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CO2 REDUCTION INITIATIVES IN LOGISTICS OPERATIONS

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**UNIVERSITY OF
PLYMOUTH**

CO₂ REDUCTION INITIATIVES IN LOGISTICS OPERATIONS

by

MARTINA HANUSKOVA

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in partial fulfilment for the degree of

MASTER OF PHILOSOPHY

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Author's declaration

At no time during the registration for the degree of Master of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

Work submitted for this research degree at University of Plymouth has not formed part of any other degree either at University or at another establishment.

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Martina Hanuskova, 13th April 2021

A handwritten signature in black ink, appearing to be 'MH', is written over a horizontal line.

Signature

Abstract

Martina Hanuskova, CO2 Reduction Initiatives in Logistics Operations

This thesis aims to identify measures or initiatives which are being implemented to reduce carbon emissions within logistics operations. Logistics remains as one of the last sectors with voluntary measures and low regulation of carbon emissions caps. There is a gap in knowledge not only on company size level but also on industry level. Therefore, there is still high need to help companies that are at their starting point, lacking needed technical and human resources. Logistics decarbonisation often remains neglected, not only as a part of manufacturer's company structure but also as main business of logistics service provider or fleet and warehouse owner. Missing understanding of competitive advantage and cost reduction from logistics decarbonisation hinders further positive development. This thesis provides a full guide to this understanding, finding perspective and identifying areas that need optimisation by various measures.

Many authors and organisations have covered some initiatives that can be applied to freight transport on technical and operational level. Transportation measures are prevailing in focus. Warehousing initiatives appeared in few papers, however, not to such extent and transportation. This can be partly reasoned by lower ratio of warehousing impact compared to transportation. However, it should not be neglected. There has also been a low number of literature that combines freight transport and warehousing, from a holistic viewpoint. To fill this gap, findings from literature, which are often practice-oriented are being complemented with findings from surveys and interviews with logistics experts or global manufacturers that are already deeply involved in their logistics decarbonisation projects. At the end, a conceptual model is created, which is then refined by surveys and interviews with practitioners to a framework for decarbonisation.

Resource-Based Theory, and in particular Resource Orchestration theory shows importance of gaining this knowledge by employees. This is particularly challenging for small-medium enterprises who do not have resources and strategic intentions to reduce their logistics carbon emissions. This thesis can be practically applied by manufacturing businesses, as well as fleet owners or forwarders who can focus on adapting their services on initiatives that solve their customer's challenges. This thesis suggests expanding further research on finding best solution for decision makers with not only two, but multiple criteria. An AHP method helps identify these criteria as a suggestion for further research.

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List of Abbreviations

Abbreviation	Meaning
3PL	Third party logistics
AHP	Analytic Hierarchy Process
CNG	Compressed natural gas
CO ₂	Carbon dioxide
CO ₂ e	Carbon dioxide equivalent
CSR	Corporate social responsibility
EC	European Commission
EDI	Electronic data interchange
EEA	European Environmental Agency
ERP	Enterprise resource planning
GHG	Greenhouse gasses
GSCM	Green Supply Chain Management
GWP	Global warming potential
HDV	Heavy duty vehicles
HGV	Heavy goods vehicles
ICT	Information communication technology
IPCC	International Panel on Climate Change
ISO	International Organisation for Standardisation
LCRS	UK Logistics Carbon Reduction Scheme
LNG	Liquified natural gas
LPG	Liquified petroleum gas
LSP	Logistics service provider
NGO	Non-governmental organisation
OEM	Original equipment manufacturer
QESH	Quality, Environment, Occupational Safety and Health
RBT	Resource-Based Theory
ROT	Resource Orchestration Theory
SCM	Supply Chain Management
SFC	Smart Freight Centre
SME	Small-medium enterprise
VRSP	Vehicle routing and scheduling problem
WH	Warehousing, warehouse
WMS	Warehouse management systems

Chapter 1 Introduction

With growing economic prosperity and diminishing trade barriers, movement of cargo increases at significant rates. Producing at low-income economies and transporting goods by container ships and e-commerce push prices of goods to minimum (WTO, 2013). This development would not be possible without complex logistics systems. Unfortunately, with rising prosperity and mass consumption, environmental burden has been put on planet. Therefore, government address these issues by placing various regulations to industries to reduce their impact. However, not all issues are addressed by regulations, therefore companies need to find their own way to act responsibly. Freight transport is the only sector with growing emissions but lacking overall regulation. There are also many inefficiencies in warehousing, connected with wasting of energy in daily operations. Companies that focus on reducing operational costs in logistics in most cases also reduce their environmental footprint and vice versa. Reviving the whole supply chain strategies and processes towards decarbonisation is one of the most efficient ways to cut costs and improve operations of the firm.

1.1 Research Background

The awareness about human impact on climate change gained on importance after findings and scientific measurements in the 1970s. The first report for the UN conference in Stockholm (1972) about human contributions to climate was prepared which concluded that new capacity for global decisions was required (Bolin, 2008). Since then, it also became a political agenda and non-governmental striving. A non-governmental body, International Panel on Climate

Change (IPCC) was created in 1988 to gather the research in the field of climate change. Scientific predictions and calculations brought warnings about the danger of increased warming of the atmosphere and the impact on humans and ecosystems. Many studies of IPCC show, that the largest increase of CO₂ emission in the atmosphere was recorded in 20th century caused by extensive burning of fossil fuels, by energy and transport sector.

In 2015, the United Nations Climate Change Conference held in Paris, lead to a significant move to action in climate change mitigation. 196 countries met and negotiated steps and policies, which were then signed in New York by 174 of them on 22 April 2016. The countries brought proposals of CO₂ emissions reduction targets on national level. 75 % of countries acknowledged transport playing a role in CO₂ reduction (OECD/ITF, 2017). However, the current commitments are still on a trajectory well above the target, at around 3,4 % (UNEP, 2016).

The countries are given yearly emission caps and their industries can either emit the amount that they are allocated or trade the remaining allowances. Nowadays, 85 % of global corporations have some carbon reduction programmes already in place (CDP, 2016). In their newest study, CDP conducted a survey on about 3500 suppliers of their main 89 partner companies. Only 22 % of their supply chain partners work on reducing their emissions as they seem to be lacking processes to decouple emissions from financial growth (CDP, 2017). Therefore, it is up on the global companies to take a leadership role in the industry.

Choice of research topic was initiated by findings in master's thesis of researcher. It studied automotive industry and anchoring of green logistics and KPIs in

company's strategy and long-term contract. Although automotive industry with large logistics capacity requirements and multiple hundreds of sub-suppliers should identify decarbonisation urgency and positives on their supply chain optimisation, only very few measures were undertaken. Modal split and initial CO₂ calculation were included in their measures. On the other hand, their logistics service providers, e.g., Ro-Ro sea freight forwarders were already proactively greening their operations.

In recent years, sustainability reports have become a benchmark of company's health and progress. In sustainability reports, logistics decarbonisation is often just a part of the big picture – economic, social, and environmental aspects. Therefore, it sometimes does not gain the full strategic attention. Companies will be increasingly under external pressure to be able to estimate their entire carbon footprint and set goals and steps to reduce them (Piecyk and Björklund, 2015). In ideal case, managers will accurately measure and reduce their CO₂ emissions to respond to regulations and external pressure and ensure long-term competitiveness. In practice, this is time consuming, and decisions are often met by previous experience.

