STRIVE
Report Series No.32

Sustainable Logistics: Towards the Development of Environmentally Conscious Supply Chains

STRIVE

Environmental Protection
Agency Programme

2007-2013

Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

The EPA is an independent public body established in July 1993 under the Environmental Protection Agency Act, 1992. Its sponsor in Government is the Department of the Environment, Heritage and Local Government.

OUR RESPONSIBILITIES

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We license the following to ensure that their emissions do not endanger human health or harm the environment:

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- large scale industrial activities (e.g., pharmaceutical manufacturing, cement manufacturing, power plants);
- intensive agriculture;
- the contained use and controlled release of Genetically Modified Organisms (GMOs);
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The work of the EPA is carried out across four offices:
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- Office of Environmental Enforcement
- Office of Environmental Assessment
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet several times a year to discuss issues of concern and offer advice to the Board.

Sustainable Logistics:
Towards the Development of
Environmentally Conscious Supply Chains

(2005-ET-MS-45-M3)

STRIVE Report

Prepared for the Environmental Protection Agency

by

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ACKNOWLEDGEMENTS

DISCLAIMER

The EPA STRIVE Programme addresses the need for research in Ireland to inform policy makers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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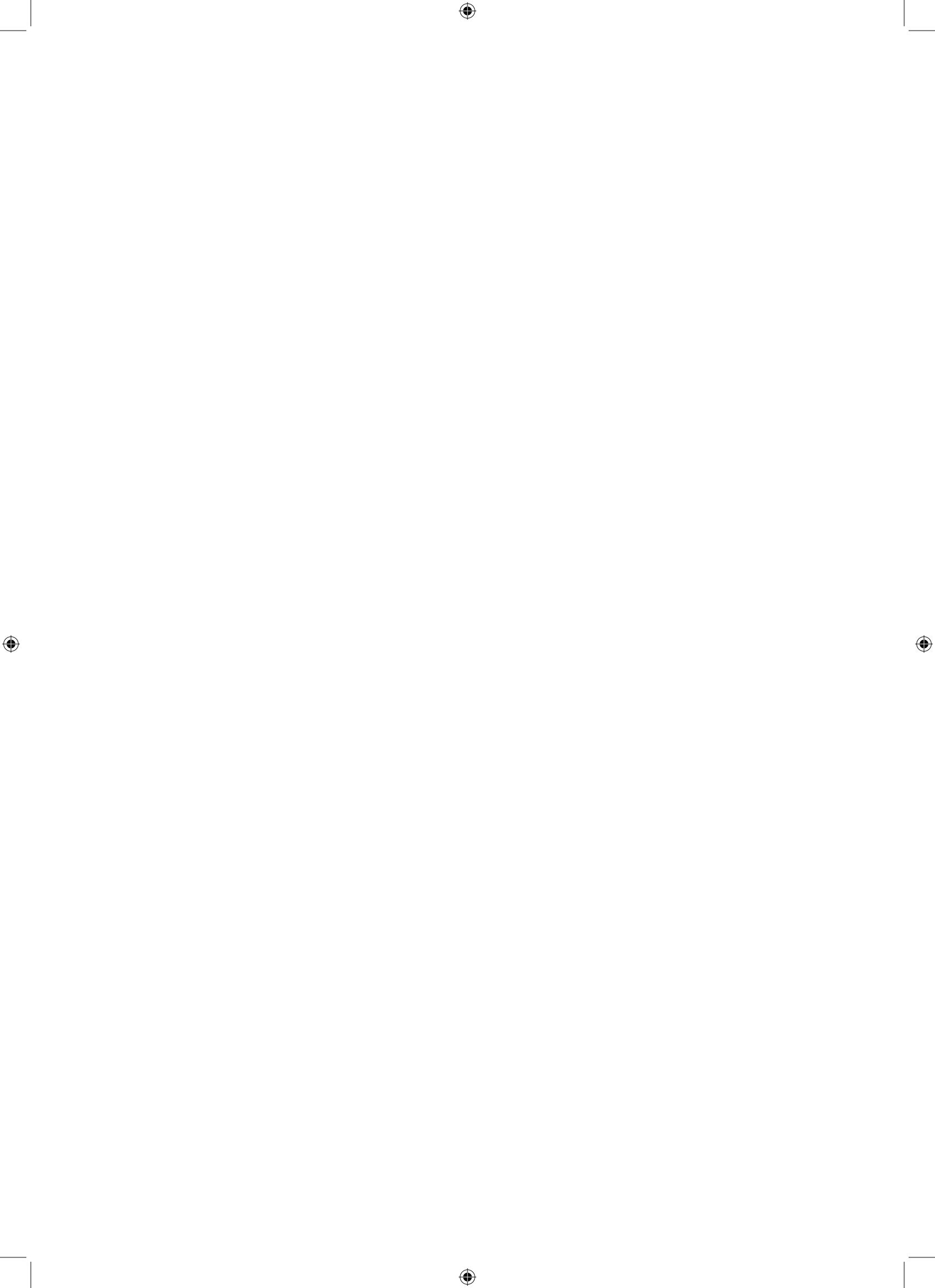Fax: +353-61-213583
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Executive Summary

1   Background

The study of the impact of supply chains on the environment is a relatively new and a rapidly growing area. The 'green' or 'sustainable' supply chain is an approach which seeks to minimise a product's ecological footprint. Within green/sustainable supply chains there are five distinct themes:

1 **Green design**: An approach to reduce a product's environmental impact throughout its complete life cycle through the design of the product.

2 **Green sourcing**: The inclusion of environmental factors in the decision-making process when sourcing products.

3 **Green manufacturing**: Reducing the environmental impact of the manufacturing function.

4 **Green logistics**: Targeted at transport, warehousing, inventory management and distribution function in the supply chain.

5 **Reverse logistics**: Represents all operations related to the reuse/disposal of products and materials.

From the above description of green supply chains it can be seen that it is an extremely broad area of study. This study focuses on one aspect, green or sustainable logistics.

2   Objectives

The research had three interrelated objectives:

● The first objective was to understand the current situation as regards sustainable logistics in Ireland.

● The second objective was to present a snapshot of the current developments in sustainable logistics and supply chains.

● The third objective was to provide insight into the trade-off between environmental impact, cost and supply-chain performance under different transport strategies.

3   Description of Work

In the survey the attitudes to and knowledge of sustainable logistics among companies and their preparedness to implement sustainable logistics methods was tested. The survey was carried out with 28 companies that were both users and suppliers of logistics in the Shannon Region of Ireland. The survey contained four categories of question:

1 **Company information**: To generate a profile of respondent companies.

2 **Environmental awareness**: To gather information on the awareness of companies of sustainability in general and specifically in relation to logistics.

3 **Logistics business practices**: To gather information on logistic services purchased and provided, and to understand the business practices used in this sector.

4 **Efficiency in logistics operations**: Here the readiness of companies to adopt more sustainable logistic operational practices was examined.

Sustainable supply-chain implementation requires standards to allow measurement of environmental impact, and methodologies and support tools to allow adoption of environment practices. The report

provides an overview of standards, methodologies and tools currently available for the implementation of sustainable supply chains.

A simulation model analysis was carried out on a three-tier supply chain, which compared different transport strategies on environmental impact, cost and supply-chain performance.

4   Results

Environmental supply-chain monitoring and analysis is a growing sector. The research reported here dealt with only one distinct theme in this topic area, but there are many more which are of relevance to Ireland as a trading nation. Also, there is scope within Ireland for job creation in developing new software solutions and service offerings in this sector.

Recommendation: Investment by funding bodies in capacity building in the area of environmental supply-chain monitoring and analysis.

It is clear from this study that many organisations, have little or no awareness of environmental issues with respect to the operations of the logistical elements of their supply chains and beyond.

Recommendation: Provision of funding for the development of industrial awareness campaigns in the environmental aspects of modern business.

The survey carried out as part of this study identified the lack of co-ordination with respect to logistical practice in Irish supply chains.

Recommendation: Provision of support in the development of more co-ordinated networks, particularly with respect to logistics provision and consumption.

Within the context of supply chains, there is uncertainty as to the cost of operating environmental practices and the economic benefits of doing so. As the majority of businesses are designed around the concept of profit making, it is important that the economic cost of environmental solutions and their effect on supply-chain performance are understood.

Recommendation: Provision of research funding into the further evaluation of environmental versus economic trade-offs in supply-chain design and operation.

1.   Introduction

'There is now a scientific consensus that global warming is happening, that it is directly related to man-made greenhouse gas emissions, and that we have little time remaining to stabilise and reduce these emissions if we are to avoid devastating impacts on our planet.' (Department of the Environment Heritage and Local Government Ireland, 2007)

The ideas of sustainable development originate from the 1987 Brundtland Report (ACE, 2004), also known as 'Our Common Future'. This report alerted the world to the urgency of making progress toward economic development that could be sustained without depleting natural resources or harming the environment. Over recent years Ireland's per capita greenhouse gas (GHG) emissions have risen to be one of the highest in Europe. This rise in emissions is in no small part attributable to the 165% increase in transport emissions in the period 1990 to 2006, a figure more than 137% higher than the EEA-32 average (EEA, 2009). The focus of this report is on supply chains and the impact that operations, and more specifically logistics, has on the environment.

1.1   Definitions

There are many different definitions in the literature for supply-chain management (SCM). However all these definitions are slight adaptations of each other. One such definition as presented by Christopher (1998) is, 'supply-chain management involves the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole'. Supply chains have been shown to be high contributors to the carbon footprint of most goods (Van Hoek, 2001), with Eyefortransport (2008) claiming that up to 75% of a company's carbon footprint is derived from supply-chain activities. The study of the impact of supply chains on the environment is relatively new and a rapidly growing research area. The green or sustainable supply chain is an approach which seeks to minimise a product's or service's ecological footprint (BearingPoint, 2008). The concept covers all the phases of a product's life cycle, from the extraction of raw materials through the design, production and distribution phases, to the use of the product by consumers and their eventual disposal of same (see Figure 1.1).

From this framework, the main research areas of green supply chains can be described as (BearingPoint, 2008):

1   **Green design** is an approach to reduce a product's environmental impact throughout its complete life cycle through the design of the product.

2   **Green sourcing** is where environmental criteria are included in the decision-making process when sourcing products or services. In the literature it is often also referred to as green procurement.

3   **Green manufacturing** has the goal of reducing the environmental impact of the manufacturing function in supply chains through the reduction of the environmental impact of the use of materials and energy.

4   **Green logistics** has the aim of meeting cost targets and customer-service levels with reduced pollution from the transport, warehousing, inventory management and distribution function in the supply chain.

5   **Reverse logistics** represents all operations related to the reuse of products and materials.
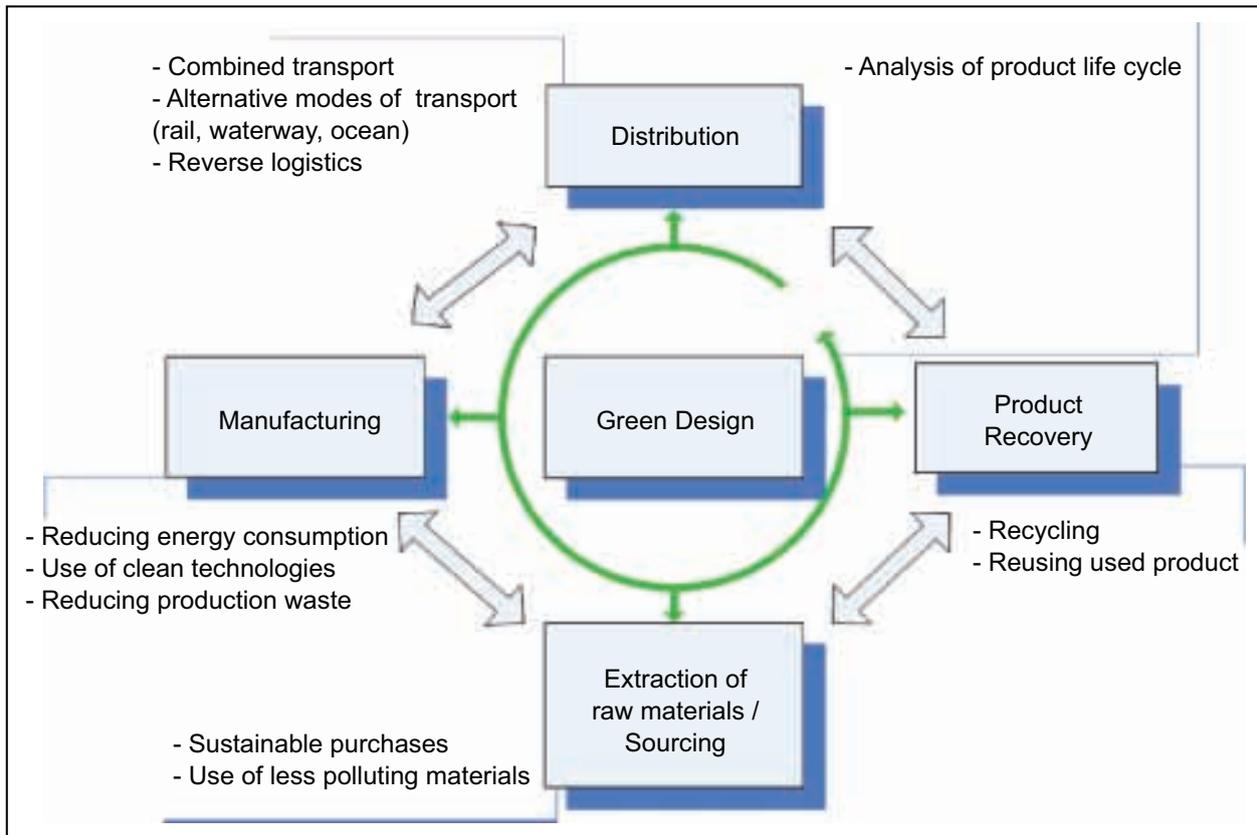
Figure 1.1. Elements to sustainable (green) supply chains, adapted from Bearing Point (2008).

It is a vital component of green supply chains, providing a means for products/materials to be returned from the user to the producer in order to be recycled, reused or reconditioned.

From the above description of green supply chains it can be seen that it is an extremely broad area of study. This study focuses on one aspect: green logistics, which is also referred to as sustainable logistics, a term which will be used in the remainder of the report.

1.2   Background

1.2.1   Global Warming

In simple terms, the greenhouse effect is the rise in temperature that the earth experiences due to greenhouse gases trapping energy from the sun (EPA, 2006a). The Stern (2006) report on climate change outlines that it is now 'widely accepted' that if no action is taken on reducing GHG emissions, and in particular CO_2 emissions, current trends predict a 2–3°C

increase in global temperature in the next 50 years or so, causing disastrous effects in the areas of:

1 **Food sources**: 150 to 550 million people at risk of hunger.

2 **Water**: 1 to 4 billion people suffering water shortages.

3 **Health**: 40 to 60 million people exposed to malaria in Africa.

4 **Land**: Up to 170 million people affected by coastal flooding.

5 **Environment**: Up to 50% extinction of species (estimate).

For Ireland, the 2006 EPA document entitled 'Implications of the EU Climate Protection Target for Ireland' (McElwain and Sweeney, 2006), outlines that if global mean temperatures are limited to a 1°C increase, some short-term benefits may occur in agriculture and food production. However, increased temperatures may also

bring widespread negative effects for agricultural and marine environments, for plant and animal distributions, and for water resources. Sea-level rises will also negatively impact certain coastal areas due to inundation and erosion (McElwain and Sweeney, 2006).

1.2.2   Environmental Compliance

The Kyoto Protocol is an agreement under the United Nations Framework Convention on Climate Change (UNFCCC), to which 186 countries are parties. It states that industrialised countries must reduce their harmful GHG emissions to 5.5% above their 1990 emission levels. The year 1990 has been chosen as a base year for comparison for all countries (Europa, 2002). Allowing for economic development or decline in member states, the EU have agreed a 'burden-sharing' agreement in which emissions are seen as an EU-wide total. In Ireland's case, the country's economic growth since 1990 has been noted, with Ireland's overall emissions target amended to 13% above its 1990 emission levels.

