policy issues (conference presentation). RoRo 2006. Ghent, Belgium.
Linster, M. (1990). Background facts and figures. Transport Policy and the Environment. European Conference of Ministers of Transport. Paris, ECMT - OECD Publications Service: 9-45.
Ludvigsen, J. (1999). "Freight transport supply and demand conditions in the Nordic Countries: recent evidence." Transportation Journal **39**: 31-54.
Maersk Sealand. (2005). "Website." Retrieved 25/02/05, 2005, from http://www.maersksealand.com/.
McCubbin, D. R. and M. A. Delucchi (2003). The health effects of motor vehicle related air pollution. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier Ltd. **4**: 411-427.
McKinnon, A. (2001). Integrated logistics strategies. Hanbook of logistics and supply-chain management. A. M. Brewer, K. J. Button and D. A. Hensher. Amsterdam, Pergamon: 157-170.
McKinnon, A. C. (2003). Logistics and the environment. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier Ltd. **4**: 665-685.
Michail, A. (2005-2006a). Doctoral work - Survey on transport buyers and operators. Cardiff.
Michail, A. (2005-2006b). Doctoral work - Noise monitoring studies in the port of Piraeus.
Michail, A. (2005a). Doctoral work - Survey on factors influencing seaport area environmnetal management. Cardiff.
Michail, A. (2005b). ECOPORTS project - D6a: Basic conceptual set-up for mobile environmental information module for commercial visitors in port areas. Amsterdam, EPF: 54.
Michail, A. (2005c). ECOPORTS project - D18:Concise plan for the implementation of environmental solution in port area. Amsterdam, ECOPORTS Foundation: 25.
Michail, A. (2006a). Environmental management of the logistic chain; Concepts and perspectives. Shipping in the era of social responsibility. Cephalonia, Greece.
Michail, A. (2006b). Doctoral work - Noise mapping study in the port of Piraeus.
Michail, A. (2006c). Doctoral work - Integrated noise management in the logistic chain

Michail, A. (2006d). Doctoral work - Efficient simulation of noise sources in noise mapping
Michail, A., A. De Leffe, et al. (2003). Environmental Performance Indicators in European Ports. Institute for Environmental Studies. Amsterdam, Vrije Universiteit: 115.
Mintcheva, V. (2005). "Indicators for environmental policy integration in the food supply chain (the case of the tomato kethcup supply chain and the integrated product policy)." Journal of Cleaner Production **13**: 717-731.
Mitchell, C. G. B. and A. J. Hickman (1990). Air pollution and noise from road vehicles. Transport policy and the environment. European Conference of Ministers of Transport. Paris, ECMT - OECD Publications Service: 46-75.
Muller, G. (1995). Intermodal freight transportation. Washington D.C., Eno foundation and the Intermodal Association of North America.
Muller, G. (1998). "The business of intermodal freight transportation." Transportation Quarterly **52**(3): 7-11.
Nationale Havenraad (2003). Living with the ports - Space for commerce and quality of life in the Dutch sea ports. The Hague, Nationale Havenraad, The Netherlands: 1-55.
Nelson, P. M. (1987). Transportation noise reference book. London, Butterworth.
Nijkamp, P., B. Ubbels, et al. (2003). Transport investment appraisal and the environment. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier Ltd. **4**: 333-355.
Noble, M. (1999). "A volcano that may or may not errupt (aerospace industry and the environment)." Interavia Business & Technology **54**(627): 19-23.
NoMEPorts project. (2007). "Website." Retrieved March, 2007, from nomeports.ecoports.com.
NoMEPorts project (2008). Good Practice Guide on Port area Noise mapping and Management. Amsterdam, In Press.
OECD (1988). Transport and the Environment. Paris, OECD Organisation for Economic Co-operation and Development: 135.
OECD (1996). Conference highlights and overview of issues. Towards sutainable transportation. The Vancouver conference, Vancouver, British Columbia, OECD.
OECD (1997). The Environmental Effects of Freight. Paris, Organisation for Economic Co-operation and Development: 35.
OECD Environment Directorate (2002). Transport and Environment. Synthesis of OECD work on Environment and Transport and Survey on related OECD, IEA and ECMT Activities. Paris, OECD: 89.