Transport sector, including movement of passengers and freight, is accounting for 18 % of total global CO₂ emissions, however, emissions of freight transport increase the most of all industries, predicted to grow by 60 % by 2050 (OECD/ITF, 2017). Movement of freight accounted for around 12 % of the global energy consumed, this corresponds to a share of approximately 10 % of energy-related CO₂ worldwide and 53 % of the global oil consumption (IPCC, 2014b). Still, international transport is 92% dependent on fossil fuel combustion.

As the global trade patterns are constantly changing, it will be very hard to calculate and impose CO₂ reduction targets on countries or transport modes. There is a lack of comprehensive and consistent assessments of the worldwide potential for the GHG emission reduction and especially costs of mitigation from the transport sector (IPCC, 2014b).

First major challenge for global decarbonisation will be decoupling of transport activity from CO₂ emissions growth (OECD/ITF, 2019). Total EU land transport emissions increased steadily between 1990s and early 2000s. EU is striving for decoupling of economic and emissions growth. In 2014, greenhouse gas emissions in the EU-28 were down by 22.9 % compared with 1990 levels, putting the EU on track to surpass its 2020 target, which is to reduce GHG emissions by 20 % by 2020 and by 40 % by 2030 compared with 1990 (EEA, 2014). EU has also set binding national targets, depending on the wealth of member country. Transport (excluding aviation) is one of the sectors that will be supported.

Secondly, in developing countries, transport demand will grow with their increasing disposable income (OECD/ITF, 2019). There is some action, even though not very much organised or standardised, already in place, considerable “lack of specific and actionable transport-related mitigation measures” (IEA, 2018). These measures will be needed especially in developing countries, as their share will have the highest increase in international trade growth. Nowadays, added service levels such as recycling and reverse logistics are still offered on a limited scale (Boer, 2014). Governmental regulation and setting goals for logistics sector are coming later than in other sectors, therefore companies already take voluntary actions towards logistics decarbonisation.

Relatively little research has examined the firm-level (especially senior managers' value-based orientation) and has been debated by academics, whether and how firms' adoption of an environmental orientation would enhance their competitiveness (Garza-Reyes, 2015). It is difficult for SMEs with limited resources, to use complex calculations for environmental performance and design and implement improvement strategies (Genovese et al., 2017).

Resource-based theory and more specific, resource-orchestration theory answer this question as manager can enhance the knowledge and later experience of their limited human resources. They will then be able to better utilize their physical and financial resources, reduce emissions and optimise their logistics processes, thus also reduce the total cost of operations.

1.2 Research Aim and Research Objectives

The primary aim of this thesis is to enhance sustainability of small and medium enterprises, or other companies that do not have enough knowledge, financial sources, external support or motivation to start with or continue decarbonisation of their logistics operations. This will be enabled through the application of freight transport and warehousing decarbonisation framework. In the past decade, some corporations were already able to collect suitable knowledge, set strategies and apply their logistics decarbonisation measures. They will be used as a best practice example for the logistics decarbonisation framework.

First objective was to collect knowledge on various initiatives for a conceptual model of logistics decarbonisation measures from literature review. Previous articles and studies have focused on initiatives in detail, mostly on specific

problem or case study for an industry. Although these papers contributed to deeper knowledge of each initiative, they were too narrow in focus. There have been a few conceptual models focusing heavily on transport initiatives. Green warehousing gained less focus than transportation. However, there is a need of holistic concept for the entire logistic system. In the world of complex IT systems and supply chains, it will be necessary to focus not solely only transportation and warehousing, but also their intersection in material flows.

Second objective was to find, in what extend this knowledge is being spread applied by practitioners. The survey of managers attending Green Freight Europe's meeting refined the conceptual model. Empirical research with experienced respondents helps to close gaps between knowledge of academia and business practice. Moreover, knowledge on current business practice brings a realistic viewpoint on how far the technological, economic, and environmental knowledge on these initiatives has been used by market leaders. This helps to form a final framework.

To apply this framework further in practice, company's decarbonisation criteria influence choice of measures found in the model.

1.3 Research Questions

Initial research questions were formed during primary literature review which pointed in direction that there is no summary of all measures that companies can undertake to reduce their logistics carbon emissions.

First question focused on finding the sense for studying this topic in a broader context:

RQ 1: “How big is logistics’ impact on environment and what are the predictions?”

Second question was then split into two sub-sections, as researcher decided to find knowledge in literature as well as current practice:

RQ 2: “Which initiatives are being used by current industry?”

RQ 2.1: “Are there any initiatives, which do not gain much focus in the research?” and

RQ2.2 “Are there any initiatives that do not gain much focus in practice?”

Third question was raised after conducting surveys and interviews, as there was already a body of knowledge in practitioners of large companies. After this body of research, further gap was identified, and thus there are many small-medium enterprises that are not that far in applying these measures.

RQ 3: “How can small and medium enterprises apply their decarbonisation measures and how limited are they?”

After identifying barriers and motivators of SMEs the last questions open a question, what their main criteria for choosing decarbonisation measure are, if they don't have same resources and knowledge as the corporate world.

RQ4: “How do companies decide upon the best suitable measures?”

1.4 Justification

Basing on climate challenges and capabilities of companies dealing with decarbonisation of their supply chains, it is obvious that since many decades, nothing is executed perfectly yet and there are still gaps in knowledge, expertise, resources and helping frameworks.

Tacke et al. (2014) concluded implications for German logistics sector (p. 78):

- The sector should develop a best-practice guide to provide support to companies
- In future, the sector should assess the financial implications of the CO2 initiatives in terms of their payback period
- Logistics service providers need to find an inter-organisational agreement to allow benchmarking of the activities
- Simulation of different scenarios considering trade-offs and different options
- Transparency of sector's periodic initiatives and targets and their compliance with overall global emissions targets

This gap, even for developed country, as Germany, shows the need of having guidance for practitioners (conceptual framework), being able to evaluate and compare given measures and to know which initiatives fit the most crucial criteria.

In this thesis, the problematic is grounded to Resource-based Theory. This theory emphasizes focus on developing knowledge of human resources as competitive advantage compared to companies who consider physical capital and newest

equipment as their advantage as humans can optimise usage of the equipment (Grant, 1991). Moreover, orchestrating resources efficiently brings innovation, and awareness of competitive advantage. Resource orchestration can be used in integrating environmental management into supply chains (Wong et al., 2015) and thus supporting logistics decision making towards strategy of green logistics. This has also been justified by latest research on SMEs in logistics industry, where half of European companies see competitive advantage in their environmental efforts (Toelke and McKinnon, 2021).

1.5 Scope of The Research

This research focuses on a part of the greening strategy of a company – CO2 reduction in logistics and supply chain management. In Chapter 2, these two terms are compared, and researcher's view of these terms is explained. From freight transport, heavy duty vehicles will be mostly examined, while other transport modes as shipping, rail and aviation will be briefly mentioned in the context. This is due to larger proportion of emissions and predicted growth in truck transport compared to other transport modes.

The respondents are mainly from the European area. However, the quality of most of the responses is not influenced by geographical boundaries, as some of the global headquarters are in Europe and the practitioners use company's global sustainability policies. Therefore, their contribution to the knowledge can be to some extent applied globally. Also, the practitioners from Western Europe have more knowledge on the topic. Mostly British, Dutch, Swedish and German practitioners pay attention to this problem. However, the model is constructed in a way, that all companies can use it, in a way it fits their environmental strategy.