In 2005, Ireland's emissions were monitored at 25.4% above 1990 (its base year), which is 12.4% above its EU target (EEA, 2006). Therefore, if Ireland is to meet its commitments to the Kyoto agreement, emissions must be reduced by at least this percentage

(25.4 – 13 = 12.4%) before 2012, or face the penalties of non-compliance. Figure 1.2 shows the increase/decrease in CO_2 emissions across all sectors from 1990–2005 along with the deviation (in kilotonnes CO_2 equivalent) from Ireland's Kyoto target.

1.3   Logistics and the Environment

Freight transportation by road is the 'dominant mode of freight transport in many economies due mainly to the flexibility and speed that the movement of freight by road offers when compared to railway, inland waterway or sea transport' (Mason and Lalwani, 2004). This is particularly true for Ireland as 90% of freight traffic occurs on the road (Ryan et al., 2003).

In freight transport the burning of petrol and diesel fuels in internal combustion engines leads to the chemical by-products of nitrous oxide (N_2O), methane (CH_4) and, most importantly, carbon dioxide (CO_2). Transport in Ireland is a major contributing factor to Ireland's overall emissions, accounting for a 20.8% share of total emissions in 2007, 97% of which is from road transport (EPA, 2008). Figure 1.3 shows the trends in transport emissions for a selection of EU countries. Ireland reported an increase of 168% in transport emissions
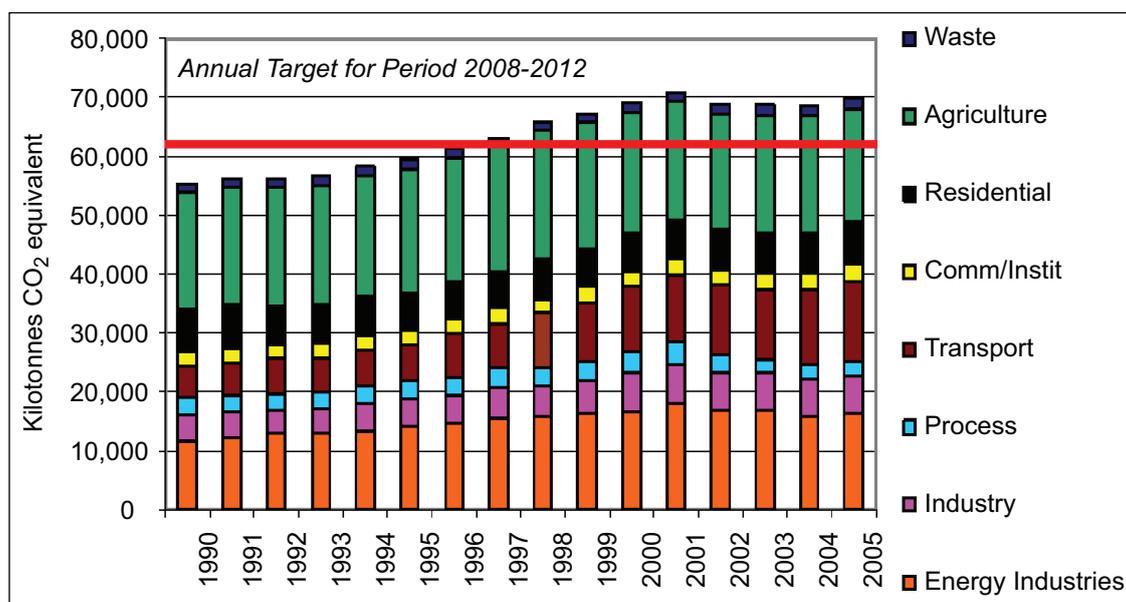

Figure 1.2. Trends in sectoral emissions (1990–2005) (EPA, 2007).
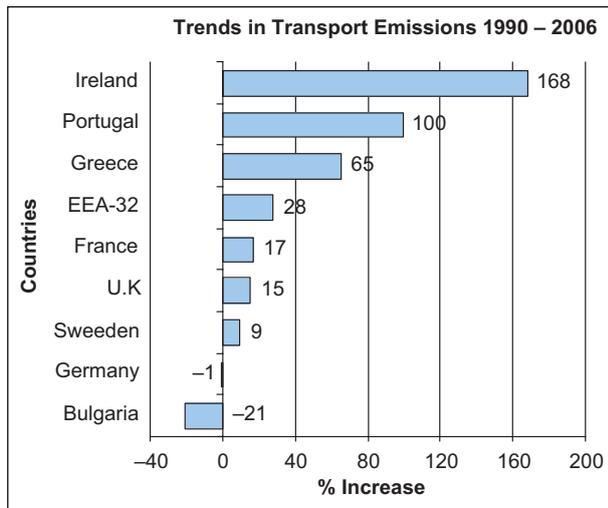
Figure 1.3. EU trends in transport emissions 1990–2006 (EEA, 2009).

for the period 1990–2006. The EEA-32 average was an increase of 28%.

As highlighted by Tenekcioglu (2004), certain modes of transportation, such as rail and maritime transport are considered 'green modes' because their effects are less detrimental to the environment. These modes produce less pollution, less noise and account for fewer accidents. However, the relatively short distances and lack of suitable infrastructure in Ireland offset any advantages which could be gained by using intermodal freight transport. This is confirmed by a 2008 survey of transport service providers in Ireland who claim they foresee a decline in the use of rail for freight in future (InterTradeIreland, 2008).

1.3.1 Freight Transport in Ireland

Over the period 1996 to 2006, the Central Statistics Office (CSO) in Ireland documented increases in the following average number of (CSO, 2007):

1. Goods vehicles (163%).

2. Vehicle-kilometres travelled by goods vehicles (115%).

3. Tonnes of goods transported (254%).

4. Tonne-kilometres travelled (180%).

Fuel consumption by the road-freight sector in Ireland increased by 264% over the period 1990 to 2005 (Department of Transport Ireland, 2008). According to the same study, 'typically around a third of vehicle-kilometres are suboptimal depending on length of haul, type of vehicle, industrial sector and the nature of the delivery operation'. For this reason, the adoption of more efficient and sustainable transport operations will be advantageous to Ireland's transport users, providers and the environment. This opinion is echoed by InterTradeIreland (2008) who state:

> Efficient freight transport is essential to the economy and to the quality of life across the island of Ireland. Economic growth generates increasing demand for freight transport. Goods have to be moved freely, reliably, efficiently to meet business needs, while minimising the impact on safety, on other transport users and on the environment.

1.4 Sustainable Logistics and Logistics: Past Studies

Recent logistics and supply-chain orientated studies in Ireland have been carried out by InterTradeIreland (2008), Sweeney et al. (2008) and the Department of Transport Ireland (2008). In Sweeney et al. (2008) the current level of diffusion of SCM among companies in Ireland is measured. The results suggest a need for more widespread adoption of SCM among Irish firms.

InterTradeIreland carried out a cross-sectoral survey of transport providers and users for the island of Ireland. The survey cites Irish infrastructure as being 'very poor relative to other key EU countries' with the resulting congestion making time planning difficult. The survey also suggests that transport customers see reverse logistics/environmental issues becoming more important over the next 10 years.

The Department of Transport Ireland (2008) document '2020 Vision – Sustainable Travel and Transport: Public Consultation Document', describes the issues

relating to sustainable travel and transport in Ireland. On describing the freight transport sector, the report highlights some key issues to be considered.

● The importance of the movement of goods to Ireland's economy.

● Recognition that movement of goods by road will remain the principle mode.

● The need to reduce the environmental impact of heavy goods vehicles and light duty vans.

Results from two international surveys on supply chains and the environment have been recently published, '2008 Supply Chain Monitor "How Mature Is the Green Supply Chain?"' (BearingPoint, 2008) and 'Logistics and Transport Industry Environmental Survey: Transport Intelligence' (Kewill, 2008). The Kewill (2008) survey, which was targeted at logisticians, surveyed 450 respondents from around the world. They claim it represented the 'full spectrum of the logistics sector' as well as manufacturers and retailers (Kewill, 2008). In this survey, respondents were seen to take a very pragmatic view to environmental issues, recognising that green and business issues must be balanced. Logistics service providers and customers were shown to recognise the importance of the environment to the long-term development of their companies. Respondents also identified how the transportation elements of the supply chain were the main focus for companies implementing green strategies; this was largely due to rising oil prices.

The BearingPoint (2008) survey attained 600 respondent views on the emerging trends in the development of green supply chains. The survey documented how environmental matters are gaining consideration among companies, pushed by four main drivers, which are:

1 Regulation.

2 Brand image.

3 Innovation.

4 Cost reduction.

The BearingPoint (2008) survey also identified how differing levels of involvement in green supply-chain strategies exits between countries, citing the lack of information as the biggest obstacle in its development. However, as with the Kewill (2008) survey, it is in logistics operations where most companies implemented green supply-chain strategies.

With the projected introduction of carbon taxes, rising fuel costs and requirements for more environmentally friendly products, creating sustainability in logistics operations is an advantage for any company or country. Unfortunately in Ireland, as reported by Comhar (2008), there appears to be few incentives currently for the logistics sector to employ approaches such as:

1 Increasing load factors.

2 Choosing the optimum type of vehicle.

3 Optimising the entire transportation chain from origin to final delivery.

4 Increasing the use of ICT tools in order to lower the environmental impact of their operations.

From the brief review above on studies of logistics in Ireland, it can be seen that there is a lack of knowledge on the current standing of sustainability within the logistics sector in Ireland.

1.5   Research Objectives

The focus of this report is on supply chains and the impact operations and, more specifically, logistics, have on the environment. The study has three interrelated objectives:

1 The first objective was to understand the current situation as regards sustainable logistics in Ireland, with specific emphasis on the Mid-West Region in Ireland. The attitudes to and knowledge of sustainable logistics among companies and the

preparedness to implement sustainable logistics methods are tested using a survey.

2   To support companies in sustainable logistics, new standards, tools and methodologies are emerging, creating a new services sector and research area that is referred to as sustainable or green logistics, or sometimes more broadly referred to as sustainable or green supply chains. A second objective was to present a snapshot of the current developments in this nascent field.

3   The third objective of this work was to carry out a quantitative analysis study to provide insight into the trade-off between environmental impact and cost/service levels in a supply chain when operating using different transport strategies. This analysis was motivated by:

(i)   Results from the survey (see objective 1) which showed that companies are reluctant to implement more environmentally friendly options if additional costs might be incurred.

(ii) To provide insight to practitioners into how advanced analysis methods (approaches that are currently appearing on the market) can compliment more standard analysis methods (i.e. life-cycle assessment (LCA)) in developing more sustainable strategies in the operation of a supply chain.

2. Survey: Sustainable Logistics

2.1 Introduction

A survey was carried out, with the purpose of (i) ascertaining the level of awareness of sustainable logistics in companies and (ii) to evaluate the preparedness of companies in adopting sustainable logistics operations strategies.

2.2 Survey Design

The survey was designed after careful study of similar past surveys on logistics and after preliminary consultations with a small number of logistic providers and users. An initial survey was piloted online and tested by academic and industrial personnel. Resulting from this pilot implementation, questions were added and reworded and a decision was made to administer the survey on a face-to-face interview basis. While this method of interviewing does increase the overall cost of conducting the survey, industrial feedback recommended this approach to ensure the quality of the responses.

Companies were selected from the Company Directory of the Shannon Development Region. In all, 58 potential respondent companies were contacted, with 28 respondents (22 companies and 6 logistics service providers (LSPs)) agreeing to participate in the survey. This gives and overall response rate of 48%. The survey was administrated between the months of November 2007 and April 2008 at company sites. The survey contains four categories of questions (see Appendix A for the complete questionnaire).

Company information: To generate a profile of respondent companies in relation to size, sector and, for LSPs, the sector(s) serviced. The demographic of the respondent's supplier/customer base is also tested.

Environmental awareness: To gather information on the awareness of companies of sustainability in general and specifically in relation to logistics.

Logistics business practices: To gather information on logistics services purchased and provided, and to understand the business practices used in this sector. This is seen as important in developing approaches for implementation of sustainability programmes in the logistics sector.

Efficiency in logistics operations: Here the readiness of companies to adopt more sustainable logistics operational practices is tested. Methods of increasing logistical efficiency as outlined by Potter and Lalwani (2005) are assessed. Questions relating to monitoring of logistics costs, the use of ICT in logistical and supply-chain operations, and the willingness to participate in shared transportation networks are used to provide indicators for company readiness.

2.3 Survey Results

Figure 2.1 gives the range of economic sectors that companies represented. The breakdown of employee numbers at the respondent company site as well as annual turnover in also shown in Figure 2.1. The majority of respondents (93%) were SMEs (according to the definition of an SME by the European Commission (2008)) with two large organisations making up the respondents. This reflects the demographic of SMEs in Ireland, with SMEs representing 90% of registered companies (BITC, 2009).

To gain an understanding of logistics operations in the companies surveyed, the geographic locations of the respondents' customers and suppliers are shown in Table 2.1. The results are split between the companies
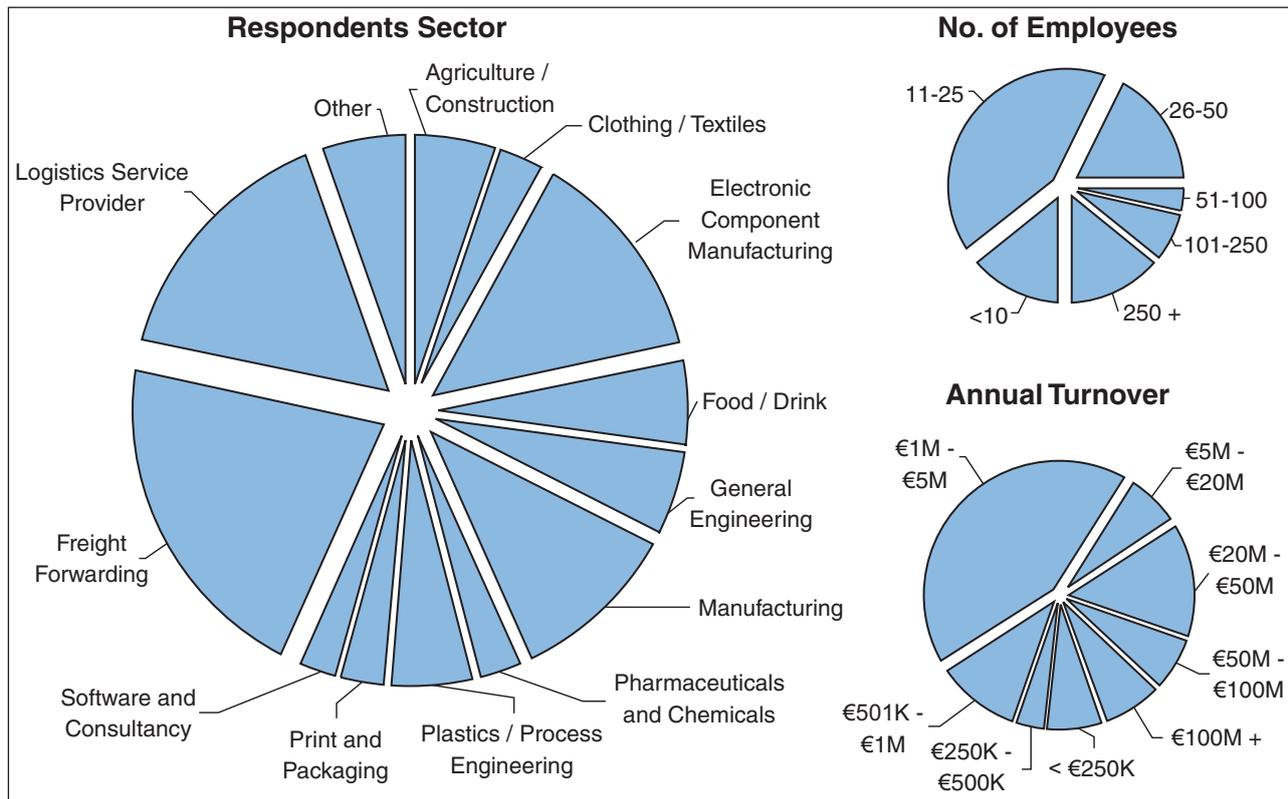
Figure 2.1. Respondent demographics.

Table 2.1. Supplier and customer demographics.