Otto Versand (2003). Shaping awareness: Sustainability report 2003, Otto Versand: 64.
Otto Versand (2004). Facts and Figures, Otto Versand: 44.
Otto Versand. (2005). "Website." Retrieved 23/02/05, 2005, from www.otto.com.
Owens, S. (1996). ' I wouldn't start from here': land use, transport, and sustainability. Transport and the Environment. The Linacre Lectures 1994-5. B. Cartledge. Oxford, Oxford University Press: 45-61.
P&O Nedlloyd (2004 a). Always taking care. P&O Nedlloyd and the environment 2004, P&O Nedlloyd: 16.
P&O Nedlloyd (2004 b). Blue & Orange, P&O Nedlloyd: 8.
P&O Nedlloyd. (2005). "Website." Retrieved 25/02/05, 2005, from www.ponl.com.

Paixao, A. C. and R. B. Marlow (2002). "Stengths and weaknesses of short sea shipping." Marine Policy **26**: 167-178.
Panayides, P. M. (2002). "Economic organization of intermodal transport." Transport Reviews **22**(4): 401-414.
Panayides, P. M. and M. So (2005). "Logistics service provider-client relationships." Transportation Research Part E **41**: 179-200.
Philips (2003). Sustainability Report 2003: Building knowledge, exploring opportunities: 81.
Pinter, N., K. Miller, et al. (2004). "Recurrent shoaling and channel dredging, Middle and Upper Mississippi river, USA." Jounal of Hydrology **290**: 275-296.
Piraeus Port Authority S.A. (2006). "Statistics (website section)." Retrieved December, 2006, from http://www.olp.gr/INDEXen.htm.
Port infolink. (2005). "Towards one single Port Community System." Retrieved 01/02/2005, 2005, from http://www.portinfolink.com/english/content/informatie/over_portinfolink.asp.
Port of Amsterdam. (2006). "RePort Overview 2006." Retrieved 01/05, 2006, from http://www.portofamsterdam.com/smartsite14601.dws.
Port of Hamburg. (2005). "Website www.port-of-hamburg.de." Retrieved 01//05/2005, 2005, from www.port-of-hamburg.de.
Preuss, L. (2005). "Rhetoric and Reality of Corporate Greening: a View from the Supply Chain Management Function." Business Strategy and the Environment **14**: 123-139.
Price, T. and D. Probert (1995). "Environmental Impacts of Air Traffic." Applied Energy **50**: 133-162.
Quinet, E. (2003). Evaluation of environmental impacts. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier Ltd. **4**: 357-373.
Radojcic, D. (2006). New Opportunities on the Danube Corridor (conference paper). RoRo 2006, Ghent.
Rao, K., W. Grenoble, et al. (1991). "Traffic congestion and JIT." Journal of Business Logistics **12**(1): 105-121.
Reid, B. (1996). Railways and sustainable development. Transport and the Environment. The Linacre Lectures 1994-5. B. Cartledge. Oxford, Oxford University Press: 81-99.
Robinson, J. B. (1990). "Futures under glass: a recipe for people who hate to predict." Futures **22**(8): 820-842.
Roeleven, D., M. Kok, et al. (1995). "Inland waterway transport: Modellling the propability of accidents." Safety Science **19**: 191-202.
Rondinelli, D. and M. Berry (2000). "Multimodal Transportation, Logistics, and the Environment: Managing Interactions in a Global Economy." European Management Journal **18**(No. 4): 398-410.
Rondinelli, D. A. and M. A. Berry (1997). "Industry's Role in Air Quality Improvement: Environmental Management Opportunities for the 21st Century." Environmental Quality Management **7**: 31-44.
Rondinelli, D. A. and G. Vastag (1996). "International Environmental Management Standards and Corporate Policies: An Integrative Framework." California Management Review **39**: 106-122.
Roth, A. and T. Kaberger (2002). "Making transport systems sustainable." Journal of Cleaner Production **10**: 361-371.

Rothengatter, W. (1990). Economic aspects. Transport policy and the environment. European Conference of Ministers of Transport. Paris, ECMT - OECD Publications Service: 147-176.