The job positions on decarbonizing the logistics have been created only in last decade. Therefore, good quality of responses relates to small number of companies. For small and medium enterprises, it is more difficult to identify to what extent their managers pay attention to their decarbonisation strategies and the level of knowledge on this topic varies. Therefore, respondents from Slovakia were also included in the last questionnaire on multi-decision-making criteria for decarbonisation measures.

As outlined in the second chapter, greenhouse gasses do not stay over the continent but move with the time around the globe. This implies the fact that if one country or company introduces decarbonizing initiatives locally, it contributes to global emissions reduction.

1.6 Method

As business research is generally based on experts' opinions and personal experience, the findings must be supported by various research methods. This thesis uses first survey, to obtain a general picture about the industry and its decarbonisation. Open-ended and multiple-choice questions ask experts about their job position, budget of projects, main drivers and barriers of implementation and knowledge about the benefits of decarbonisation measures they use. This survey helps to complement findings from literature and help the researcher in finding suitable questions for the further methods. In the next stage, researcher uses close-ended questions around decarbonisation initiatives, where respondents answer which initiatives are, they are using currently and which ones they expect to be upcoming within next five years. Therefore, it is possible to

obtain more specific answers and fill in the gap of non-response bias and survey structure of the first survey. As the second questionnaire only names the specific initiatives and asks respondents to name new initiatives that were not mentioned yet, it is not explanatory enough. To enhance the reasoning behind usage of the initiatives, e.g., internal, or external drivers, benefits and future, further in-depth interviews elaborate on chosen measures. To close the loop of applicability on small-medium firms, the main decision-making criteria of choice are explored, to be able to find suggestions for these companies based on large corporation experience and expertise. An example of group multi-decision making evaluated by AHP method is finalising this research.

1.7 Thesis Structure

Content of the thesis was divided into eight main chapters.

Theoretical part (Chapter 2 and 3) starts with bringing focus on climate change and importance of reducing greenhouse gas emissions in logistics for identifying gaps in the logistics processes, cost reduction and anchoring this strategy within Resource-Based Theory and Resource Orchestration Theory in terms of competitiveness enhancement of small-medium enterprises.

Chapter 2 brings a brief introduction into the research topic. The key terms – logistics and supply chain management are defined and their relationship and use of the terms in this thesis are explained. It shows to what proportion logistics, respectively freight transport and warehousing contribute globally and why lately the research on this topic started growing. It depicts a logical flow starting with corporate sustainability and embedding green supply chain management and

importance of conducting life cycle analysis before heading straight into single measures.

Chapter 3 narrows the problem down to practical application of decarbonisation initiatives or measures in logistics and supply chain management which are core of this chapter. Transportation and warehousing initiatives are described and listed in categories. It is also acknowledging, that some small-medium enterprises or industries that find life-cycle analysis as too time-and resource consuming, need better understanding of weight of these measures. This is later compared to findings from initial exploratory survey in further Chapter 5. Concluding the literature review in Chapter 2 and 3, initial conceptual model for logistics decarbonisation initiatives is created that needs to be reviewed by practitioners.

Research methodology part in Chapter 4 justifies the researcher's paradigm and how it depicts ontology, epistemology, and suitable methods choice. Theory underpins the application of research methods on respondents and further steps into analysis. It also links the theoretical findings with the empirical research in Chapters 5 to 7.

Chapter 5 starts with paper-based questionnaire, which is an initial exploratory study of practitioners that have already been involved in their logistics decarbonisations. This underpins the findings of current practice's focus, resources, barriers and motivation and expectations. Later, a more specific web-based survey on each initiative found in the literature follows. It outlines initiatives that are most being used at current practice, as well as expectations within next years.

Chapter 6 further elaborates on the initiatives in detail by knowledge from the current top greenest freight forwarders as well as manufacturer with state-of-the-art sustainable warehouse. They are analysed based on Grounded Theory and reviewed by CSR report. Findings and further suggestions of Chapter 5 and 6 also complement the conceptual model and a decarbonisation framework is finalised in Chapter 8. It is a practicable framework for companies without financial or human resources needed for life-cycle analysis.

Chapter 7 further discusses under which circumstances companies decide to apply these various measures. It completes the framework by finding eight most important criteria to small-medium enterprises, which can guide service providers in strengthening knowledge and portfolio.

Chapter 8 concludes the findings of this research, contribution to theory and its practical implications including comprehensive conceptual framework for decarbonisation initiatives. The suggestions for future research are also proposed. Researcher is aware of their limitations and shortcomings of this thesis are mentioned.

Figure 1-1 shows the deductive logical path of the research. Firstly, literature review is conducted in specific sub-topics, subsequently, its gaps are filled in by questionnaires and interviews. By obtaining full knowledge, conceptual framework is created. At the end, the framework is placed into current problematics of SME's and different criteria of choice based on barriers and drivers.