Location	Supplier Locations	Customer Locations	
	Companies %	Companies %	LSPs %
Local < 100 km	23.3	16	35.7
National (within island of Ireland)	26.7	16	35.7
Western Europe	18.3	17.3	14.3
Eastern Europe	11.7	13.6	7.1
Americas (North and South)	8.3	13.6	7.1
Western Asia	8.3	13.6	0
Eastern Asia	3.3	9.9	0

and the LSPs (for LSPs, only customer locations were asked for). Companies source half their supplies from within the island of Ireland, with the majority of supplies imported into Ireland sourced from other European countries. Companies supply customers globally with a more balanced spread among regions than that for company suppliers. The majority of the LSPs surveyed served a domestic market (71.4%).

2.3.1 *Environmental Awareness of Companies*

Questions on environmental awareness showed that:

- 36.4% of companies had an environmental officer, of which 14.3% had a remit that extended to the supply chain.

- 22.7% of companies have implemented ISO 14001.

- 9% of companies state they have measured their carbon footprint.

- No LSPs surveyed have implemented ISO 14001 or ever measured their full carbon footprint. However 33% of respondents say it is in their future plans.

Comparing the results above with those obtained by Kewill (2008) where 450 respondents from around the world were surveyed, 34.4% of those companies had measured their carbon footprint compared to 9% of companies and none of the LSPs in this survey. This indicates that environmental-impact measurement by companies is low in Ireland when compared internationally. However, of the 91% of companies who have never measured their carbon footprint, 55% of these stated it was in their company's future plans to do so.

The Kewill (2008) survey highlights that 73% of companies now make environmental compliance part of their tender documents. In an effort to assess Irish companies' attitudes towards using more environmentally friendly LSPs, respondents were asked the following two questions:

1   Would your company consider using a LSP that proved to be more environmentally sustainable over its competitors, and provided equal price?

2   Would your company consider using a LSP that proved to be more environmentally sustainable over its competitors, but cost 5% more to use?

The results in Figure 2.2 show that a majority (23% 'Consider' and 31% 'Maybe use') of companies would be willing to use LSPs that prove to be more environmentally sustainable over their competitors. However this is not the case if the LSP charges more for their business. Interestingly, respondents who answered 'Never use in decision making' (which relates to question 1 above) all cited cost as the overriding factor, which indicates that companies perceive that there is a cost associated with environmental sustainability (i.e. a supplier must be less competitive in terms of cost if they provide a greener service). Section 4 explores this issue quantitatively – the trade-off between cost and environmental impact.

2.3.2   *Logistic Business Practices*

To introduce sustainability approaches into the logistics sector in Ireland it is important to gain an understanding of business practices in this sector. Table 2.2 gives the logistics services that companies outsource to LSPs and the services that the LSPs provide to their customers. Companies were also asked how many LSPs their companies worked with. The results were that:

1   23.8% worked with between 1–3 LSPs.

2   38.1% worked with between 4–8 LSPs.

3   33.3% worked with between 9–13 LSPs.

4   4.8% worked with between 14–18 LSPs.
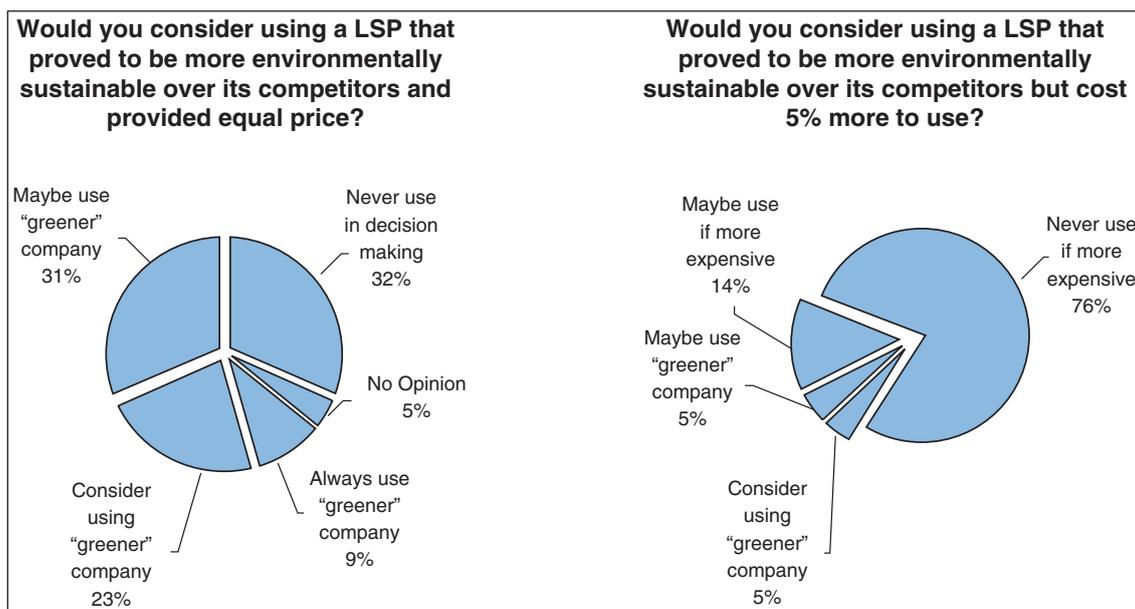
Figure 2.2. Companies views on environmentally conscious logistics service providers (LSP).

Table 2.2. Logistics services outsourced by companies/offered by logistics service providers (LSP).

Answer Options	% Used by Companies	% Offered by LSPs
Warehousing	33.3	83.3
Cross-Docking	38.1	50
Air Freight Forwarding	81	16.7
Ocean Freight Forwarding – Full Container Loads	52.4	0
Ocean Freight Forwarding – Consolidation Services	52.4	0
Returns Management	33.3	50
Temperature Controlled Transport	38.1	83.3
Transport of Hazardous Goods	42.9	66.7
Documentation and Invoicing	52.4	66.7
Purchasing/Procurement	23.8	16.7
Product or Component Assembly	14.3	16.7
Pick Pack Kitting	9.5	50
Labelling	33.3	33.3
Testing/Quality Control	9.5	16.7

Combining these results gives a picture of a sector that is highly fragmented. This is an important factor to take into account in developing a strategy in promoting sustainability in this sector.

2.3.3 Efficiency in Logistics Operations

Results given here report on the preparedness of both the purchaser of logistic services and the provider of these services in adopting strategies for more sustainable operations. Measurement is a key cornerstone in implementing sustainable approaches. Therefore, questions were asked about measurement of logistic costs, which would provide a strong indication of the preparedness of companies to measure the environmental impact of their logistic operations. Another cornerstone in implementing sustainability in logistics operations is ICT, to support, for example, collaborative relationships, consolidated shipments, measurement and monitoring of environmental impact, etc. Therefore questions relating to ICT usage are reported here.

2.3.3.1 Logistic Costs

Companies were asked how often their logistics costs were calculated and by what method they do so (see Figure 2.3). Approximately half the companies review their logistics costs on an ongoing basis with all but one of the LSPs surveyed stating that they do. Most companies say their logistics costs are calculated by weight. All respondents who used the 'Other' category state that the costs are negotiated as per the specific contract set out by the company and the LSP.

2.3.3.2 Exploitation of ICT

ICT in logistics operations is vital to efficiently manage supply-chain operations, and in this survey 86.4% of companies have implemented some form of ICT in their logistics operations, the breakdown of which is in Table 2.3. Also presented in Table 2.3 are the results from LSPs in the survey and LSPs in the Larson and Gammelgaard (2001) survey. When referenced against their Danish counterparts, there is a low level of adoption in ICT services among LSPs in the Mid-West Region of Ireland. Also of note is that the Larson and Gammelgaard survey took place in the summer of 1999, almost nine years prior to the survey analysis carried out here, thus compounding the level of advancement of the Danish logistics sector.

Choy (2004) argues that supplier relationship management (SRM) tools can create competitive

How often does your company review its logistics costs / operations?

Every 3 Months 10%
Ongoing 52%
Every 6 Months 14%
Every year 14%
Never 10%

How are your company's logistics costs calculated?

Per Case / Tonne 38%
Per Journey 26%
% of Sales 10%
Other 24%
Don't Know 2%
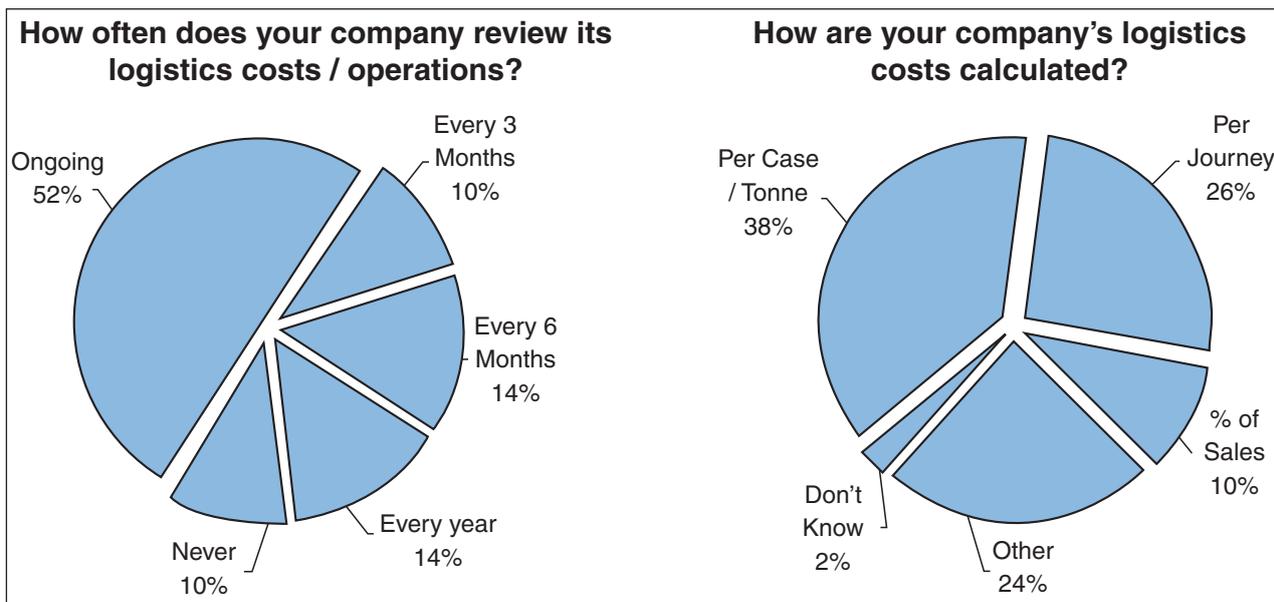
Figure 2.3. Calculation of logistics costs.

Table 2.3. Use of ICT in logistical operations.

Answer Options	Response (%) Companies	Response (%) LSPs	L&G survey
Web Track and Trace of Consignments	89.5	33.3	44.3
Electronic Proof of Delivery Systems (e-Pod)	73.7	33.3	
SMS Alerts	15.8	33.3	
Transport Planning Tools	5.3	16.6	
Fleet Monitoring/Tracking Systems	5.3	16.6	42.6
In-Cab Communication systems	0	16.6	
GPS/Satellite Navigation Systems	0	16.6	
Co-ordinated Distribution Network Optimisation	0	50	
Vehicle Routing Systems	0	33.3	

advantage through substantial reductions in the true cost of parts and materials, increased flexibility to respond to changes in customer demand and faster cycle times. Companies were asked about their use of SRM tools, with 45.5% of them using an SRM tool at the time of the survey. To gather further insight into the level of use of SRM tools, companies were asked what methods they use when placing orders with their suppliers, see Table 2.4. In the survey, seven options for answering the question were given as indicated in the table. The response count for each option and the percentage breakdown of the resulting percentiles are then given (i.e. 16 companies use phone when ordering supplies with 46.7% of the 16 using it < 20% of the time). E-mail

is the most popular method of ordering, with 31.6% of companies who use e-mail ordering 81–100% of their orders in that way. 36.4% of companies use some form of electronic data interchange (EDI) for ordering products. Note that LSPs were not asked this question. The results given for 'Phone' and 'Fax' show that there is a still a high level of non-state-of-the-art ICT tools use by companies in the operation of their supply chains.

2.3.3.3 *Utilising Collaborative Relationships*

Sweeney et al. (2008) state that the development of collaborative and partnership relationships throughout the supply chain is a fundamental principle of effective SCM. From the results given in Subsection 2.3.2, it is

Table 2.4. Breakdown of company ordering methods (suppliers).

By what method are your company's orders usually placed?						
	Response Count	**< 20%**	**21–40%**	**41–60%**	**61–80%**	**81–100%**
E-mail	19	47.4	15.8	5.3	0	31.6
Fax	17	76.5	5.9	11.8	5.9	0
Phone	16	46.7	20.0	13.3	13.3	6.7
EDI	8	62.5	12.5	12.5	12.5	0
Internet	7	85.7	14.0	0	0	0
Mail	2	100.0	0	0	0	0
Other	1	0	0	0	100	0

clear that, due to the level of outsourcing of logistics, collaboration among enterprises will be an important factor in implementing more sustainable practice. The report by O'Regan and Moles (2009) makes a similar point when stating that SMEs could influence transport practices through collaborative procurement.

As identified earlier in Table 2.1, companies are sourcing a high proportion of their goods locally. However, of the surveyed companies, 77.3% are *not* involved in any collaborative/shared transportation relationships with their customers/suppliers/other companies. On answering this question, respondents who answered 'No' were then asked if they would ever consider getting involved in a shared transportation network under differing circumstances, see Figure 2.4.

What becomes evident from the results is that there is interest in setting up shared transportation networks among companies where possible. 50% of companies reported that they would be interested in setting up a transport network, but would not be interested if it impacted on the responsiveness of the transport network, i.e. having to wait for shipment of their goods less than 1 day. It must be noted that a high proportion of freight forwarders (who constitute 29% of total surveyed respondents) said they would not like to get involved in shared transport relationships as company policy. Surprisingly, as it is a very competitive sector, 83% of the LSPs surveyed
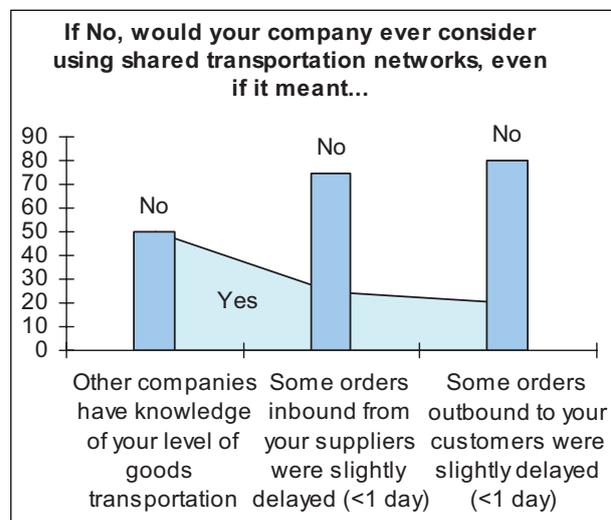
Figure 2.4. Company opinions on adopting shared transportation networks in the Mid-West Region of Ireland.

were involved in collaborative or shared transport relationships with other LSPs at the time of the survey.

2.3.3.4 Transport Practices

Transport practices such as shipment consolidation and backloads play an important role in reducing the environmental impact of a transport network, and therefore companies were questioned on such practices. The survey results are:

1   77.3 % of companies consolidate their inbound or outbound shipments.

2   50% of LSPs currently have a system for acquiring backloads on shipments and journeys.

3   50% of LSPs match vehicles to transport assignments.

4   No LSPs implemented bonus schemes for drivers for fuel efficiency.

The results show that a high number of companies (77% for consolidation of orders) do implement strategies that improve logistic efficiency resulting in lower environment impact. It is interesting to compare this level of internal company activity against collaborative activities where the results show the exact opposite (77% do not participate in collaborative transport sharing). LSPs implement a lower level of practices that address environmental impact.

According to Huber and Sweeney (2007), transport infrastructure has been identified by 45% of companies as an overriding constraint of the continuing development of business in Ireland. The problems reported by companies in the Huber and Sweeney survey mainly relate to costs and to ensuring that deliveries are on time. Transport efficiency is tightly coupled to environment impact, therefore questions were framed to test the companies' perceived understanding of the trend in transport efficiency over time. Specifically, companies were asked if they felt their transport efficiency had improved over the last 6 months, 1 year, 5 years and 10 years, see Figure 2.5. Results are presented separately for companies and LSPs (see Figure 2.6), as differences in perception would be important to understand when engaging the sector in sustainability initiatives.