Rothengatter, W. (2003). Environmental Concepts - Physical and Economic. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier. **4**: 9-35.
Rothengatter, W. (2003). Environmental concepts - Physical and Economic. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier 9-35.
Royal Commission on Environmental Pollution (1994). Transport and the Environment - Report 18. London, UK, Royal Commission on Environmental Pollution.
Sakris, J. (2001). "Introduction to GMI theme issue." Greener Management International **35**: 21-25.
Sarlis S.A. (2005). "Website." Retrieved 25/02/05, 2005, from http://www.sarlis.gr/final/mainpage.htm.
Saunders, M. N. K., P. Lewis, et al. (1997). Research methods for business students. London, Pitman.
Schenker (2004). Environmental report: 19.
Schenker. (2005). "Website." Retrieved 22/02/05, 2005, from www.schenker.com.
Semeijn, J. and D. B. Vellenga (1995). "International logistics and one-stop shopping." International Journal of Physical Distribution & Logistics Management **25**(10): 26-44.
Shell Chemicals. (2005). "Website." Retrieved 01/02/05, 2005, from www.shellchemicals.com.
Short sea shipping promotion centre Flanders (2001). Market - oriented Short Sea Shipping - study and - action within the Flemish region, Short sea shipping promotion centre Flanders: 25.
Shortsea Promotion Centre Finland. (2003). "Shortsea shipping and the environment." Retrieved 01/12/2005, 2005, from http://www.shortsea.fi/cutenews/data/upimages/Environment_2003.pdf.
Shortsea Promotion Centre Germany. (2005). "Environmental data." Retrieved 01/12/2005, 2005, from http://www.shortseashipping.de/eng/umwelt/umwelt.html
Silverleaf, A. and J. Turgel (1991). Environmental assessment methods in transport: Measurements and their Applications. Paris, International Transport group (INTRA): 22.
Silverleaf, A. and J. Turgel (1993). Transport in transition; Political, Social and Economic infuences. Paris, International Transport Group (INTRA): 42.
Slack, B. (1998). Intermodal Transportation. Modern Transport Geography. B. Hoyle and R. Knowles. Chichester, John Wiley & Sons: 263-289.
Slack, B. (2001). Intermodal Transport. Handbook of logistics and supply-chain management. A. M. Brewer, K. J. Button and D. A. Hensher. Amsterdam, Pergamon: 141-154.
Slats, P. A., B. Bhoda, et al. (1995). "Logistic chain modelling." European Journal of Operational Research **87**: 1-20.
Somerville, H. (1996). Airlines, aviation, and the environment. Transport and the Environment. The Linacre Lectures 1994-5. B. Cartledge. Oxford, Oxford University Press: 110-131.

Somerville, H. (2003). Transport energy and emissions: Aviation. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier Ltd. **4**: 263-278.
Southampton Airport. (2007). "The local environment - Noise (website section)." Retrieved December 2007, from http://www.southamptonairport.com/portal/page/.
Southworth, F. and B. E. Peterson (2000). "Intermodal and international freight network modeling." Transportation Research Part C **8**: 147-166.
Spice, B. (1999). "Ship pollution study: emissions cool earth." Journal of Commerce(23 Aug): 2.
Stank, T. P. and T. J. Goldsby (2000). "A framework for transportation decision making in an integrated supply chain." Supply Chain Management: An International Journal **5**(2): 71-77.
Stanners, D. and P. Bourdeau, Eds. (1995). Europe's Environment, The Dobris Assessment. Copenhagen, European Environmental Agency (EEA).
Stojanovic, T. A., H. D. Ormerod Smith, et al. (2006). "The impact of the Habitats Directive on European port operations and management." GeoJournal **65**: 165-176.
Stora Enso (2003). Sustainability 2003: 56.
Stora Enso (2004 a). Sustainability news. Helsinki, Stora Enso Corporate Communications.: 4.
Stora Enso (2004 b). Sustainability booklet: 20.
Stora Enso. (2005 a). "Website." Retrieved 21/02/05, 2005, from www.storaenso.com.