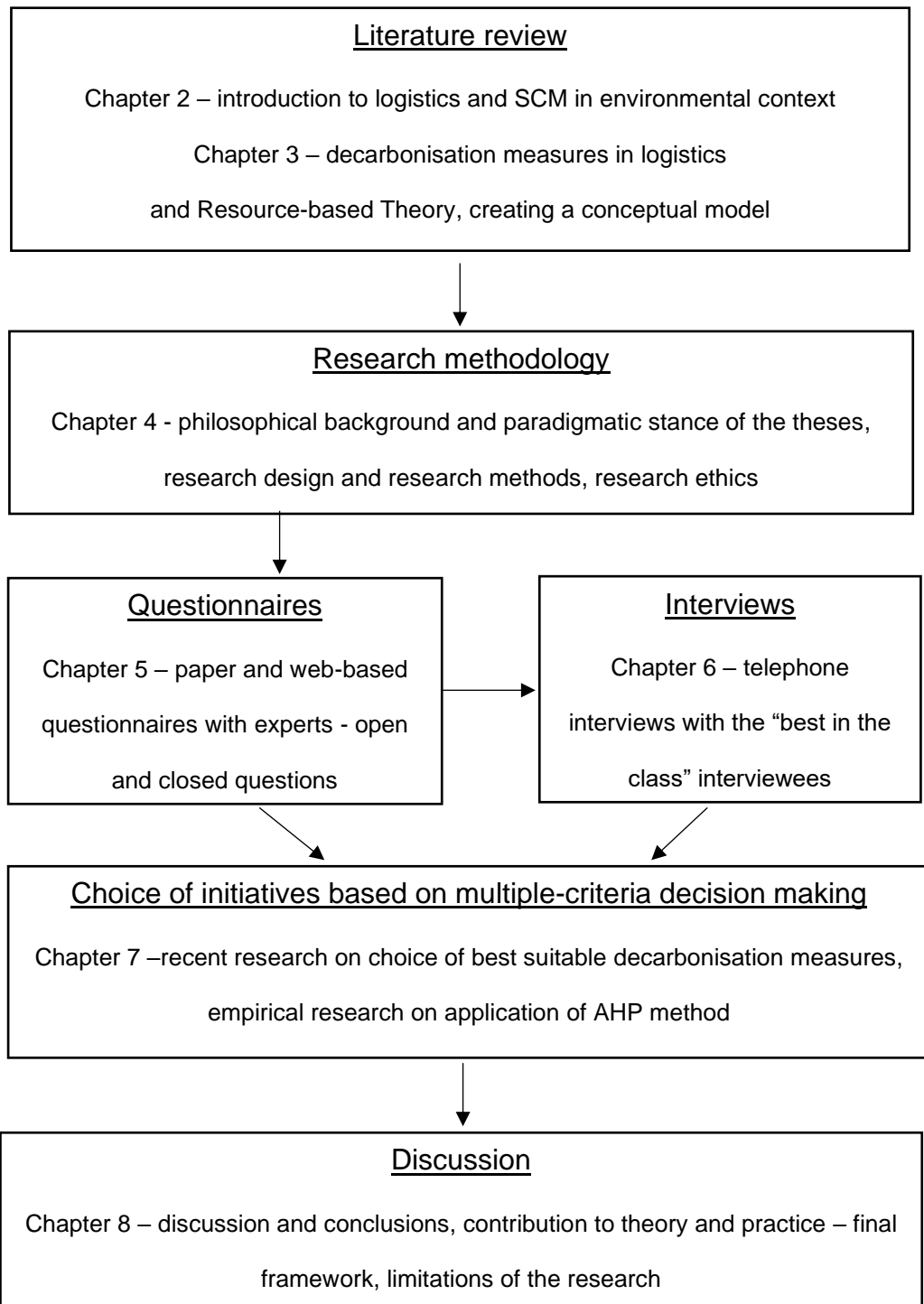


Figure 1-1 Thesis structure and logical path

Source: Author

Chapter 2 Logistics and Climate Change

2.1 Introduction

This chapter aims to explain definitions of terms that will be used throughout this thesis and serves as a theoretical basis for the next chapters. It also helps reader to navigate through further chapters in researcher's viewing of the elements of logistics, supply chains and their impact on climate change.

First part outlines and compares different definitions and perspectives on logistics and supply chain management, describes how they evolved during the time, as the logistics systems and supply chain processes became more complex. It explains all components of logistics that can have interactive purpose with the conceptual framework's elements. Due to improving information technologies, impact of changes on whole material flow needs to be taken into consideration, including purchasing, production, packaging, sales, and reverse logistics. Therefore, a unionist point of view is justified for this thesis.

In the second part of this chapter, one of the environmental externalities of logistics, greenhouse gas pollution and its impact on climate change is explained. This section brings justification of decarbonisation importance.

The third part concludes this chapter with specific contribution of transport and warehousing activities, describes scale and scope of contribution to the climate change to highlight relevance of each part of logistics to the climate change.

2.2 Supply Chain Management and Logistics Understanding

2.2.1 Supply chain management (SCM)

In the early 1990's the term 'supply chain' has started to be widely used in the scientific papers and in the business language. In 1995, on Annual Conference of the Council of Logistics Management, this term was used 13,5% of the articles, whereas in 1997 it rose to 22,4% (Mentzer et al., 2001). In order to satisfy requirements of a customer, whole journey of the product, from materials sourcing until it reached the customer, was examined.

Cooper and Ellram (1993) defined SCM even in scope of philosophy as

*“...an integrated **philosophy** to manage the total flow of a distribution channel from supplier to consumer” (p. 13).*

It lies among fully-vertically-integrated systems, where functions are performed within one company. Each channel member, however, operates fully independently.

In the present, Mangan and Lalwani (2016) understand supply chain as

*“**network** of organisations that are involved, through upstream (supplier to focal firm) and downstream (focal firm to customer) **linkages**, in the different processes and activities” (p. 10).*

Mentzer et al. (2001) classified more than 20 SCM definitions into three categories – direct supply chain (supplier, organization, and customer), extended supply chain (including supplier's suppliers and customer's customers) and ultimate supply chain (adding third party logistics service providers, financial providers, market research firms).

2.2.2 Logistics

In different publications, different understanding of logistics is defined. Therefore, it is necessary to outline it in terms of various definitions, to understand the scope of the logistics can have. The term of logistics has occurred already in articles of the 19th century, connected with military logistics. It gained much attention during the First and Second World War, when moving the troops from one place to another (Lummus et al., 2001). In the late 20th century, with the revolution of electronic data interchange (EDI) the definitions started to appear within the context of business management (Waters, 2003). Definitions found in the main logistics literature are chronologically sorted, the logistics components of the definitions are printed boldly and later discussed.

Similarly, Hoekstra and Romme (1992) see logistics in a manufacturing company as:

*“The organization, planning, implementation and control of the **procurement, movement and storage** activities from the initial exploitation of **raw materials** up to and including deliveries of **finished products** to customer.” (p. 152)*

Lambert et al. (1998) in their book on logistic management write that it is

*“...the **process of planning, implementing, and controlling** the efficient, effective **flow and storage** of goods, services and related information **from point of origin to the point of consumption** for the purpose of conforming to customer requirements.” (p. 3)*

Waters (2003) defines logistics as integration along supply chain management or

*“...a function responsible for the **flow of materials** from suppliers into an organisation, through **operations** within the organisation and then to customers.” (p. 4)*

The Handbook of Logistics & Distribution Management (Rushton, 2014) defines logistics as

“Logistics = Materials management + Distribution” (p. 4)

From the theoretical viewpoint, logistics is seen as physical movement of goods and process planning and management around it. More recent literature on trends in logistics and supply chain see the importance of not looking only at logistics as distribution but sees the realisation of logistics in perspective of integrating upstream and downstream material flows as a concept of supply chain management (Waters and Rinsler, 2016).

2.2.3 Operational components of logistics

Logistics includes many tasks in the daily operations of a company. For example, in manufacturing company, following tasks are executed during daily logistics operations (Hoekstra and Romme, 1992). The terms relevant for this thesis are underlined and explained by author:

- **Order reception** – accepting orders from customers and booking them into the system
- **Ordering** – sending orders to suppliers
- **Goods reception** – receiving the ordered cargo from a haulier
- **Incoming inspection** – checking goods quality before storing them in
- **Handling** – movement of the goods around the premises, e.g. to production, warehouse or expedition
- **Storage** – physical placement of the goods in a space where it is held for later usage

- **Transport** – internal transport of the material or finished goods, by e.g., forklifts
- **Production preparation** – e.g., unpacking, measuring, cutting
- **Issue of product orders** – preparation of what needs to be produced in given period of time and in given quantity
- **Issue of materials** – preparation of material for production orders, usually on behalf of bill of materials
- **Packaging** – placing goods into boxes, containers, or other protective material against transport damage or other marketing material
- **Shipment documents** – documents accompanying the shipment
- **Forwarding** – shipment of goods from one destination to another
- **Information processing** - recording, invoicing, writing off...

Similarly Gourdin (2001) names components that represent the functional activities (items relevant for this thesis are underlined and explained by author):

- **Customer service** – spans from accepting sales orders and confirming delivery dates and conditions, to advising on product
- **Inventory management** – systematic approach to quantity of stored goods which then influences the overall financial situation of a company, corelates with function of supply chain management
- **Transportation** – movement of the goods
- **Storage and materials handling** – see previous page
- **Packaging** – see previous page
- **Information processing** – number of tasks needed to receive needed instructions for further steps

- **Demand forecasting** – estimating future sales of the goods
- **Production planning** – short-, mid- and long-term scheduling of production
- **Purchasing** – operational (ordering) and strategic (negotiating) acquirement of materials or finished goods
- **Facility location** – more strategic approach to whole supply chain structure

The operational components of logistics have changed with utilisation of information technology. Physical logistics involves the movement of products (raw materials, parts, and finished goods) from point-of-origin to point-of consumption (Stock and Lambert, 2001).