In the current survey most companies believe that their transport efficiency has increased over recent years, citing the proliferation of ICT in logistical operations as a reason why. This statistic correlates to use of ICT in companies as highlighted in Table 2.3, where, for instance, 89.5% of the companies surveyed use web track-and-trace for their shipments. However,

the majority of companies believe there has been a decrease in efficiency over the last 6 months. This possibly relates to the time when the survey took place, which was before the current economic downturn, when there was still growth in road traffic.

In direct contrast to the companies, LSPs believed that over the last 10 and 5 years there was no increase in the transport efficiency of their company, citing traffic congestion as the main impediment. However, LSPs believe their recent adoption of ICT has helped increase overall efficiency over the last year/6 months, see Figure 2.6. With no correlation between the views of companies and LSPs on recent transport efficiency, the statistics suggest that different approaches for
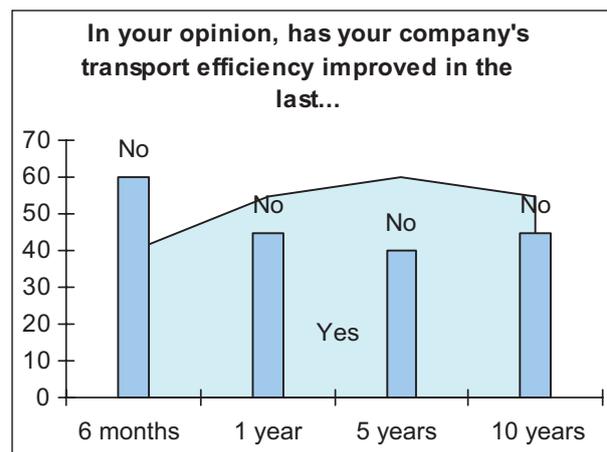

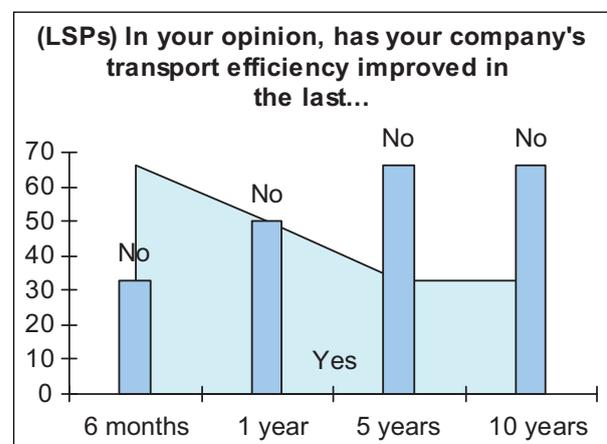**Figure 2.5. Companies' opinions on transport efficiency.**

Figure 2.6. Logistics service providers (LSP) opinions on transport efficiency.

engagement on the topic of sustainable logistics of both buyer and seller may be needed.

2.4   Conclusions

A summary of the main points from this survey are:

- Results from supplier and customer demographics (Table 2.1) show that companies operate in a global market.

- Companies employ fewer strategies to lower environmental impact, compared to companies internationally. This is shown most clearly by the fact that 34.4% of the companies in the survey by Kewill (2008) had measured their carbon footprint, compared to 9% in the present survey.

- Measures to address the impact of logistics in companies and LSPs is currently non-existent. For example, no LSPs surveyed have implemented ISO 14001 or ever measured their full carbon footprint. However, with all LSPs except one measuring their costs on an ongoing basis, the results show that LSPs have the capability to implement logistic environmental-impact measurement systems.

- There is a willingness among companies to implement practices to address the environmental impact of their activities. This is seen from the result where 33% of LSPs say it is in their future plans to measure their carbon footprint and where, of the 91% of companies who have never measured their carbon footprint, 55% of these stated it was in their company's future plans to do so.

- The results seem to highlight that there is a lack of understanding of the relationship between efficiency and the environmental impact of logistics activities by purchasers of logistics services. This is highlighted by the result that 32% of companies surveyed stated that they would never use in their decision making the criteria of environmental sustainability when comparing competing logistics service providers, due to the perceived increase in cost.

- Results from logistics business practices show clearly that the logistics sector is a very fragmented sector, due the high level of outsourcing. This is an important factor to take into consideration when implementing policy to address sustainability in this sector. This view is backed up by Comhar (2008) which notes that there are many small freight transport operators in Ireland with little co-ordination or external leadership.

- There is a low penetration of ICT in companies in support of logistics operations. This is shown in the results on company ordering methods where there is still a high level of reliance on dated ICT tools in supply-chain practices (Table 2.4). This is also borne out by the results shown in Table 2.3, where LSPs are shown to have a lower level of usage of ICT tools against Danish companies surveyed in 1999. This indicates that there is scope in improving the efficiency and hence sustainability of logistics via the wider adoption of ICT.

- Increased collaboration is often cited as a means to reduce the environmental impact of logistics networks (Barrat, 2004; Mason and Lalwani, 2005). The results show that among companies there is a level of collaboration on transportation, albeit low (23%). In the case of LPSs, the level of collaboration (83%) is high. However, the survey does not reveal the benefits to the environment of this collaboration. It would be useful to carry out a study that would give an understanding of these benefits and improve collaboration strategy in this sector.

- Mason and Lalwani (2006) identify low fill rates and bad vehicle utilisation as factors that adversely affect the efficiency (and sustainability) of a freight transport system. According to the Department of

Transport Ireland (2008) 'typically around a third of vehicle-kilometres are suboptimal depending on length of haul, type of vehicle, industrial sector and the nature of the delivery operation'. The results from the survey on transport practice (only 50% of LSPs implement back ordering) show that this is an area with scope for improvement. Also, empty haulage in Ireland is not monitored as in other countries and no definitive statistic currently exits. The authors believe that this is an area for future research and monitoring.

3. Standards, Tools and Methodologies for Sustainable Supply-Chain Development

3.1 Aims

Sustainable supply-chain implementation requires standards to allow measurement of environmental impact, and methodologies and support tools to allow adoption of environment practices. This sector is a new and emerging field and currently without a standard framework to allow it to be established as a standard business practice. Recent developments such the recently published specification *PAS 2050 – Assessing the Life Cycle Greenhouse Gas Emissions of Goods and Services* (BSI, 2008) are providing the momentum to have environmental management of supply chains become a de facto business practice. The purpose of this section is provide an overview of standards, methodologies and tools currently available for the implementation of sustainable supply chains.

3.2 The Green Supply Chain

The negative environmental aspects of freight movements and manufacturing have focused a vast quantity of study on environmental or green logistics, environmental or green supply-chain management and sustainability in manufacturing and service delivery. In terms of both practice and theory, the green supply chain has emerged as an effective management tool and philosophy for proactive and leading organisations and business in general.

The scope of green supply-chain management practices implementation ranges from green purchasing to integrated life-cycle management for supply chains flowing from supplier through to manufacturer and then customer, and closing the loop with reverse logistics. Similar to the concept of supply-chain management,

the boundary of green supply-chain management is dependent on the researcher/practitioner goals and the problems at hand, e.g. should it be just the procurement stage or the full logistics channel that is to be investigated (Zhu et al., 2008).

Given its broadest characterisation, the concept of the green supply chain covers all the phases of a product's life cycle, from the extraction of raw materials through the design, production and distribution phases, to the use of products by consumers, and their disposal at the end of the product's life cycle (reconditioning, reuse or recycling) (BearingPoint, 2008). However, irrespective of the focus of a particular researcher/practitioner in defining the green supply chain, there is one central core objective in all related efforts – as described by Srivastava (2008), adding the 'green' component to supply-chain management involves addressing the influence and relationships between supply-chain management and the natural environment and that its purpose is to minimise a product's or service's ecological impact.

3.3 Standards

One of the main difficulties associated with the area of green supply chains and the integration of its environmental aspects with business activity is the ambiguity surrounding its structures, constructs and definitions. The trade-offs between economic and environmental goals makes environmental management a challenging task. In an attempt to reduce this ambiguity and to streamline the area's development, a number of standards have been designed and developed over a period of time. As with the definition of the area associated with green

supply-chain management, there are also considerable differences of opinion when it comes to standards in the area. As has been pointed out by the Carbon Trust (2008), as of 2006 there was no standard approach to measuring a product's carbon footprint, let alone a credible way to communicate them to consumers.

One body of work in the area of standardisation has been the development of what is termed environmental management systems (EMSs). Guidelines and instruments in the form of EMSs have been developed to assist businesses in reviewing their environmental impact in a business context. As illustrated by Schaltegger et al. (2003), implementing a defined set of standards helps businesses in analysing, controlling and reducing their environmental impacts. Definition of an environmental policy ensures that environmental goals are made operational and equally considered. Additionally, internal and external auditing processes verify the implementation of a functioning EMS.

3.3.1   Environmental Management Systems

The following extract from the National Standards Authority of Ireland (NSAI, 2009) outlines in relative terms the main background to the EMS standards and the ways in which they are implemented.

> Environmental issues and the need for protection of the environment is the focus of increasing concern and over the past number of years governments, businesses and the public are demanding a reasonable and effective response. The 'Earth Summits' of world leaders in Rio de Janeiro and Kyoto brought much attention to these issues and encouraged tangible steps towards sustainable development which would allow for continued economic prosperity without compromising future generations. Many companies and organisations have responded positively to the challenge to contribute to economic development and prosperity in a way that respects the environment. They are actively implementing economically viable programmes that reduce the adverse environmental impacts of their operations and that result in sustained benefits for all parties.

> EMS standards have been developed as tools to allow the management of organisations to better identify, manage and control their activities that can impact the environment.

> By a systematic analysis of the aspects of an organisation's operations, and by quantifying the impacts on the environment of these aspects, the organisation can respond in a planned and co-ordinated way. Defining clear goals and objectives in relation to environmental performance gives direction to the organisation by reducing waste and energy use, substitution of non-renewable resources, risk avoidance, good citizenship and image enhancement. This contributes to increased stakeholder confidence, competitive advantage and long-term viability. (NSAI, 2009)

Although there is a range of EMSs, in practice the EU-issued Eco-Management and Audit Scheme (EMAS) and the international standard series ISO 14000 are the most frequently applied EMSs.

3.3.1.1   Features of EMS Standards

Environmental management system standards were developed in the early 1990s in several countries. The first standard was approved by the British Standards Institution (BSI) in 1992 and became a model for the international standard ISO 14001, which was elaborated on in the years 1991–1996. The European EMAS was adopted in 1993 (EEB, 2003).

ISO 14000 specifies a set of measures to be incorporated into a company's management system aimed at dealing with environmental aspects in a systematic way including the following major elements:

1   Definition of an environmental policy including performance objectives.

2   Assessment of environmental aspects.

3   Identification of legal obligations.

4   Establishing an environmental management programme.

5   Definition of procedures to achieve the objectives.

6   Monitoring of the system and improvements.

The European EMAS is based on the international standard but contains additional requirements:

1   Initial environmental review.

2   Independent verification.

3   An accreditation system for verifiers.

4   Validated environmental statements.

5   Employee involvement.

3.3.2   *Industrial Carbon Footprinting Standards and Methodologies*

A carbon footprint is 'the total set of greenhouse gas emissions caused directly and indirectly by an [individual, event, organisation, product] expressed as CO_2' (Carbon Trust, 2007).

One of the major impediments for carbon footprinting is the lack of standards associated with the methods of analysis, in combination with a lack of standardisation of GHG emission factors for calculation.

Again, as was the case with the environmental-management systems, a number of different standards have been developed by independent bodies on both a national and an international scale. The two more dominant carbon footprinting standards presently are the ISO 14040/4 and the PAS 2050. The ISO 14040/4 standard has been in existence since 1997, with the PAS 2050 published in late 2008. The PAS 2050 standard builds on existing life-cycle assessment (LCA) methods (discussed below) established through ISO 14040/4.

3.3.2.1   *ISO 14040/4*

ISO standard 14040 describes the principles and framework for LCA. It provides an overview of the practice and its applications and limitations. It does not describe the LCA technique in detail, nor does it specify methodologies for the individual components of the LCA (goal and scope definition, inventory, impact assessment and interpretation). Because the standard must be applicable to many industrial and consumer sectors, it is rather general. Nonetheless, it includes a comprehensive set of terms and definitions, the methodological framework for each of the four components, reporting considerations, approaches for critical review, and an appendix describing the application of LCA. ISO 14044 specifies requirements and provides guidelines for LCA. It is designed for the preparation, conduct and critical review of life-cycle inventory analysis, and provides guidance on the impact assessment and interpretation phases of LCA, and on the nature and quality of the data collected (Elcock, 2007).

3.3.2.2   *PAS 2050*

The BSI developed the Publicly Available Specification (PAS) 2050 as a method for measuring the embodied GHG emissions from goods and services. As part of the development of this standard, the BSI analysed GHG product emissions in general. From this report they highlight the fact that a substantial element of GHG product emissions can be attributed to the transport and storage of goods and services (logistics).

BSI Standards Solutions (BSI, 2008) have led the development since June 2007 of the PAS method for measuring the embodied GHG emissions from goods and services at the request of Defra (Department for Environment, Food and Rural Affairs) and the Carbon Trust in the UK. The PAS document provides a workable standardisation process, providing a benchmark for future development aimed at reducing GHG emissions.

Aim:

The PAS method for measuring embodied GHG emissions of goods and services will enable organisations, e.g. businesses, to effectively measure the climate-change related impacts of their goods and services with a view to using this information to improve the climate-change related performance of these.

Scope:

PAS specifies requirements for the assessment of the GHG emissions associated with the life cycle of goods and services. This PAS is applicable to organisations assessing the life-cycle GHG emissions of goods and services across their life cycle.

Measurement method:

1   Applies to all goods and services with consideration given to how and whether it may need customising for specific product groups, e.g. food, buildings, electronics, etc.

2   Considers all life-cycle stages along the supply/value chain of a product (goods and/or services), i.e. from raw materials to end of life.

3   Includes the six GHGs identified under the Kyoto Protocol.

4   Could be used by all sizes and types of organisation.

3.4   Tools

There is a vast array of tools available in the environmental modelling area. These range from tools that have been designed to calculate an individual's carbon footprint, to household calculators, business calculators, to total supply-chain calculators. The range of developers of these tools includes individual organisations, organisational networks, environmental agencies, national and international bodies and research institutes. The tools that have most relevance to this study can be categorised into three broad areas: life-cycle analysis, static modelling and supply-chain environmental modelling. In addition

to these three areas are the carbon accounting tools. These carbon accounting tools are prerequisites to the three areas and are used to allocate carbon emissions to specific activities in question in order to build up its overall carbon footprint.

3.4.1   *Carbon Accounting Tools*

The carbon footprint of a specific product includes the total carbon output from the product, i.e. raw material extraction, manufacturing, distribution, retailing, consumption, disposal and recycling (Carbon Trust, 2006). A company's full carbon footprint covers three main areas:

1   Direct emissions from activities the company controls, such as heating and energy use used in manufacturing or processing.

2   Emissions from electricity use.

3   Indirect emissions from products or services, (i.e. the sourcing of products and their eventual disposal or reuse).

The Carbon Trust (2007) defines five steps which must be used for the calculation of a carbon footprint:

1   Define the methodology – use consistent conversion factors, and a reliable method of calculation.

2   Specify the boundary and scope of the coverage – which and what emissions are included, and how far up and down the supply chain to calculate.

3   Collect emissions data and calculate the footprint – accuracy relies on calculating the correct data.

4   Verify the results – verification from a third party to add credibility.

5   Disclose the footprint – make all the above information available for review.

There are many carbon calculation tools available over the internet; with many of these focused specifically

on the individual or household carbon footprinting level. Carbon calculating tools already in use typically calculate household energy, including transportation, examples of which include:

- 'Act on CO$_2$' – available from http://actonco2.direct.gov.uk/index.html

- 'The Footprinter' – available from www.footprinter.com

- The Irish based 'Repak' carbon footprint calculator – available from www.repak.ie/Carbon_Footprint_Caluclator.html

In the Irish case, Repak also state through their website that they are 'working with international consultants on the development of a carbon calculator for Irish businesses in relation to their product supply chain'; however, no update has been provided on this since late 2007.