Stora Enso. (2005 b). "Stora Enso's environmental principles." Retrieved 01/12/2005, 2005, from http://www.storaenso.com/CDAvgn/main/0,,1_-3194-3628-,00.html.
Stora Enso (2005 c). Sustainability news. Helsinki, Stora Enso Corporate Communications: 4.
Talley, W. K. (2003). Environmnetal impacts of shipping. Handbook of transport and the environment. D. A. Hensher and K. J. Button. Amsterdam, Elsevier Ltd. **4**: 279-291.
Talley, W. K., D. Jin, et al. (2001). "Vessel accident oil-spillage: post US OPA-90 " Transportation Research Part D(6): 405-415.
Tavasszy, L. A., C. J. Ruijgrok, et al. (2003). "Emerging global logistics networks: Implications for transport systems and policies." Growth and Change **34**(4): 456-472.
Taylor, D. (1997). Global Cases in Logistics and Supply Chain Management.
Taylor, J. C. and G. C. Jackson (2000). "Conflict, power, and evolution in the intermodal transportation industry's channel of distribution." Transportation Journal **39**(3): 5-17.
Taylor, S. Y. (2001). Just-in-time. Hanbook of logistics and supply-chain management. A. M. Brewer, K. J. Button and D. A. Hensher. Amsterdam, Pergamon: 213-224.
The Logistics Systems and Dynamics Group (LSDG). (2004). "LSDG Homepage." Retrieved 01/02/2004, 2004, from http://www.cf.ac.uk/carbs/lom/lsdg.
The Other Side. (2004). "Channel ferries and ferry ports." Retrieved September, 2004, from http://www.theotherside.co.uk/tm-heritage/background/ferries.htm.
The Port Authority of New York and New Jersey. (2005). "Website." Retrieved May, 2005, from http://www.panynj.gov/.

TRB (1998). Policy options for intermodal freight transportation, Transportation Research Board, National Research Council, Washington, DC.
UIRR. (2004). "Intermodal Loading Units - Encourage interoperability instead of forcing it." Retrieved December, 2005, from www.uirr.com.
United Nations Economic Commission for Europe Statistical Division and European Union Eurostat (1997). Glossary for Transport Statistics. European Conference of Ministers of Transport.
Vanderhaegen, M. (2006). Motorways of the sea in the European Short Sea policy. RoRo 2006, Ghent.
Vidal, J. (2007). And you thought air travel was bad for the climate... the guardian: weekend edition. London, Manchester: 1.
Vlek, S. and M. Vogels (2000). "AERO - Aviation Emissions and Evaluation of Reduction Options." AIR & SPACE EUROPE **2**(3): 41-44.
Walker, W. E. (2000). "POLSSS: overview and cost-effectiveness analysis." Safety Science **35**: 105-121.
Whitelegg, J. (1988). Transport Policy in the EEC. London, Routledge.
Williams, R. (2007). A responsible approach. The Times (Media Planet: Power of logistics, 30/01/07). London: 3.
Witte, R. (2007). (pers.comm.) Noise consultant DGMR Netherlands.
Wooldridge, C. F. (2004 b). "The Positive Response of European Seaports to the Environmental Challenge." Ports & Harbors **49**(8): 9-12.
Wooldridge, C. F. (2006). Promoting sustainable development: Progress through partnership. European Sea Port Organisation's Conference, Stockholm.
Wooldridge, C. F. (2007). "Turning up the volume control." Ports & Harbours(March 2007): 28-29.
Wooldridge, C. F. and T. Stojanovic (2004). Integrated environmental management of ports and harbours - The European experience from policy to practice. CHECK AND UPDATE: 191-211.
Workport Project. (1999). "Project's website." 2003, from http://hermes.civil.auth.gr/workport/wp.html.
Woxenius, J. (1994). Modelling European Combined Transport As an Industrial System. Gothenburg, Department of Transportation and Logistics Chalmers University of Technology: 166.
Wu, H. J. and S. C. Dunn (1995). "Environmentally responsible logistics systems." International Journal of Physical Distribution & Logistics Management **25**(2): 20-38.
Zsidisin, G. A. and S. P. Siferd (2001). "Environmental purchasing: A framework for theory development." Journal of Purchasing & Supply Management **7**: 61-73.