When a company does not own their own vehicles or the whole transportation department, they subcontract these services to external company. There are several actors operating the transport services (Stock and Lambert, 2001):

- External truck/train/airplane/vessel owners
- Freight forwarders
- Transportation brokers or agents
- Intermodal agents
- Package carriers
- 3PL or 4PL companies
- Terminal operators

Warehousing can be defined as the part of a firm's logistics, where goods are stored, and information on their status, condition and disposition is provided to

further managers. Warehouse handles products in four cycles – receive, store, ship, and pick. Warehouses of the 21st century focus more on the customer's needs via the communication and value-added services such as quality checking, cross-docking, electronic tracking and control of products, customized services (on-demand packaging, labelling, palletization) (La Londe, 1994). There are following types of warehouses by roles performed (Rushton, 2014):

- **Inventory holding point** – for holding of substantial inventory or repository (archive)
- **Consolidation centre** – grouping more products into one shipment
- **Cross-docking centre** – combining incoming goods from diverse suppliers to more trucks of diverse recipients, mostly perishable goods, it usually does not keep the inventory
- **Sortation centre** – sorting goods by the same principle as cross-docking, mostly for parcel services or fashion goods
- **Assembly facility** – used as last assembling stage of the product, may offer also additional services such as testing, labelling and packaging
- **Trans-shipment point** – smaller than consolidation centre, mostly used to regroup goods to smaller vehicles for urban deliveries
- **Returned goods centre** – mostly used by e-commerce shops with high return rates, to assess the returned goods and repack them for future sale

Warehouses might be owned by the manufacturer, or leased from developer, or can be outsourced to 3PL logistics provider. Scale of ownership of the warehouse usually determines changes that might be done in the construction, equipment, and operations. Although warehousing is nowadays highly automated, there is

still a need of human labour, especially for hand-picking of goods or in returned goods centres relying on human judgement (Grant et al., 2015).

Inventory management “encompasses the cost of holding inventory, on one hand, and of not holding inventory, on the other hand” (Gourdin, 2001). This means, it balances the volume of demand and supply, and the storage costs with the transportation costs. Keeping more stock means less frequent transport orders, on contrary, less goods in the warehouse means having more often deliveries.

When deciding upon changes and improvements in the whole logistics system, the total cost analysis must be considered. Reduction in costs of individual activities may lead to total cost increase (Cavinato, 1992). For example, deciding for higher amount of small distribution centres may lead to substantial increase in freight expenses. The higher customer service level in terms of high inventory, the more inventory costs associated with that.

Minimizing the total logistics costs includes minimizing the transportation costs, warehousing costs, order processing and information costs, lot quantity costs and inventory carrying costs (Stock and Lambert, 2001). These efficiencies result in less energy consumption and lower emissions. However, logistics should also think of the end of the product life and bringing it back to logistics process in terms of repurposing.

2.3 Relationship of Logistics and Supply Chain Management

In previous two-chapter sections, it was stressed that it is hard to define a boundary of the two terms. When speaking to practitioners, meaning of these terms might be obvious to them due to usage in their practice. Thus, it is important to outline different understanding and position author's viewpoint in this context. This will further explain the structure of the conceptual model.

Definitions of 'logistics' and 'supply chain management' get overlapped and confused in understanding of many managers (Lummus et al., 2001). There have been various understandings of relationships of these two terms. Larson et al. (2007) developed a model on perspectives on these relationships. They surveyed academics and practitioners, and came up with four perspectives:

- **Traditionalist** – positions SCM as a subset or a function of logistics
- **Unionist** – on the contrary to traditionalist, logistics is a function of SCM
- **Re-labelling** – considers the change of the name of logistics onto SCM, such as names of functions of managers
- **Intersectionist** – in contrary of functional understanding of SCM and logistics, they are not subordinated, hence integrated and their functions cut across the whole organization

Following examples show the different views of both definitions.

Institute of Logistics and Transport in the UK had an intersectionist viewpoint on supply chain management, hence it was considered to be other term for logistics (Waters, 2003).

Council of Supply Chain Management Professionals (CSCMP), former Council of Logistics Management (CLM), came to a re-labelling stance, as they define supply chain management as:

“...planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies... It includes all of the logistics management activities noted above, as well as manufacturing operations, and it drives coordination of processes and activities with and across marketing, sales, product design, finance, and information technology.” (CSCMP, 2016).

For the comparison, their understanding of logistics management includes:

“... inbound and outbound transportation management, fleet management, warehousing, materials handling, order fulfilment, logistics network design, inventory management, supply/demand planning, and management of third-party logistics services providers. To varying degrees, the logistics function also includes sourcing and procurement, production planning and scheduling, packaging and assembly, and customer service. It is involved in all levels of planning and execution--strategic, operational and tactical. Logistics management is an integrating function, which coordinates and optimizes all logistics activities, as well as integrates logistics activities with other functions including marketing, sales manufacturing, finance, and information technology.” (CSCMP, 2016).

Cooper and Ellram (1993) represent unionist viewpoint, they confirm that logistics and SCM should not be defined the same, they stated that supply chain management plays a long-term, strategic role,

“its objectives are to reduce inventory levels, improve total cost efficiencies, reduce the supplier base, and/or increase the speed of

operations. Purchasing and logistics play key roles here due to their direct influence and management of inventories.” (p. 19).

Thus, the logistics is only understood a part of the whole supply chain management, on the same level as sales, marketing, finance, production, research and development and other company's functions.

Supply chain in this thesis is understood closest to the unionist viewpoint, as a number of processes that extend across organisational boundaries. In unionist view, SCM is an integrating function on basic business functions into a cohesive business model (Grant et al., 2015). In simple terms, transportation is a part of inbound, otubound and also inter-company transportation. Warehousing in cradle-to-grave approach must be studied not only on interalogistics perspective of manufacturer or warehousing owner, but also warehousing that is part of supplier's supply chain and finished goods distributor's supply chain. Mostly, inbound logistics is a part of material purchasing strategy of supply chain management and outbound logistics is a function of distribution SCM. Logistics exists in each department, as material management, production planning, warehousing management and sales distribution but they all work together in projects of supply chain management, which unite the planning across the whole value chain. To identify decarbonisation initiatives, each logistics activity must be looked at in order to have a wide scale of options. Thus the focus stays mainly on single processes but also holistic approach to find the benefits and counteractions for the entire supply chain should be considered. To graphically explain that, a Figure 2-1 is the best depiction of the meaning.