3.4.2   Life-Cycle Analysis

Life-cycle analysis is a methodological tool that applies life-cycle thinking in a quantitative way on environmental analysis of activities related to processes or products (goods and services). A central characteristic of life-cycle analysis is the holistic focus on products or processes and their functions, considering upstream and downstream activities.

The European Commission (2007) define the life-cycle concept as follows: An LCA of a product includes all the production processes and services associated with the product through its life cycle, from the extraction of raw materials through production of the materials that are used in the manufacture of the product, over the use of the product's life, to its recycling and/or ultimate disposal of some of its constituents. Such a complete life cycle is also often name 'cradle to grave' or even, in the case of the full recycling of the product, 'cradle to cradle'. Transportation, storage, retail and other activities between the life-cycle stages are included where

relevant. This life cycle of a product is hence identical to the complete supply chain of the product plus its use and end-of-life treatment.

Shown in Table 3.1 are the standard elements that make up the measurement of a products life-cycle emissions. As evident from this figure, transport and logistics make up a large portion of the life cycle of a product and/or service.

LCA is not without its critics, and the majority of this criticism is encapsulated in the comparatives that are required in order to develop definitive results. These comparatives can exist between the calculation of the environmental output(s) of differing processes and process types, to the comparatives between the impact(s) on different environmental elements. Such comparative issues include, for example (as described by GDRC (2009)):

1   How can heavy energy demand be compared with heavy water use: which imposes a greater environmental burden?

2   How should the use of non-renewable mineral resources like oil or gas (the ingredients of plastics) be compared with the production of softwoods for paper?

3   How should the combined impacts of the land filling of wastes (air and groundwater pollution, transport impacts, etc.) be compared with those produced by the burning of wastes for energy production (predominantly emissions to air)?

Some studies attempt to aggregate the various impacts into clearly defined categories; for example, the possible impact on the ozone layer, or the contribution to acid rain. Others go still further and try to add the aggregated figures to arrive at a single 'score' for the product or process being evaluated. It is doubtful whether such simplification will be of general benefit. Reliable methods for aggregating figures generated by LCA, and using them to compare the life-cycle impacts of different products, do not yet exist.

Table 3.1. Life-cycle analysis (adapted from BSI (2008)).

Raw Materials	Manufacture	Distribution/Retail	Consumer Use	Disposal/ Recycling
All inputs used at any stage in the life cycle	All activities from collection of raw materials to **distribution**	All steps in **transport** and related **storage**	Energy required during use phase: – **Storage** – Preparation – Application Maintenance/repair (e.g. for long use phases)	All steps in disposal: – **Transport** – **Storage** – Processing
Include processes related to raw materials: – Mining/extraction (minerals) – Farming – Forestry – Pre-processing – Packaging – **Storage** – **Transport**	All production processes: – **Transport/ storage** related to production – Packaging – Site-related emissions (e.g. lighting, ventilation, temperature)	Retail **storage** and display		Energy required in disposal/ recycling process
Account for impact of raw materials: – Fertilisers (production, **transport**, application) – Land-use change	All materials produced: – Product – Waste – Co-products (useful by-products) – Direct emission			Direct emissions due to disposal/ recycling: – Carbon decay – Methane release – Incineration

In addition, many LCAs have reached different and sometimes contradictory conclusions about similar products. Comparisons are rarely easy because of the different assumptions that are used; for example in the case of food packaging, about the size and form of container, the production and distribution system used, and the forms and type of energy assumed.

3.4.3 *Environmental Modelling*

There are a number of environmental modelling tools available which have been designed for supply-chain operations, and many more are being devised and developed by both industry and academia on an ongoing basis.

From the research carried out in this study, it was found that the majority of these modelling tools can be best described as static in nature. Static models are models that have direct relationships between activities and carbon output and do not have the capacity to change over time. These models are typically spreadsheet or database driven.

3.4.3.1 *Static Modelling*

One such set of tools has been developed by the Greenhouse Gas Protocol Initiative (2008). These tools have been specifically developed for a number of different industrial areas. The tools have been developed using Microsoft Excel and equate industrial

activities with environmental impacts using a defined set of emission factors. The default emission factors used are averages based on the most extensive data sets available and they are largely identical to those used by the Intergovernmental Panel on Climate Change (IPCC). However, organisations have the capacity to substitute these emissions factors with their own if necessary. A screen shot of one the transport element of one of these tools is shown in Figure 3.1.

3.4.3.2 Supply-Chain Mapping

A second set of tools have been developed around the concept of supply-chain mapping, which is sometimes also referred to as value-stream mapping (VSM). This supply-chain mapping is not a new concept and is a technique which is used in lean manufacturing to map the flow of material and data, and associated time

requirements from initial supplier to end customer for a given business process. In most instances it is used to define improvement areas and sources of waste. Building on this lean technique, Braithwaite and Knivett (2008) developed a supply-chain mapping technique in Microsoft Excel for estimating and visualising the carbon intensity of products as they move from source to consumption. This model has been developed for the Australian wine industry, focusing on the transportation of wine to the UK. This model has taken the traditional costing mechanism from this mapping exercise and replaced it with carbon emissions outputs. The carbon emissions used in this model have been devised specifically for each of the elements of this example, with all elements then being normalised to the carbon (CO_2) per unit of output/consumption.

Braithwaite and Knivett (2008) discuss the primitive and somewhat unreliable nature of this mapping technique,

Figure 3.1. GHG protocol environmental modelling tool.

describing it as a prototype for further analysis. While critiquing their own static supply-chain analysis, Braithwaite and Knivett (2008) note the difficulty in this type of modelling, stating three requirements for further analysis:

1   A requirement to access and catalogue reliable carbon emissions data from the different activities that make up the supply chain.

2   The model should be refined to incorporate supply-chain costs alongside the carbon assessment to support the decision-making process about when and where businesses might carry higher costs to reduce carbon emissions.

3   The modelling should be enhanced to allow the creation and retention of scenarios, allowing comparisons and hence supporting decision making.

3.4.3.3   Commercial Tools

SEAT: The Supply Chain Environmental Analysis/ Optimisation Tool (SEAT) is an interactive software tool from CleanMetrics. Details of the tool's functions are limited and information provided hereafter has been extracted from the company's website (CleanMetrics, 2009). The tool can be used to quantify and improve the environmental performance of supply chains. It allows users to easily model supply-chain elements – including transportation, storage and production – from an energy and carbon dioxide emissions perspective, and provides methods to analyse, report, and explore improvements to supply-chain environmental performance.

The tool can be used for detailed analysis of existing supply chains, 'what-if' experiments, and comparisons of alternative supply-chain configurations. Optional optimisation modules are available for minimising transport fuel consumption in supply/distribution networks, and for determining the best transport modes and shipping sizes throughout a supply chain.

The tool can operate in a variety of applications, such as (CleanMetrics, 2009):

1   Achieving overall cost savings from reduced energy use in supply chains.

2   Meeting GHG emission reduction targets.

3   Emission calculations for use in offsetting carbon footprints.

4   Carbon footprint analysis for eco-labelling of consumer products;

5   Detailed corporate reporting of energy use and emissions.

CarbonView: CarbonView is a supply-chain footprinting tool from Supply Chain Consulting (www.supply-chain.com.au/). Details of the tools abilities are as described on the above referenced source. The CarbonView tool allows companies to optimise its supply chain by focusing on financial and carbon emission metrics. The tool can help companies achieve reductions in costs and carbon emissions from within the organisation and across the supply chain. The tool uses static footprinting to provide its carbon footprint at a point in time. The tool develops 'static ecological and carbon footprint data for products, processes, the entire organisation, or the extended supply chain'. Using LCA databases to provide the ecological and carbon data, the tool is able to analyse and report on the static carbon footprint.

3.4.3.4   Other Tools

The SEAT and the CarbonView tools are indicative of a number of tools that are coming to the market presently. In many cases these tools are provided by consultancy companies and are sold as part of a service offering. Other providers that have developed tools in this area are:

ILOG: ILOG has released a Carbon Footprint extension to its LogicNet Plus XE supply-chain application.

The software can map out several scenarios to assess the cost of, for example, adding new distribution facilities in various locations, and then factor in different modes of transporting goods and the impact that the various configurations would have on service. It can also estimate the carbon impact of changes to the supply-chain network by computing the total carbon emissions associated with the new distribution facilities, plants and modes of transportation used between various points (ILOG, 2009).

Aravo Sustain: Aravo Sustain provides a framework for managing supplier information within enterprise requirements planning (ERP) and e-procurement applications such as Oracle, SAP and Ariba. Organisations can obtain, analyse and manage sustainability data, such as supplier and factory regulatory compliance, toxic-substance monitoring, carbon footprinting and labour practices (Aravo, 2009).

IBM: IBM has unveiled a tool designed to allow firms to calculate and reduce costs and carbon dioxide emissions in their supply chains, leading to reduced environmental impact and greater efficiency. Supply Chain Network Optimisation Workbench (SNOW) uses mathematical algorithms to delve deeper into a company's overall supply-chain logistics, ultimately helping clients take stock of their various distribution centres (IBM, 2009).

Freight Management Inc.: Freight Management Inc. (FMI) has introduced a new offering dubbed 'OptiGreen'. The OptiGreen program is built around the company's new software Distribution Pollution Solution, which FMI says can calculate carbon emissions between departure and arrival, and then recommend alternative shipping strategies, methods or routes to lower those carbon emissions.

3.5   Conclusions

There is a myriad of tools, techniques and standards which attempt to encapsulate the supply chain in an environmental context. The fact that the area has expanded so rapidly has meant that a number of parallel tracks have been followed, particularly in the area of standardisation of carbon measurement and in reporting techniques. This has led to certain fragmentation, overlaps and contradictions in the reporting on the environmental impacts of product and service supply chains. However, these discrepancies and overlaps are beginning to reduce, particular in relation to the underpinning standards, with the ISO 14000/4 and the PAS 2050 becoming the accepted standards. With respect to the carbon accounting tools, more work is required to create similar accepted standards. At present many carbon accounting mechanisms are used, and in some cases the results from these different mechanisms are in contradiction of each other. In general, this can lead to disenchantment from the public and scepticism with respect to the outputs from these techniques.

In addition, some of these tools and techniques attempt to introduce the multi-objectives of economic versus environmental costs. However, many of these tools and techniques simply attempt to measure or model the environmental impact of a particular supply chain as it is presently constructed. Little or no attempt has been made in many cases to introduce the trade-off concept of economic versus environmental cost of supply-chain design. As is the case in most organisations, a good business case must be made to instigate change. With the exception of legislature directives, supply-chain redesign in an environmental context will be driven by economic concerns. This economic element and its dynamic relationship with environmental change are presently under-represented in the majority of work in this area.

4.   Quantitative Analysis of Environmental and Economic Trade-Offs

4.1   Aims

This section reports on the results of a quantitative-analysis study carried out with the primary purpose of providing insight into the trade-off between environmental impact and cost/service levels in a supply chain when operating using different transport strategies. This analysis was motivated by (i) results from the survey reported in Section 2 which showed that companies are reluctant to implement more environmentally friendly options if additional costs might be incurred; and (ii) to provide insight to practitioners into how advanced analysis methods can compliment more standard analysis methods (i.e. LCA) in developing more sustainable operating strategies in the operation of a supply chain. With regard to (i), there are no results reported in the literature that quantify the trade-offs between the three measures of environmental impact, cost and service level in a realistic supply-chain setting. From the review reported in the last section it can be seen that tools have recently appeared on the market with advanced analysis capabilities, for example, the SEAT and the SNOW. However, being commercial tools, there is little transparency on the inner workings of these tools. This study provides practitioners with a better understanding of the capabilities of advanced analysis methods in reducing the environmental impact of supply chains.

4.2   Methodology

4.2.1   Selecting the Case Scenario

The scenario selected, which is based on a real case study, focuses on the freight transportation activities between three tiers of a supply chain: a product manufacturer together with its preceding and succeeding supply-chain nodes (as illustrated in Figure 4.1). Typically, the different partners in the supply chain outsource the supply of components/products. For example, the customer (typically an original equipment manufacturer (OEM)) will outsource the manufacture of a product to a contract manufacturer (CM), who in turn purchases or outsources the manufacture of the components.

This outsourcing practice can recur along the supply chain, resulting in complex multi-echelon supply-chain networks with numerous transportation activities between the various nodes (Byrne et al., 2008). While the demand along any supply chain is ultimately driven by the end customers, operational constraints at each node, such as batch sizes, processing times and safety stock levels, cause additional fluctuations which make supply-chain management difficult and ultimately affect the transportation operations between the different nodes (Liston et al., 2007). Lean manufacturing strategies such as just-in-time (JIT) place the emphasis on reducing the stock held by each node, resulting in an increase in transport frequency.
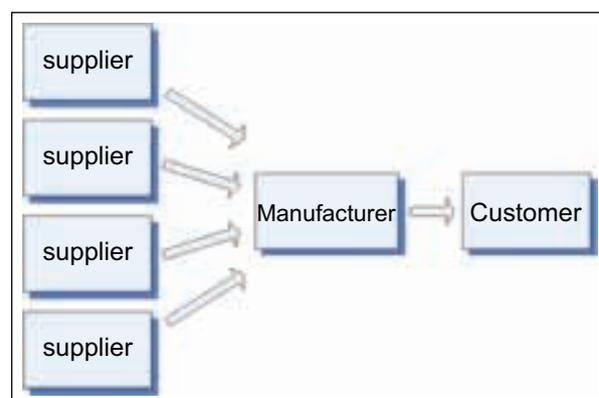

Figure 4.1. Supply-chain scenario.

The scenario studied is based on a real case study where a CM produces a sub-assembly for an electronic medical device under contract with an OEM. The CM employs lean manufacturing principles and has a materials requirements planning (MRP) system to control the ordering of material from suppliers, while deliveries to the OEM are subject to quantity flexibility terms which the OEM has stipulated in the outsourcing contract. In these contracts the buyer, at the beginning of the horizon, commits to purchase a certain quantity in each period of the contract. This above scenario reflects the circumstances of many companies operating in Ireland which can be involved in a number of these supply chains at any given time.

4.2.2 Supply-Chain Analysis

There is a wide range of modelling techniques that can be used to address supply-chain design and operational analysis. From the user's point of view it is important to differentiate between generative models and evaluative models, see Figure 4.2.

Generative models provide the user with an 'optimal solution' that satisfies the user's objective function. Evaluative models, unlike generative models, do not provide the user with an 'optimal solution'. Instead, these models evaluate a given set of decisions by providing the user with performance measures. Although generative models have the advantage of providing the user with an optimal solution, they

are, in general, restrictive in terms of their structural assumptions, which are usually only transparent to the model developer. Although evaluative models do not guarantee the user an optimal solution, they usually provide the user with valuable insights into the problem being addressed.

An evaluative model is the appropriate model for the purposes of the study here. There are two main classes of evaluative models that can be used in supply-chain analysis: queuing network models and simulation. Huang et al. (2003), as an example, used queuing models to study dyadic supply-chain structures (i.e. structures consisting of two echelons: a buyer and a vendor, for example), but states that discrete-event simulation (DES) is required to analyse more complex supply-chain structures such as that shown in Figure 4.1.

Simulation modelling of supply chains has to date focused on providing economic- and performance-related metrics. Examples of these metrics include the expected lead time on products, the expected percentage of sales orders that will be delivered on time and in full to the customer, the amount of sales demand the system can cope with, and the cost of providing products to customers. In this study, environmental impact metrics are added to a simulation-based supply-chain analysis. This will allow for the trade-off between cost, performance and environmental impact to be quantified when assessing operational issues in supply-chain design.