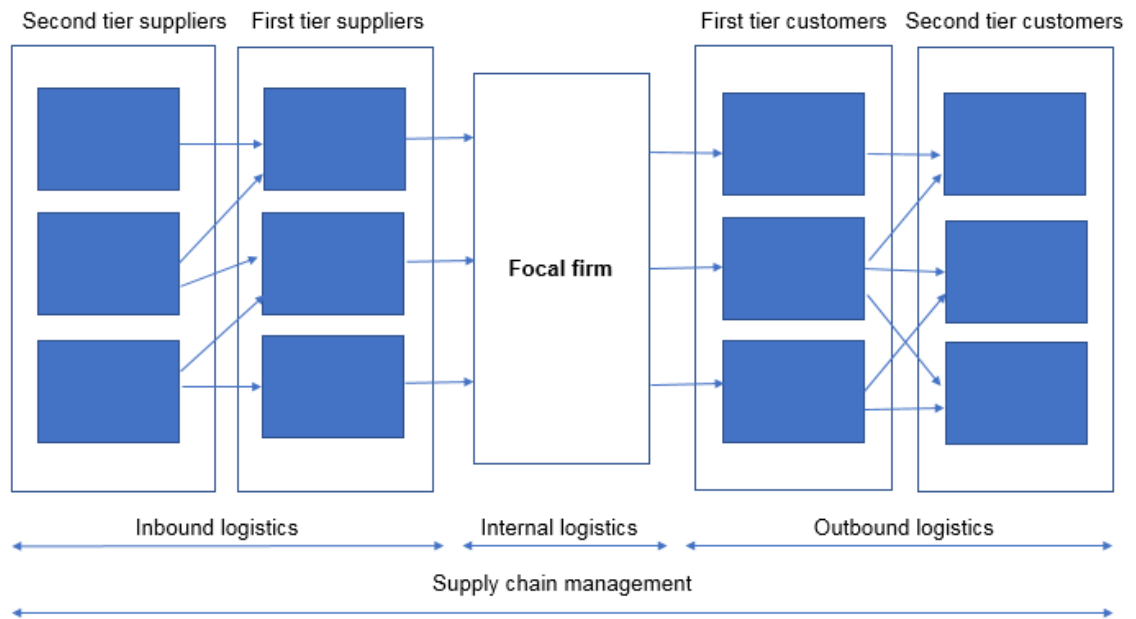


Figure 2-1 Supply network

Source: Harrison (2011), adapted from Slack et al. (1998)

It depicts SCM as overlooking all activities across whole organization or more organizations (Harrison, 2011):

“SCM encompasses the planning and controlling all processes involved in procurement, conversion, transportation and distribution across a supply chain. It includes collaboration between partners, which can be suppliers, intermediaries, third party service providers and customers. In essence, SCM integrates supply and demand management within and between companies to serve the needs of end-customer” (p. 7).

In this thesis, the framework for decarbonisation of logistics shall not only look at single component of logistics but also will consider relationships between them. Therefore, function of supply chain management is used for connection of operational components which are single logistics activities that later contribute to the bigger picture.

2.4 Environmental Impact Of Logistics Activities

Logistics activities cause many externalities on the environment, including air pollution, noise, accidents, vibration, congestion, land-take and visual intrusion (Piecyk et al., 2015). As this thesis focuses on CO₂ reduction, this chapter will take closer look at greenhouse gas emissions from freight transport and warehousing by burning fossil fuels and using energy from fossil-fuelled power plants. When considering a complete ecological assessment of logistics activities and the development of comprehensive decarbonization strategies, it's important to address not only transportation but the warehousing and transshipment processes as well (Rüdiger et al., 2016).

Firstly, terminology used in this chapter and whole thesis needs to be clarified. In different corporate GHG reduction targets, different expression of the greenhouse gas unit is being portrayed. Some companies focus solely on carbon dioxide, others express their reductions in CO₂e (carbon dioxide equivalent) as a relative measure of different greenhouse gases embodied in one unit of CO₂. CO₂e is calculated by multiplying different greenhouse gasses by their global warming potential (GWP), where CO₂ has global warming potential equal to 1. Table 2-1 below demonstrates GWP of the main greenhouse gasses in the time horizons of 20 years and 100 years. Most companies and standards use 100 years for their calculations. This is to demonstrate, that for example methane has much stronger short-term effects, and carbon tetrafluoride has rather long-term effects on the global warming. These calculations do not vary over time, different sources might have slightly different GWP calculation methodology.

Table 2-1 GWP values of greenhouse gasses

Source: IPCC, 2013, p. 714

GHG	GWP time horizon	
	20 years	100 years
Methane (CH ₄)	86	34
Nitrous oxide (N ₂ O)	268	298
Hydrofluorocarbon (HFC-134a)	3790	1550
Chlorofluorocarbon (CFC-11)	7020	5350
Carbon tetrafluoride (CF ₄)	4950	7350

As there is diverse usage of CO₂, carbon, respectively CO₂e terminology in the articles and companies' understanding, this thesis uses CO₂ for the following chapters, as the universal term.

2.4.1 Climate change and its scientific understanding

Climate change represents change of temperatures and weather conditions over longer period. It has been here over past thousands of years. The climate always changes and there have been much hotter and cooler periods than now. Scientists have used various methods to collect and compare the data on global temperatures and CO₂ in atmosphere for last thousand years, for example archiving local temperature records, comparing ice cores, wood rings, coral reefs or lake mud drills (IPCC, 2007). Over the last 10000 years the climate has been stable, however, in this relatively stable period, the temperature increase has been recorded in the last twentieth century (Jones et al., 2001). The graph below (Figure 2-2) shows the temperature development in past 1000 years, following different sources and methods of measuring but demonstrating similar oscillation of the lines.

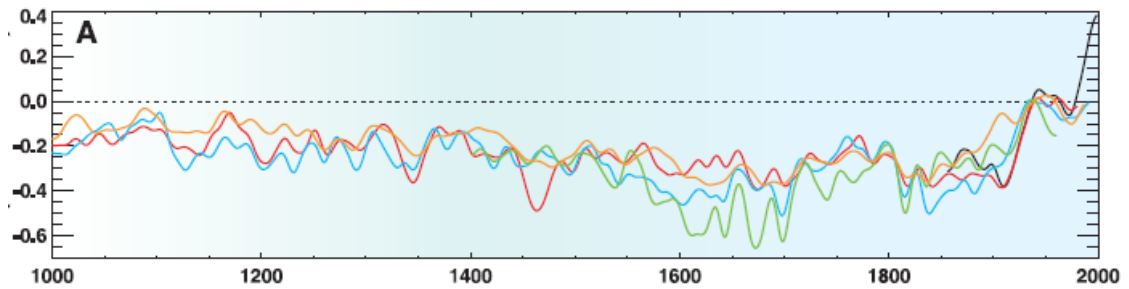


Figure 2-2 Northern hemisphere surface temperature anomalies (Degree Celsius) relative to the 1961-1990 mean (dotted line)

Source: Jones et al. (2001), p.664.

In the nineteenth century, physicists Tyndall and Fourier discovered the effect of carbon dioxide, methane, and water vapour, causing global warming. Tyndall in his experiment proved that they create the atmospheric layer that prevents the heat to escape the earth's atmosphere. They called these gasses 'greenhouse gasses'. Later, the nitrous oxide and other chlorine gases were discovered.

The awareness about human impact on climate change arose after findings and scientific measurements in the 1970s when the first report for the UN conference in Stockholm (1972) about human contributions to climate was prepared. Since then, it also became a political agenda and non-governmental striving. A non-governmental body, International Panel on Climate Change (IPCC) was created in 1988 to gather the research in the field of climate change. Scientific predictions and calculations brought warnings about the danger of increased warming of the atmosphere and the impact on humans and ecosystems. IPCC gathers leading climate scientists and government advisers and their results of their research. As it brings together scientific evidence from different parts of the world, diverse observations, and measurement methods, it is being considered as conservative.

In its 2007 report, it stated that the evidence for warming of the climate system is unequivocal (IPCC, 2007).

In 2010, a survey of 1,372 researchers most actively publishing in the field showed that 97–98% of the climate researchers surveyed here support the tenets of anthropogenic climate change outlined by the IPCC (Anderegg et al., 2010). (Cook, 2016) also confirms this with a range of 90%–100% depending on the exact question, timing, and sampling methodology.

IPCC defines greenhouse gasses as *“the gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the earth’s surface, the atmosphere itself and by clouds”* (IPCC 2007, p. 82).

2.4.2 Position of carbon dioxide among greenhouse gases

27 greenhouse gases have been identified, grouped by the Kyoto Protocol in December 1997 into these categories (United Nations, 1998):

- Carbon dioxide (CO₂)
- Methane (CH₄)
- Nitrous oxides (NO_x)
- Hydrofluorocarbons (HFC)
- Perfluorocarbons (PFC)
- Sulphur hexafluoride (SF₆).

Out of all greenhouse gasses, CO₂ is the most widespread gas as shown in Figure 2-3 below.

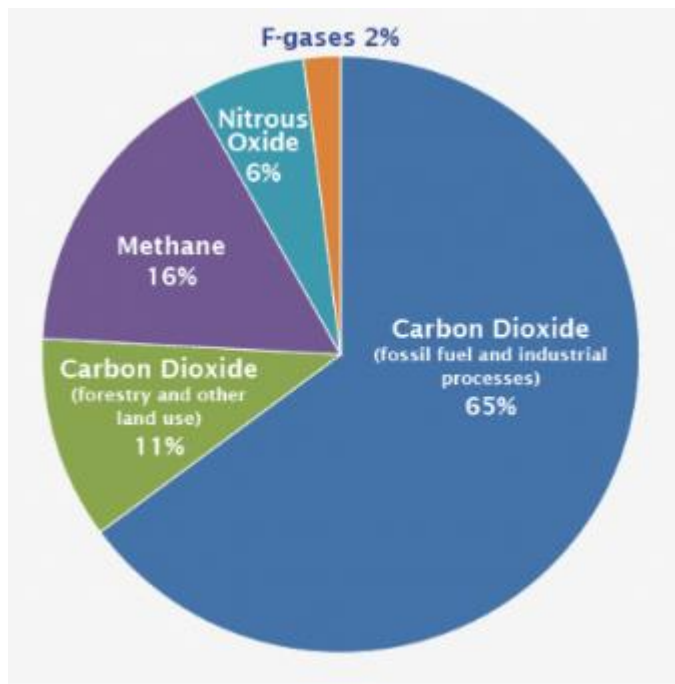


Figure 2-3 Global greenhouse gas emissions by gas, based on year 2010

Source: IPCC (2014), p. 26.

While methane and other greenhouse gasses cause short-term effects, carbon dioxide has shown the long-time effects on warming of the earth. Even more, adding more carbon dioxide into the atmosphere creates 'positive feedback', supporting intensity of all effects of climate change.

On one hand, CO₂ can be added to the atmosphere naturally, as it is stored under the earth's surface already for thousands of centuries. Carbon molecules are trapped below the earth's surface, contained in all dead bodies of organic compounds, as well as in rocks and in water. Carbon reacts with oxygen and creates CO₂ molecules. It can be released by volcano explosions, large fires, or tectonic movements inside the sea. It can be also influenced by life cycles of plants seasonally, as more CO₂ is released in the autumn by decomposition of fallen leaves and less in spring and summer by plants inhaling the carbon dioxide back.

On the other hand, there has been scientific consensus about the human impact on climate change, largely after the industrial revolution, by burning fossil fuels. Figure 2-4 takes a closer look at annual temperatures in the period between 1880 and now, measured by various national climatology bodies. It shows that clear majority of data shows the steep trajectory upwards, since the 1980's.

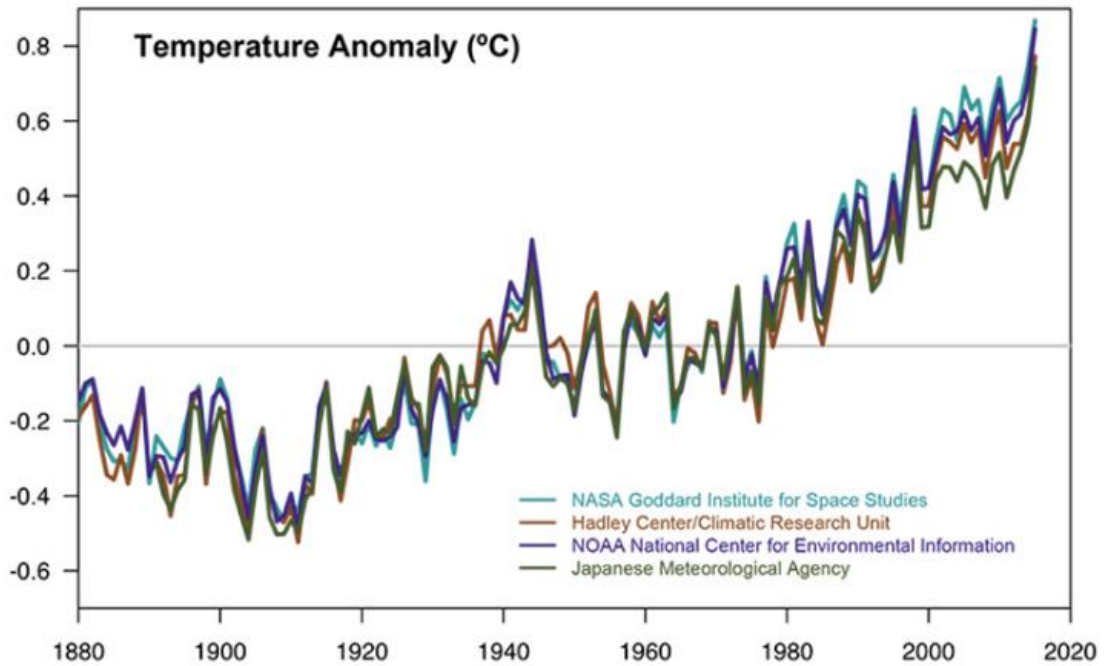


Figure 2-4 Temperature data from four international science institutions

Source: <http://climate.nasa.gov/scientific-consensus/>. Accessed: 28.11.2016 (Data sources: NASA's Goddard Institute for Space Studies, NOAA National Climatic Data Center, Met Office Hadley Centre/Climatic Research Unit and the Japanese Meteorological Agency)

There is a significant evidence of recent climate change negative effects on a planet (<http://climate.nasa.gov>, accessed on 28.11.2016):

- Sea level rise – global sea levels rose about 17 centimetres, in the last century, however, in the last decade it nearly doubled that of the last century

- Global temperature rise - since 2009, many months have recorded the record temperatures
- Warming oceans – oceans absorb much of the heat, causing shifting of ecosystems
- Shrinking ice sheets – Greenland and Antarctic ice sheets have decreased in mass
- Glacial retreat – almost all mountain glaciers have retreated
- Decreased snow cover – spring snow in northern hemisphere is melting earlier
- Extreme weather events – extreme high and low temperatures, intense rainfalls, hurricanes, tsunamis
- Ocean acidification – causing decline of coral reefs and extinction of sea species

In 1992, United Nations Framework Convention on Climate Change (UNFCCC) was signed by 154 member states, entering into force in 1994. This conference's objective was *"stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic human-induced interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."* (WHO, 2020). In 2010, on the UNFCCC conference, global leaders agreed upon maximum temperature increase of 2 °C compared to pre-industrial levels. The latest predictions by the IPCC WGII showed that even less than 2 °C increase will cause main threads to

human wellbeing (IPCC, 2014a). In 2015, at the COP 21, 11th Meeting of the Parties to the 1997 Kyoto Protocol, countries agreed to keep the temperatures below 1.5 °C increase and between 2045 and 2060 on zero increase and stressed the importance of removing the greenhouse gases from the atmosphere. According to current development, the world is not on trajectory to temperature decreases yet. The predictions of the IPCC WGIII assessment report show that the trend is leading towards 2.5°C to 7.8°C by the end of the century, when accounting for full climate uncertainty (SDSN and IDDRI, 2014).