4.2.3 Developing the Model

Figure 4.3 gives an overview of the scope of the developed DES model. As can be deduced from the inputs and outputs listed here, this model does not attempt to capture the entire environmental impact of operating a supply chain, and many drivers of GHG emissions (such as the lighting and heating of buildings, for example) are not considered. The objective here is not to conduct extensive life-cycle analyses but to
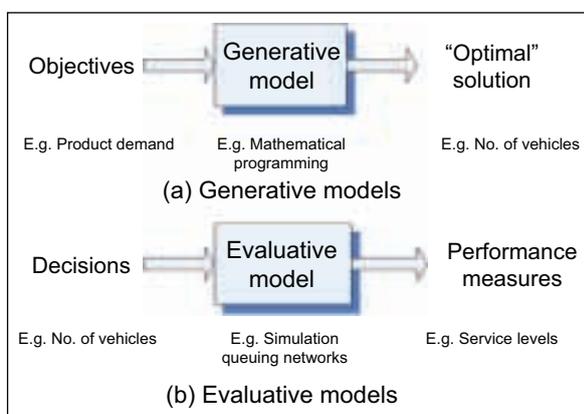

Figure 4.2. Models for systems design.
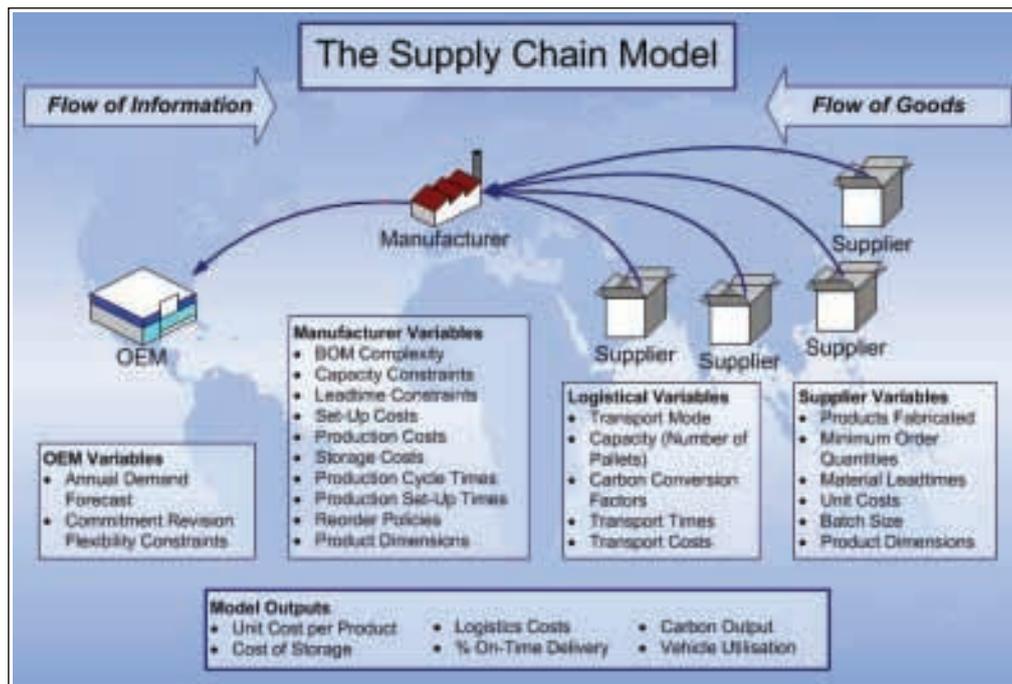
Figure 4.3. Simulation model overview.

study the effect of transport operational decisions on the environment, and customer-service levels, as well as costs.

The following gives an overview of the supply chain as simulated in the DES model:

1   Initial product demand is based on an inputted annual demand forecast. As the simulation runs, the OEM passes sales orders to the CM and revises previously placed orders according to contractually agreed commitment revision terms (these allow the OEM to change previous order quantities by amounts dependent on the immediacy of the delivery date).

2   The CM references this demand information against the bill of materials (BOM) data, corresponding raw-material inventory levels and open purchase orders. Where necessary, components are ordered from suppliers to maintain levels of stock adequate to satisfy forthcoming product demand. Purchasing constraints (i.e. minimum order quantities and batch sizes) for products on the supplier side will have influence on the size of these orders.

3   The suppliers then ship the requested amount of their respective components to the CM. If they are unable to ship the entire requested amount, then the remainder is placed on backorder and shipped when available. The number of units per pallet is cross-referenced with the transport mode used, to determine vehicle utilisation rates. These utilisation rates and the distance from supplier to manufacturer are used to calculate carbon emissions.

4   The CM determines its maximum production capacity (based on physical capacity and material constraints) and produces the outsourced product accordingly. Any available or required buffers of finished goods are also considered at this point.

5   Once manufactured, the products are tested and then shipped to the OEM where they are recorded into stock. Again, the product dimensions, transport mode and distance travelled are used to calculate the carbon output for this shipping activity.

These activities are repeated over a simulated 1-year period. Each time an activity is triggered the model accumulates the cost associated with conducting the

activity and, in the case of transportation activities, the carbon emitted. Customer-service levels are also recorded. The frequency and nature of the activities are dependent on the interaction of the different operations and model variables. Due to variable demand, the simulation model is replicated 30 times. Figure 4.4 shows the demand profile inputted to the model. This profile is based on a real product demand experienced by an electronics manufacturer and typifies the demand volatility that exists in the sector. Each replication represents possible future customer demand, and in the results section will be presented using box plots.

The carbon conversion factors used in the model (see Table 4.1) are derived from a report released by the UK Department for Environment, Food and Rural Affairs called 'Guidelines for Company Reporting on Greenhouse Gas Emissions', (DEFRA, 2005). As
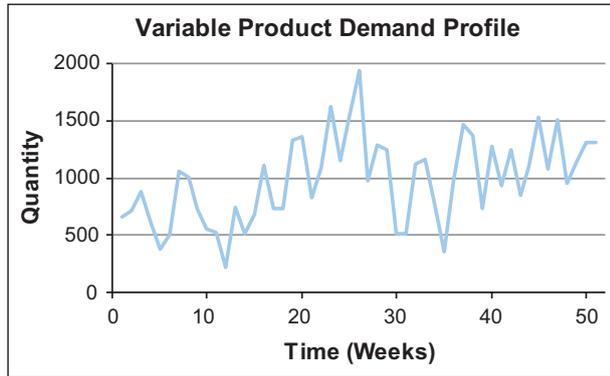
Figure 4.4. Demand profile data.

noted in Section 3, in the absence of a global standard, environmental standards like this are numerous and continually evolving. The DEFRA factors were selected for this analysis due to the geographical proximity of the UK to Ireland. Within the DES model, each time a transportation activity is simulated, the distance travelled is multiplied by the appropriate fuel conversion factor to calculate the amount of carbon emitted. As can be seen in Table 4.1, the choice of appropriate conversion factor is dependent on the vehicle type and the percentage of load capacity that is utilised.

A screenshot of the developed simulation model is shown in Figure 4.5. The simulation software package used for building the model was Plant Simulation™. This is an object-oriented discrete event simulation package developed by Siemens (www.plm.automation. siemens.com).

The next subsection presents experiments, based on the model presented, that explore the trade-off between environmental impact, customer-service levels and cost under different transport strategies.

4.3 Experimentation and Results

The supply chain used in this simulation experimentation relates to an assembled component (consisting of seven independent parts of four distinct types) that is used in an OEM-produced medical device. The model

Table 4.1. Carbon conversion factors.

Transport Model Details		
Transport Mode	**Fuel Conversion Factor (kg CO_2/km)**	**No. of Pallets Carried**
Van	0.19	2
Rigid Truck 25%	0.26	2
Rigid Truck 50%	0.29	4
Rigid Truck 75%	0.31	6
Rigid Truck 100%	0.34	8
Articulated Truck 25%	0.36	6
Articulated Truck 50%	0.38	12
Articulated Truck 75%	0.41	16
Articulated Truck 100%	0.45	22
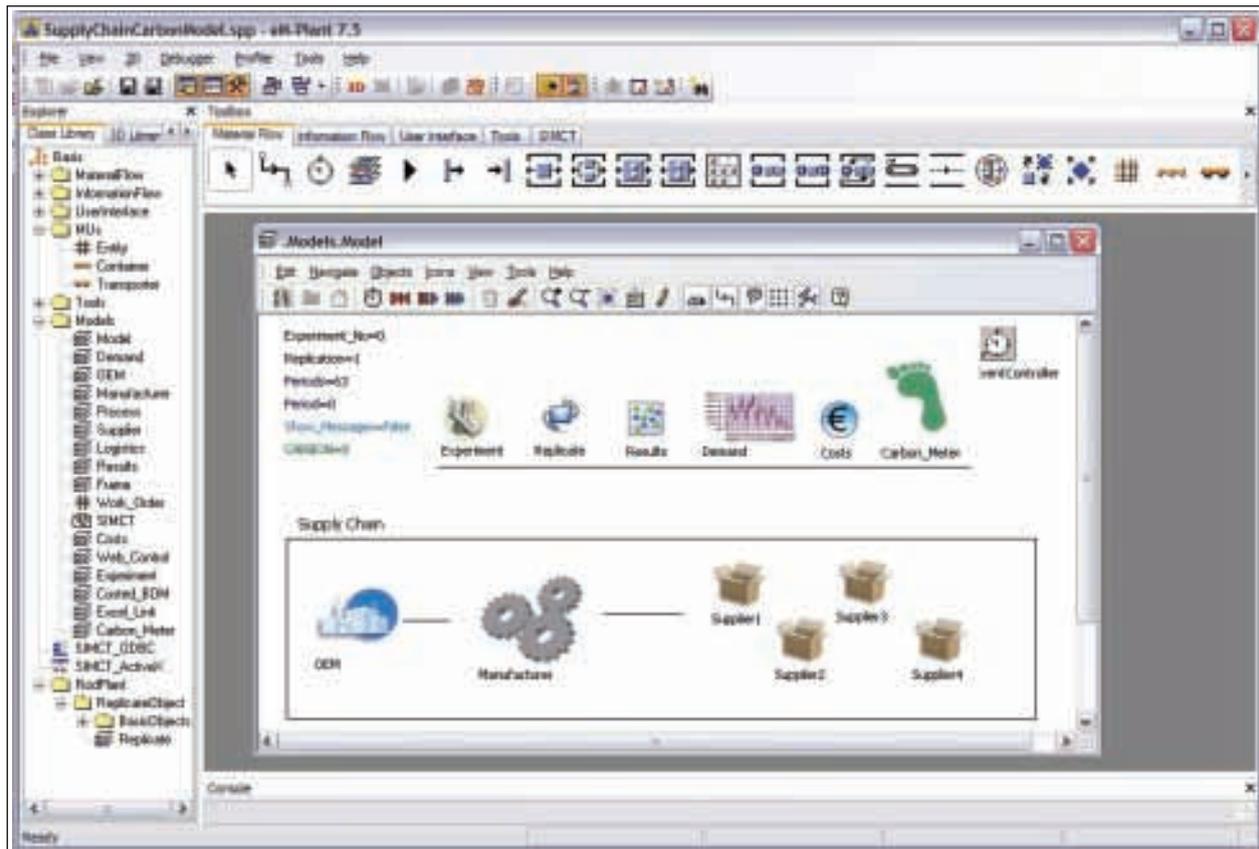
Figure 4.5. The simulation model.

inputs for the manufacturer, OEM and the four supplier nodes are provided in Figure 4.6.

The following six experiments are based on two factors: purchase-order batch size and transport vehicle type. Two levels are used for batch size: the first is based on MRP-driven purchase orders which follow JIT principles, and the second is based on ordering material to fully utilise the transport vehicle. For the transport vehicle factor there are three levels; van, rigid truck and articulated lorry (each sized according to Table 4.1). Specifically, the experiments are as follows:

1   JIT-based batch sizes are used and goods are only transported by van.

2   JIT-based batch sizes are used and goods are only transported by rigid truck.

3   JIT-based batch sizes are used and goods are only transported by articulated lorry.

4   Batch sizes are customised for maximum vehicle utilisation and goods are only transported by van.

5   Batch sizes are customised for maximum vehicle utilisation and goods are only transported by rigid truck.

6   Batch sizes are customised for maximum vehicle utilisation and goods are only transported by articulated lorry.

The six model outputs (as noted in Figure 4.3) are presented in the following figures (Figure 4.7 – Figure 4.12). To clarify, the *total cost* is the overall cost per item to the manufacturer of producing and delivering the finished assembly to the OEM. Also, the *logistics costs*, *storage costs* and *carbon output* are average values per individual assembly, while the *on-time delivery* and *vehicle utilisation* metrics are for the entire supply chain over the simulated year. For each model output, the six experiments are presented beside

Manufacturer Variables	Factory 1
Product Name	Gizmo
BOM Complexity	7 Parts
Capacity Constraints	40-hour week
Lead-time Constraints	Part specific
Set-up Costs (€)	100
Production Costs (€)	20
Logistics Costs	See table
Storage Costs (Raw Material)	5€/pallet/week
Storage Costs (Finished Goods)	7€/pallet/week
Production Cycle Times (hrs)	0.0276
Production Set-up Times (hrs)	5
Distance to OEM (km)	75
Units per Pallet	30

Logistics Costs		
Model	Base Cost	Per Pallet Cost
Van	60	25
Rigid Truck	100	30
Articulated Lorry	140	30

OEM Variables	OEM
Product Name	Assembly
Annual Demand Forecast	50000 Gizmos
Contract Flexibility Constraints	See table

Commitment Flexibility Constraints		
Periods to Due Date	Flexibility Upwards	Flexibility Downwards
1	20%	20%
2	40%	40%
3	100%	100%

Supplier Variables	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Product Name	Part A	Part B	Part C	Part D
Products Fabricated	1	1	1	1
Minimum Order Quantity	500	300	450	50
Lead-time (Days)	15	10	8	12
Unit Cost (€)	2.50€	4.00€	4.50€	0.75€
Reorder Policy	MRP	MRP	MRP	MRP
Batch Size	250	50	150	50
Distance to Manufacturer (km)	150	220	90	45
Units per Pallet	50	100	150	200

Figure 4.6. Discrete even simulation (DES) model inputs.

each other in box-plot format. The box plots show the location and spread of results for 30 replications of the simulation sequence and allow the experimental results to be quickly compared.

For the most part, the results are as would intuitively be expected. For instance in Figure 4.8, Experiments 1 and 4 (using only vans for transport) showed the highest logistic costs per item, while Experiment 6
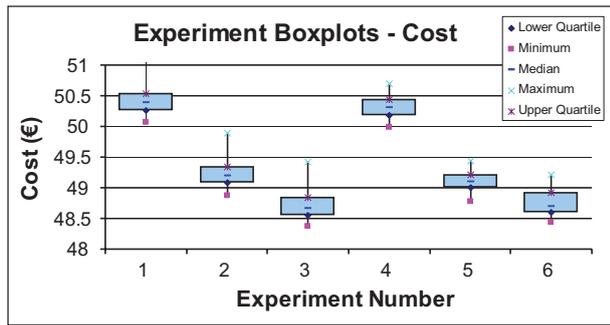
Experiment Boxplots - Cost

Cost (€)

Legend:
- ◆ Lower Quartile
- ■ Minimum
- — Median
- × Maximum
- × Upper Quartile

Experiment Number

Figure 4.7. Results for total cost metric.

Experiment Boxplots - Storage Cost

Cost (€)

Experiment Number
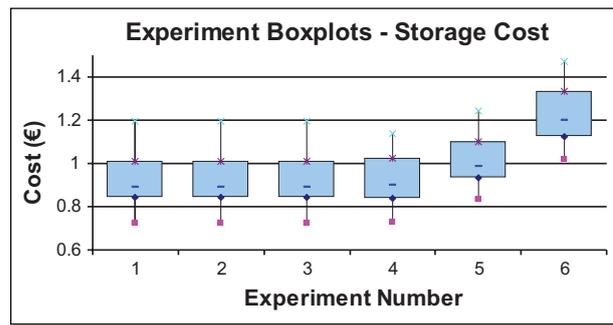
Figure 4.10. Results for storage cost metric.

Experiment Boxplots - Logistics Cost

Cost (€)

Experiment Number
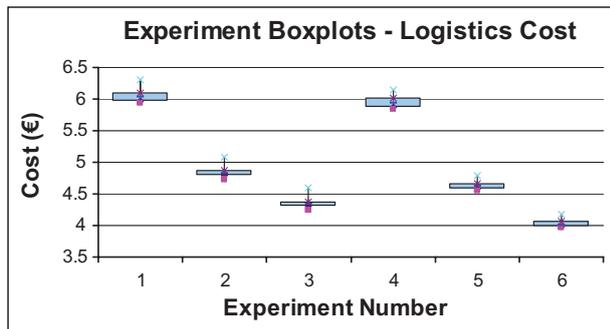
Figure 4.8. Results for logistics cost metric.

Experiment Boxplots - Carbon

CO_2 (kg)

Experiment Number
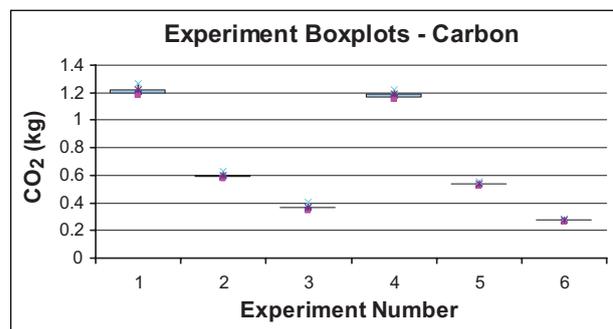
Figure 4.11. Results for carbon output metric.

Experiment Boxplots – On-time Delivery

On time (%)

Experiment Number
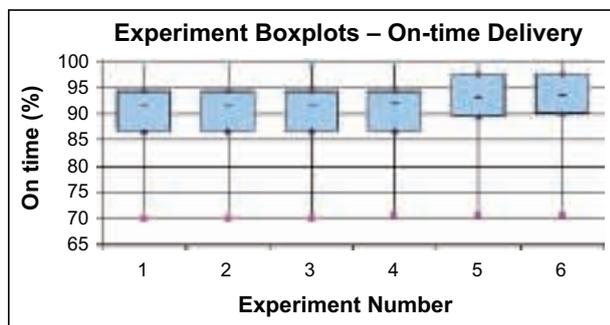
Figure 4.9. Results for on-time delivery metric.

Experiment Boxplots - Vehicle Utilisation

Utilisation (%)

Experiment Number
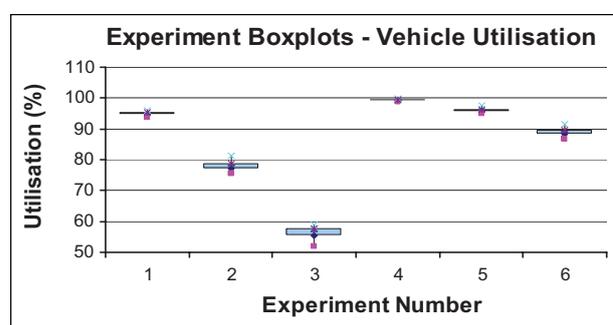
Figure 4.12. Results for vehicle utilisation metric.

(using fully loaded lorries to transport goods) showed the lowest. Similarly in Figure 4.10, Experiment 6 yielded the highest storage costs by far; while this is a logical consequence of purchasing larger quantities of components that have to be held in storage until consumed by the production process, the financial impact would be difficult to quantify without this type of dynamic analysis.

Figure 4.9 shows the results for the percentage of goods delivered on time at the OEM. Not only does this metric give an indication of customer satisfaction

but many supply-chain contracts specify that the manufacturer must pay penalties for late deliveries; therefore it is important to include this performance metric in the analysis.

The carbon output results in Figure 4.11 confirm that smaller vehicles moving at greater frequencies create a greater carbon output per product. The adverse effects of JIT production may not appear as pronounced as one would initially expect, but, as the values shown are per item produced, the cumulative effect over time would be substantial.

Interestingly, the trade-off between cost and carbon output for Experiments 3 and 6 showed that, for similar cost, significantly lower carbon output could be achieved with Experiment 6. This is an example of how the trade-off between financial and environmental metrics is not always initially clear. In this case, the similarity in total-cost results for Experiments 3 and 6 is owing to the higher logistic cost for Experiment 3 being offset by lower storage costs; showing that the balance could easily shift if transportation costs were to rise. In the light of recent fluctuations in fuel costs, it is clear that optimal supply-chain design can be quickly distorted by changes in road-haulage activity and this should be considered in supply-chain management analyses.

4.4   Conclusions

The above study presented a methodology for the analysis of supply chains that allows for the environmental impact, service level and cost trade-off of different operational strategies to be ascertained. While the experiments presented are case specific and therefore limited, conclusions can be made and two general results can be drawn from the study. First they show that there is a high correlation between total cost per product and carbon output per product, which, as the results from the survey from Section 2 show, seems to be misunderstood by some practitioners. Secondly the results show that larger freight vehicles, even if not fully utilised, give lower carbon output and lower costs than smaller freight vehicles.

Using the analysis framework presented, quantitatively backed guidelines for practitioners in operating supply chains in a more sustainable manner can be provided. Finally, the framework has a role when combined with more standard LCA methods in providing decision support in designing and operating more sustainable supply chains.

5.   Conclusions

The survey shows that no company is currently measuring the environmental impact of their logistic operations. However, it does show that there is some awareness of environmental issues as indicated by a number of the companies' future plans to measure their carbon footprint. This, it is felt, indicates that the sector would be responsive to engagement in a programme for the development of sustainable practices. However, the fragmentation evident in the sector as a result of the high level of outsourcing practices is seen as a major barrier that would need to be overcome. Strategies that could be leveraged to increase environmental sustainability of the sector are wider adoption of ICT and increased collaborations, either among common parties in the sector (i.e. LSPs) and/or across different parties that exist along the supply chain.

It is clear from the analysis of the standards, methodologies and tools that general environmental awareness has grown considerably in the last few years. As a consequence of this rapid growth, a number of parallel streams of work have taken place in the development of standards and methodologies to determine the environmental impact of business activity. Two dominant standards have emerged for EMSs: the ISO 14000/4 and the PAS 2050. In relation to carbon conversion factors and carbon accounting tools, less consensus has been reached. At present many carbon accounting mechanisms are used, and in some cases the results from these different mechanisms are in contradiction of each other. Within the last 1–2 years several new toolsets have been brought to the market to address environmental management of supply chains. The efficacy of these toolsets is difficult to assess without detailed access to the tools. Being commercial products and with these tools being very recently introduced into the market, this was not possible in this study. For supply-chain management there are many companies offering software solutions and services. These companies are well placed to develop environmental management additions to their current offerings. However, not withstanding this, it is felt that there are opportunities for companies in Ireland to develop new innovative software and service offerings in this sector.

The quantitative-analysis study, while being case specific, did provide insight into the trade-off between environmental impacts, cost and service level in a realistic supply-chain setting. As cost reduction will be a prime motivator for companies in implementing more sustainable approaches, increased understanding of their effect in lowering costs in supply-chain management will help achieve increased take-up by industry. There is scope for further research on this topic.

5.1   General Recommendations

As has been outlined throughout this report and in the conclusions above, the area of supply chain and its interactions with the environment is continuing to grow at an exceptional rate. Organisations, researchers and practitioners are investing large sums of time, money and effort towards environmentally friendly deliverance of products and services. The deliverance of these products and services is encapsulated in ever evolving supply chains, which continue to grow in complexity. This change provides both opportunities and threats. For Ireland, as a country, to remain competitive in an international market, it needs to embrace this change, particularly with respect to environmental supply-chain management.

This study and report focused particularly on the operational elements of the transport sector in Irish-based supply chains. From this study and report it is clear that Ireland's policy makers need to address a number of key areas that will have a significant bearing on the competitiveness of Irish supply chains in the future. These areas are being driven by both changing consumer patterns and legislative requirements. With these points in mind, the following recommendations have been formulated from this study:

1   First and foremost, environmental supply-chain monitoring and analysis is continuing to grow at an extraordinary pace. This can be seen from the number of large-scale research works that are being carried out in this area at an EU level, and the number and scale of large organisations which are carrying out related initiatives. This report deals with only one distinct theme in this topic area, but there are many more that are of relevance to Ireland as a trading nation. There is scope within Ireland for job creation in developing new software solutions and service offerings in this sector.

    Recommendation: Investment by funding bodies in capacity building in the area of environmental supply-chain monitoring and analysis.

2   It is clear from this study that many organisations have little or no awareness of environmental issues with respect to the operations of the logistical elements of their supply chains and beyond. What is slightly more worrying is the lack of motivation for such organisations (particularly SMEs) to embrace environmental issues in the supply-chain domain. Ultimately, organisations that do not embrace such business evolution will find it difficult to remain competitive in the longer term.

Recommendation: Provision of funding for the development of industrial awareness campaigns in the environmental aspects of modern business.

2   The survey carried out as part of this study identified the lack of co-ordination with respect to logistical practices in Irish supply chains. These findings relate to both logistical service providers and their customers. This is an area which is further developed in both the UK and mainland Europe, particularly with respect to issues surrounding empty hauling.

    Recommendation: Provision of support in the development of more coordinated networks, particularly with respect to logistic provision and consumption.

3   As the majority of businesses are designed around the concept of profit making, it is important that the economic cost of environmental solutions is not ignored. Organisations must remain competitive in the marketplace, and the environmental aspect is only one variable in the larger profit-making equation. There is still an uncertainty as to the cost of operating in an environmental friendly fashion and the economic benefits of doing so. The instances where this issue has been addressed are limited and in many cases are based on underlying assumptions, such as static supply chains. This work is not unique to Ireland, but a better understanding of the economic versus environmental trade-offs must be undertaken.

    Recommendation: Provision of research funding into the further evaluation of environmental versus economic trade-offs in supply-chain design and operation.

References

Atmosphere, Climate and Environment Information Programme (ACE) (2004), Brundtland Report, Available from: www.ace.mmu.ac.uk/eae/Sustainability/Older/Brundtland_Report.html, Accessed on 03-04-2008.

Aravo (2009), Aravo Solutions – Aravo Sustain, Available from: www.aravo.com/solutions/sustain.html, Accessed on 24-04-2009.

Barrat, M. (2004), Understanding the meaning of collaboration in the supply chain. *Supply Chain Management: An International Journal,* 9, 30–42.

BearingPoint (2008), 2008 Supply Chain Monitor 'How Mature is the Green Supply Chain?', Available from: www.supplychainstandard.com/Articles/1403/BearingPoint+-+2008+Supply+Chain+Monitor+'How+mature+is+the+Green+Supply.html, Accessed on 29-08-2008.

Business in the Community (BITC) (2009), Corporate Social Responsibility for SMEs, Business in the Community – Ireland, Available from: www.bitc.ie/corporate_responsibility/index.html, Accessed on 16-03-2009.

Braithwaite, A. and Knivett, D. (2008), Evaluating a Supply Chain's Carbon Footprint – A Methodology and Case Example of Carbon-to-Serve, Available from: www.lcpconsulting.com/pages/about/logistics_research_network_lrn_299.html, Accessed on 05/12/2008.

British Standards Institute (BSI) (2008), PAS 2050: 2008 Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services, British Standards Institution, Available from: www.bsigroup.com/en/Standards-and-Publications/Industry-Sectors/Energy/PAS-2050/, Accessed on 13-12-2008.

Byrne, P.J., Liston, P. and Heavey, C. (2008), Supply Chain Design – In an Outsourcing World. In Dwivedi, A. and Butcher, T. (Eds) *Supply Chain Management and Knowledge Management – Integrating Critical Perspectives in Theory and Practice.* Palgrave Macmillan.

Carbon Trust (2006), Carbon Footprints in the Supply Chain: The Next Step for Business, Available from: www.carbontrust.co.uk/publications/publicationdetail?productid=ctc616, Accessed on 15-05-2008.

Carbon Trust (2007), Carbon Footprinting – An Introduction for Organisations, Available from: www.carbontrust.co.uk/publications/publicationdetail?productid=CTL004, Accessed on 24-04-2008.

Carbon Trust (2008), Product Carbon Footprinting: The New Business Opportunity, Available from: www.carbontrust.co.uk/publications/publicationdetail?productid=CTC744.

Choy, K.L., Lee, W.B., Lo, V. (2004), An enterprise collaborative management system – A case of supplier relationship management. *Journal of Enterprise Information Management,* 17, 191–207.

Christopher, M. (1998), *Logistics and Supply Chain Management,* London, FT Prentice Hall.

CleanMetrics (2009), CleanMetrics Products, Available from: www.cleanmetrics.com/html/seat.htm, Accessed on 01-Feb-09.

Comhar (2008), Freight Transport Policy Seminar Report, Comhar – Sustainable Development Council, Available from: www.comharsdc.ie/themes/index.aspx?TAuto=7, Accessed on 18-02-2009.

Central Statistics Office (CSO) (2007), Road Freight Transport Survey 2006, Government of Ireland, Available from: www.cso.ie/releasespublications/pr_transport.htm, Accessed on 17-02-2009.

Department for Environment, Food and Rural Affairs (DEFRA) (2005), Guidelines for Company Reporting on Greenhouse Gas Emissions, UK Department for Environment Food and Rural Affairs, Available from: www.defra.gov.uk/environment/business/reporting/index.htm, Accessed on 11-09-2007.

Department of the Environment, Heritage and Local Government Ireland (2007), *National Climate Change Strategy*, Available from: www.environ.ie/en/PublicationsDocuments/FileDownLoad,1861,en.pdf, Accessed on 26-01-09.

Department of Transport Ireland (2008), *2020 Vision – Sustainable Travel and Transport: Public Consultation Document*, Available from: www.sustainabletravel.ie/download/1/874_2020_STTPC_DoT.pdf, Accessed on 18-02-2009.

European Environment Agency (EEA) (2006), Greenhouse Gas Emissions Trends and Kyoto Protocol Targets for 2008–2012, Available from: www.eea.europa.eu/pressroom/newsreleases/GHG2006-en, Accessed on 23-10-2006.

European Environment Agency (EEA) (2009), Transport at a Crossroads, Available from: www.eea.europa.eu/publications/transport-at-a-crossroads, Accessed on 01-04-2009.

European Environmental Bureau (EEB) (2003), *ANEC/EEB Position Paper on Environmental Management System Standards*, European Environmental Bureau, Available from: www.eeb.org/activities/standardisation/ANEC-EEB-paper-on-EMS-Feb2003.pdf, Accessed on 03-04-2009.

Elcock, D. (2007), *Life-Cycle Thinking for the Oil and Gas Exploration and Production Industry*, Argonne National Laboratory, Available from: www.evs.anl.gov/pub/doc/LCA_final_report.pdf, Accessed on 23-06-2008.

Environmental Protection Agency (EPA) (2006a), The Greenhouse Gas Effect, Available from: http://epa.gov/climatechange/kids/greenhouse.html, Accessed on 11-09-2008.

Environmental Protection Agency (EPA) (2007), Irelands Greenhouse Gas Emissions Provisional Estimate for 2005, Available from: www.epa.ie/environment/climate/ghg/, Accessed on 19-2-2007.

Environmental Protection Agency (EPA) (2008), Irelands Greenhouse Gas Emissions in 2007, Available from: www.epa.ie/downloads/pubs/air/airemissions/name,25283,en.html, Accessed on 12-11-2008.

Europa (2002), The Kyoto Protocol and Climate Change – Background Information, Available from: http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/02/120&format=HTML&aged=0&language=EN&guiLanguage=en, Accessed on 12-12-2006.

European Commission (2007), Introduction to LCA, Available from: http://lca.jrc.ec.europa.eu/lcainfohub/introduction.vm, Accessed on 03-04-2008.

European Commission (2008), SME Definition, Available from: http://ec.europa.eu/enterprise/enterprise_policy/sme_definition/index_en.htm, Accessed on 10-07-2008.

Eyefortransport (2008), Summary and Analysis of Eyefortransport's European Survey: 'Green Transport and Logistics', Available from: www.greenlogisticsforum.com/europe/free_report.shtml, Accessed on 17-02-2009.

Global Development Research Centre (GDRC) (2009), Life Cycle Analysis and Assessment, the Global Development Research Center, Available from: www.gdrc.org/uem/lca/lca-for-cities.html, Accessed on 24-04-2009.

Huang, G.Q., Lau, J.S.K. and Mak, K.L. (2003), The impacts of sharing production information on supply chain dynamics: a review of the literature. *International Journal of Production Research,* 41, 1483–1517.

Huber, B. and Sweeney, E. (2007), The need for wider supply chain management adoption: Empirical results from Ireland. *Supply Chain Management: An International Journal,* 12, 245–248.

IBM (2009), IBM Tool Boosts Green Supply Chain, Available from: www.ibm.com/news/ie/en/2009/01/26/u862440c66188x81.html, Accessed on 24-04-2009.

ILOG (2009), ILOG LogicNet Plus Carbon Footprint Extension, Available from: www.ilog.com/products/logicnet-plus-xe/carbon-footprint/, Accessed on 24-04-2009.

InterTradeIreland (2008), Freight Transport Report for the Island of Ireland, Available from: www.intertradeireland.com/module.cfm/opt/29/area/Publications/page/Publications/, Accessed on 13-10-2008.

Kewill (2008), Logistics and Transport Industry Environmental Survey, Transport Intelligence, Available from: www.supplychainstandard.com/liChannelID/16/Articles/1876/ Kewill+Green+Logistics+Survey.html, Accessed on 16-02-2009.

Larson, P. D. and Gammelgaard, B. (2001), Logistics in Denmark: A survey of the industry. *International Journal of Logistics Research and Applications,* 4, 191–206.

Liston, P., Byrne, J., Byrne, P.J. and Heavey, C. (2007), Contract costing in outsourcing enterprises: Exploring the benefits of discrete-event simulation. *International Journal of Production Economics,* 110, 97–114.

Mason, R. and Lalwani, C. (2004), Integrating Transportation into the Supply Chain to Improve Supply Chain Performance. In proceedings of 9th Annual Logistics Research Network Conference, Quinn School of Business, University College Dublin, 9–10 September 2004, 370–378.

Mason, R. and Lalwani, C. (2005), Alternative Models for Collaboration in Transport Optimisation Management. In proceedings of 10th International Symposium on Logistics, Lisbon, Portugal, 269–276.

Mason, R. and Lalwani, C. (2006), Transport integration tools for supply chain management. *International Journal of Logistics; Research and Applications,* 9, 57–74.

McElwain, L. and Sweeney, J. (2006), *Implications of the EU Climate Protection Target for Ireland*, Available from: www.epa.ie/downloads/pubs/research/climate/erc%20report%205.pdf, Accessed on 19-2-2007.

National Standards Authority of Ireland (NSAI) (2009), ISO 14001 – Environmental Management Systems, Available from: www.nsai.ie/index.cfm/area/page/information/ISO14001EMS, Accessed on 24-02-2009.

O'Regan, B. and Moles, R. (2009), *Establishing an Eco-Industrial Network for SMEs in the Mid-West Region*, EPA Ireland, Available from: www.epa.ie/downloads/pubs/research/econ/STRIVE_19_ORegan_SME_syn_web.pdf, Accessed on 24-April-2009.

Potter, A. and Lalwani, C. (2005), *Supply Chain Dynamics and Transport Management: A Review*. CUIMRC Working Paper Series No. 014. Cardiff Business School.

Ryan, P., Dundon, T., Byrne, E. and Shovlin, S. (2003), *Branch Report for the Road Transport Sector in Ireland*, NUI Galway, Available from: www.fr.eurofound.eu.int/ewco/employment/documents/RoadIreland.doc, Accessed on 13-3-2007.

Schaltegger, S., Burritt, R. and Petersen, H. (2003), *An Introduction to Corporate Environmental Management: Striving for Sustainability,* Sheffield, Greenleaf Publishing.

Srivastava, S. K. (2008), Green supply chain management: A state of the art review. *International Journal of Management Reviews,* 9, 53–80.

Stern, N. (2006), The Economics of Climate Change, HM Treasury, Available from: www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm.

Sweeney, E., Wagner, C.-M. and Huber, B. (2008), Supply chain management diffusion among firms in the Republic of Ireland *International Journal of Logistics Research and Applications,* 11, 347–358.

Tenekcioglu, G. (2004), Increasing Intermodal Transportation in Europe through Realising the Value of Short Sea Shipping. Masters thesis submitted to the Department of Ocean Engineering. Massachusetts Institute of Technology.

The Greenhouse Gas Protocol Initiative (2008), Calculation Tools, Available from: www.ghgprotocol.org/calculation-tools, Accessed on 12-03-2009.

Van Hoek, R. I. (2001), The rediscovery of postponement a literature review and directions for research. *Journal of Operations Management,* 19, 161–184.

Zhu, Q., Sarkis, J. and Lai, K.-h. (2008), Confirmation of a measurement model for green supply chain management practices implementation. *International Journal of Production Economics,* 111, 261–273.

Acronyms

BSI	British Standards Institution
CM	contract manufacturer
CSO	Central Statistics Office
DEFRA	Department for Environment, Food and Rural Affairs
DES	discrete event simulation
EDI	electronic data interchange
EEA	European Environment Agency
EEB	European Environmental Bureau
EMAS	Eco-Management and Audit Scheme
EMS	environmental management system
EPA	Environmental Protection Agency
ERP	enterprise requirements planning
GDRC	Global Development Research Centre
GHG	greenhouse gas
ICT	information and communication technology
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JIT	just-in-time
LCA	life cycle assessment/analysis
LSP	logistics service provider
MRP	material requirements planning
NSAI	National Standards Authority of Ireland
OEM	original equipment manufacturer
SCM	supply-chain management
SEAT	Supply Chain Environmental Analysis/Optimisation Tool
SME	small-to-medium sized enterprise

SNOW   Supply Chain Network Optimisation Workbench

SRM   supplier relationship management

UNFCCC   United Nations Framework Convention on Climate Change

Appendix A: Sustainable Logistics Questionnaire

1	Company Information		
1.1	**Company Name**		
1.2	**Annual Turnover**		
	< €250K		
	€250K - €500K		
	€501K - €1M		
	€1+M - €5M		
	€5+M - €20M		
	€20+M - €50M		
	€50+M - €100M		
	€100M +		
1.3	**No. of Employees**		
	< 10		
	10 – 25		
	26 – 50		
	51 – 100		
	101 – 250		
	250+		
1.4	**Year Established**		
	Pre 1950		
	1950 – 1970		
	1971 - 1985		
	1986 – 1995		
	1996 - 2005		
	Post 2005		
1.5	**Contact Name**		
1.6	**Contact Email**		
1.7	**Contact Job Title**		
1.8	**Contact Phone No.**		
1.9	**Remain Anonymous**	Yes	No
1.10	**Request results of Questionnaire**	Yes	No
1.11	**As a company, are you making an effort to carbon reduction**	Yes	No

1.14	Please indicate your company's sector	(please tick box)
	Agriculture / Construction	
	Clothing / Textiles	
	Electronic Component Manufacturing	
	General Engineering	
	Food / Drink	
	Manufacturing	
	Pharmaceuticals and Chemicals	
	Plastics / Process Engineering	
	Print and Packaging	
	Transport and Warehousing	
	Software and Consultancy	
	Other;	

2	General Logistics Information		
2.2	Does your company currently work with a Logistic Service Provider (LSP), and or Outsource any of your logistic services? *(if No go to question 2.6)*	Yes	No
2.3	If Yes, how many LSPs does your company currently work with?		
2.4	Please rate your satisfaction with your company's current outsourced Logistics Service Provider(s)		

```
        0         1         2         3         4
        |         |         |         |         |

      Very    Un-satisfied    No      Satisfied   Very Satisfied
  Un-Satisfied              Opinion
```

2.5	Which (if any) of the following activities does your company outsource to a LSP?	
	Transportation of Full Loads	
	Transportation of Partial Loads	
	Warehousing	
	Cross-Docking	
	Air freight Forwarding	
	Ocean Freight Forwarding – Full Container Loads	
	Ocean Freight Forwarding – Consolidation Services	
	Returns Management	
	Hazerdous transport	
	Temperature Controlled Transport	
	Documentation / Invoicing	
	Purchasing / Procurement	
	Product or Component Assembly	
	Pick Pack Knitting	
	Labelling	
	Testing / Quality Control	
	Other;	

2.6	When did your company last review its logistic costs / operations?		
	Up to 1 Month ago		
	Between 1 and up to 3 Months ago		
	Between 3 and up to 6 Months ago		
	Between 6 Months and up to 1 Year ago		
	Between 1 and up to 3 Years ago		
	3 and more Years ago		
	Never;		
2.7	How often does your company review its logistic costs / operations?		
	On-going		
	Every 3 Months		
	Every 6 Months		
	Every Year		
	Every 3 Years		
	Every 5 Years		
	Never;		
2.8	How are your company's logistics costs rates calculated?		
	Per case/tonne	Yes	No
	Per Journey	Yes	No
	% of Sales	Yes	No
	Other please specify;		
2.9	Does your company use any form of Information Communication Technology (ICT) in its logistics operations?	Yes	No
	If Yes, please state;		
	Vehicle Routing Systems		
	Transport Planning Tools		
	GPS/ Satellite Navigation Systems		
	In-Cab Communication systems		
	SMS Alerts		
	Fleet Monitoring / Tracking systems		
	Web Track and Trace of Consignments		
	Electronic Proof of Delivery Systems (e-PoD)		
	Distribution Network Optimisation		

3	Supplier information					
3.1	By what method are your company's orders usually placed? (and please estimate, in percentage, the distribution of orders placed) *(i.e if most orders are by phone but some by e-mail then you could possibly answer phone 80%; email 20%)*	%				
		<20	20-40	41-60	61-80	81-100
	Phone					
	Fax					
	E-Mail					
	Mail					
	Internet					
	EDI (Electronic Data Interchange					
	Other; Please specify?					
3.2	Does your company use any form of Supplier	Yes		No		

Question 3.4 is looking for information from the vehicles carrying supplies from your suppliers to your company, where they are generally coming from and their typical fill rate on entering the company. Question 3.5 concerns the same vehicles fill rate on leaving the company.

3.3	Of your suppliers, please state how many are located in each region; and please estimate the average the fill percentage *(relative to max weight or dimension of vehicle used)* of the delivery vehicles on entry?						
	i.e. please try to estimate the average empty fill of inbound vehicles	No. in Location	% fill rate of vehicle used				
			<20	20-40	41-60	61-80	81-100
	Local < 100km						
	National (within the Island of Ireland)						
	Western Europe						
	Eastern Europe						
	Americas (North and South)						
	Western Asia						
	Eastern Asia						
	Other;						
3.4	Please estimate the average level of fill *(relative to max weight or dimension of vehicle used)* of the same supply vehicles on leaving your company?						
	0-20%						
	21-40%						
	41-60%						
	61-80%						
	81-100%						

4	Warehousing Information		
4.1	Has company warehousing space decreased in recent years (5 – 10) due to utilisation of Lean manufacturing techniques?	Yes	No
	(comments)		
4.2	Does your company utilise RFID (Radio Frequency Identification) for product management	Yes	No

5	Customer Ordering Information					
5.1	By what method are your company's orders usually received? (and please estimate, in percentage, the distribution of orders received)	%				
		<20	21-40	41-60	61-80	81-100
	Phone					
	Fax					
	E-mail					
	Mail					
	Internet					
	EDI (Electronic Data Interchange)					
	Other;					
5.2	Does your company use any form of Customer Relationships Management (CRM) Tool	Yes		No		

Question 5.3 is looking for information from the vehicles carrying products from your company to your customers; where your customers at generally located, and their typical fill rate on leaving your company. Question 5.4 concerns the <u>same</u> vehicles fill rates as they <u>enter</u> your company.

5.3	Of your customers, please state how many are located in each region and estimate the average the fill percentage (*relative to max weight or dimension of vehicle used*) of the delivery vehicles on leaving your company?						
	i.e. please try to estimate the average fill of <u>outbound</u> vehicles	No. in Location	% fill rate of vehicle used				
			<20	20-40	41-60	61-80	81-100
	Local < 100km						
	National (within the Island of Ireland)						
	Western Europe						
	Eastern Europe						
	Americas (North and South)						
	Western Asia						
	Eastern Asia						
	Other;						
	Please estimate the average level of fill (*relative to max weight or dimension of vehicle used*) of <u>the same</u> vehicles on <u>entering</u> your company?						
	0-20%						
	21-40%						
	41-60%						
	61-80%						
	81-100%						

6	**Environmental Awareness**				
6.1	**Does your company's have a system for acquiring Backloads on shipments?**	Yes		No	
	(Comments)				
6.2	**Is your company involved in any collaborative / shared transport relationships with other suppliers / customers / companies?**	Yes		No	
6.3	**If no, would your company ever consider using shared transportation networks, even if it meant,,**				
	Other companies have knowledge of your level of goods transportation		Yes		No
	Some orders inbound from suppliers may be slightly delayed (< 1 day)		Yes		No
	Some orders outbound to customers may be slightly delayed (< 1 day)		Yes		No
6.4	**Are any of your company's <u>inbound</u> or <u>outbound</u> shipments ever consolidated? (i.e. mixing products to create fuller vehicle loads)**		Yes		No
6.5	**Are <u>Reverse Logistics</u> networks utilised in your company's supply chain decisions? (e.g. return of used/ defective products or goods)**		Yes		No
6.6	**In your opinion has your company's transport efficiency improved in the last…**				
	6 months		Yes		No
	1 year		Yes		No
	5 years		Yes		No
	10 years		Yes		No
6.7	**Does your company have the facility to assign different vehicles to different operations to carry out specific functions?** *(i.e. using a small van for a small load rather than a large van for a small load)*		Yes		No
6.8	**Are your company's vehicles specially designed to accommodate for the maximum utilisation of space for the products to be transported?**		Yes		No
6.9	**Does your company have bonus schemes for drivers who use the least amount of fuel over specified journeys?**		Yes		No

7	**Environmental Changes**		
7.1	Does your company have an environmental officer	Yes	No
7.2	If Yes, are they involved in any supply chain decisions	Yes	No
7.3	Has your Company ever measured its Carbon Footprint	Yes	No
7.4	Has your company implemented ISO14001?	Yes	No
7.5	If No, Does your company have any future plans to measure its Carbon Footprint, in the next….,		
	6 months	Yes	No
	1 year	Yes	No
	3 years	Yes	No
	5 years	Yes	No
	Not in Future Plans	Yes	No
7.6	Does your company have a means of <u>calculating</u> its Carbon Footprint?	Yes	No
7.7	Does your company have a means of <u>examining</u> its Carbon Footprint?	Yes	No
7.8	Does your company ever employ methods to <u>minimise</u> its carbon Footprint?	Yes	No
7.9	Would your company consider using a Logistics Service Provider that proved to be more environmentally sustainable over it compeditors, and provided equal price? 0 — Always use "Greener" Company 1 — Consider using "Greener" Company 2 — Maybe Use "Greener" Company 3 — Never Utilise this in decision making 4 — No Opinion		
7.10	Would your company consider using a Logistics service provider that proved to be more environmentally sustainable over it compeditors, but cost 5% more to use? 0 — Always use "Greener" Company 1 — Consider using "Greener" Company 2 — Maybe Use "Greener" Company 3 — Maybe use if more expensive 4 — Never use if more expensive		

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil agus Rialtais Áitiúil a dhéanann urraíocht uirthi.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail.
- Scardadh dramhuisce

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

Science, Technology, Research and Innovation for the Environment (STRIVE) 2007-2013

The Science, Technology, Research and Innovation for the Environment (STRIVE) programme covers the period 2007 to 2013.

The programme comprises three key measures: Sustainable Development, Cleaner Production and Environmental Technologies, and A Healthy Environment; together with two supporting measures: EPA Environmental Research Centre (ERC) and Capacity & Capability Building. The seven principal thematic areas for the programme are Climate Change; Waste, Resource Management and Chemicals; Water Quality and the Aquatic Environment; Air Quality, Atmospheric Deposition and Noise; Impacts on Biodiversity; Soils and Land-use; and Socio-economic Considerations. In addition, other emerging issues will be addressed as the need arises.

The funding for the programme (approximately €100 million) comes from the Environmental Research Sub-Programme of the National Development Plan (NDP), the Inter-Departmental Committee for the Strategy for Science, Technology and Innovation (IDC-SSTI); and EPA core funding and co-funding by economic sectors.

The EPA has a statutory role to co-ordinate environmental research in Ireland and is organising and administering the STRIVE programme on behalf of the Department of the Environment, Heritage and Local Government.

Comhshaol, Oidhreacht agus Rialtas Áitiúil
Environment, Heritage and Local Government