2.5 Logistics Greenhouse Gas Emissions

Mitigation, or reducing climate change, can be achieved by implementing various initiatives from product design throughout material and supplier choice, manufacturing processes, energy purchasing, waste management to product disposal or recycling as every step in the process produce carbon emissions to some extent. This thesis focuses on logistics sector logistics sector; therefore, this closing section of this chapter will explain the impact of freight transport and warehousing in detail.

2.5.1 Greenhouse gas emissions from freight transportation

International Transport Forum (ITF) (2015) suggested that freight transport will grow slower, than the estimated economic growth, and by 2050 CO₂ emissions from Europe's surface freight will increase by 28 to 55% (OECD/ITF, 2015). Three-fold increase in transport demand is inevitable in business-as-usual basis, as seen in Figure 2-5 (OECD/ITF, 2017).

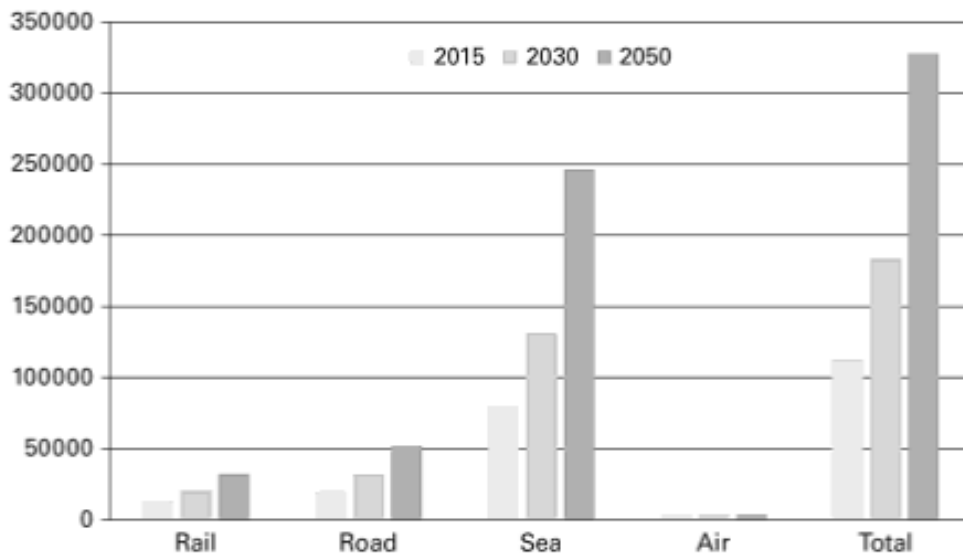


Figure 2-5 Forecast of total freight growth between 2015-2050 (in tonne-km)

Source: McKinnon (2018) adapted from ITF (2017), p. 10

Freight transport does impact environment with following greenhouse gases, with following impact:

- Nitrogen Oxides (NOX) result from combustion, where nitrogen and oxygen combine. Long-time effects are lung diseases and emphysema (EPA, 2008)
- Hydrocarbons (HCs) result from incomplete combustion of organic materials in the fuels, cause lung problems and are carcinogenic (Piecnyk et al., 2015)
- Carbon monoxide also results from incomplete combustion and it can cause death (HPA, 2009)

For vehicles, a unit of grams of carbon dioxide (or carbon dioxide equivalents) / km is used. 93-95% of GHG emissions from transport operations is accounted for by CO₂ emissions (ECTA and Cefic, 2011).

For example, Department for Environment Food & Rural Affairs in UK, uses following conversion factors of direct GHG emissions from fuels, it is important to know, that they must be updated in company's calculations yearly, as the calculations are being yearly updated due to innovations in the fuel manufacturing (Table 2-2 and Table 2-3).

Table 2-2 Road freight transport fuel conversion factors

Adapted from DEFRA (2013) and DEFRA (2019)

Fuel type	Unit	Kg CO ₂ e per unit	
		2013	2019 HGVs >33t
Petrol	Litre	2.2144	
Diesel	Litre	2.6008	1,0956
CNG	Kg	2.7072	
LPG	Litre	1.4929	

Number of emissions from freight transport largely depends on combustion engines and type of fuel used. Diverse fuels used by different modes of transport and alternative fuels will be briefly examined in the next chapter.

The energy intensity of different transport modes shows that aviation is the most intensive mode of transport. However, it is not the most problematic one, as it does not carry the most tons of cargo transported. Table 3 shows the average emission factors from different transport modes in Europe.

Table 2-3 Average emission factors for freight transport mode within Europe

Source: IFEU (2008), p. 34. EC = energy consumption

	EC (kj/tkm)	CO2 (g/tkm)	NOx (mg/tkm)
Aircraft	9876	656	3253
Truck EURO 3	1082	72	553
Truck EURO 4	1050	70	353
Truck EURO 5	996	66	205
Diesel train	530	35	549
Electric train	456	18	32

Following graph shows the proportion of the CO2 emissions of transport on global emission levels (Figure 2-6). Transport, in some statistics, is meant for both passengers and cargo. Warehousing is reported as part of the building emissions.

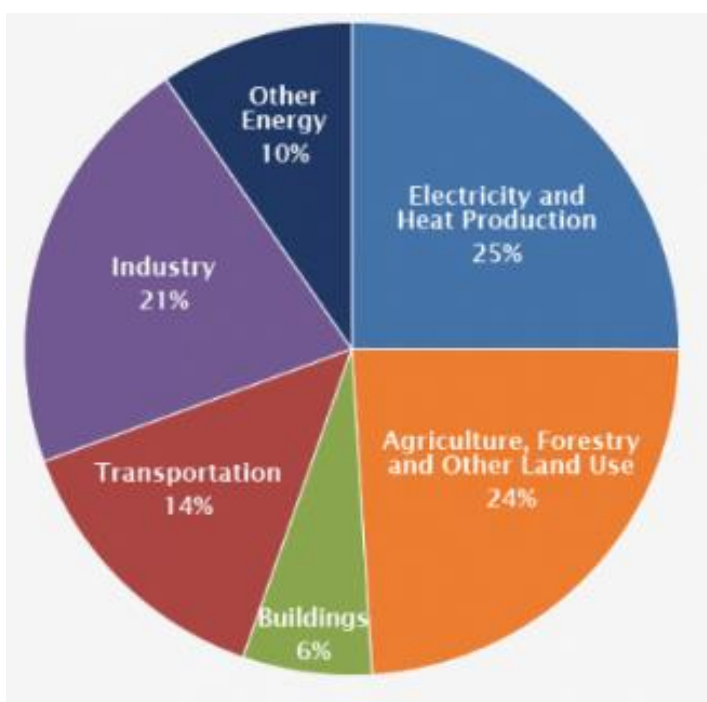


Figure 2-6 Global Greenhouse gas emissions by economic sector, year 2010

Source: IPCC WGIII (2014) p. 18

More recent graph shows, that in EU, the transport emissions take up the larger proportion than the global average (Figure 2-7). This is due to higher consumption, diminishing barriers of international trade and therefore more international transport intensity, similarly as in the US and other developed countries.

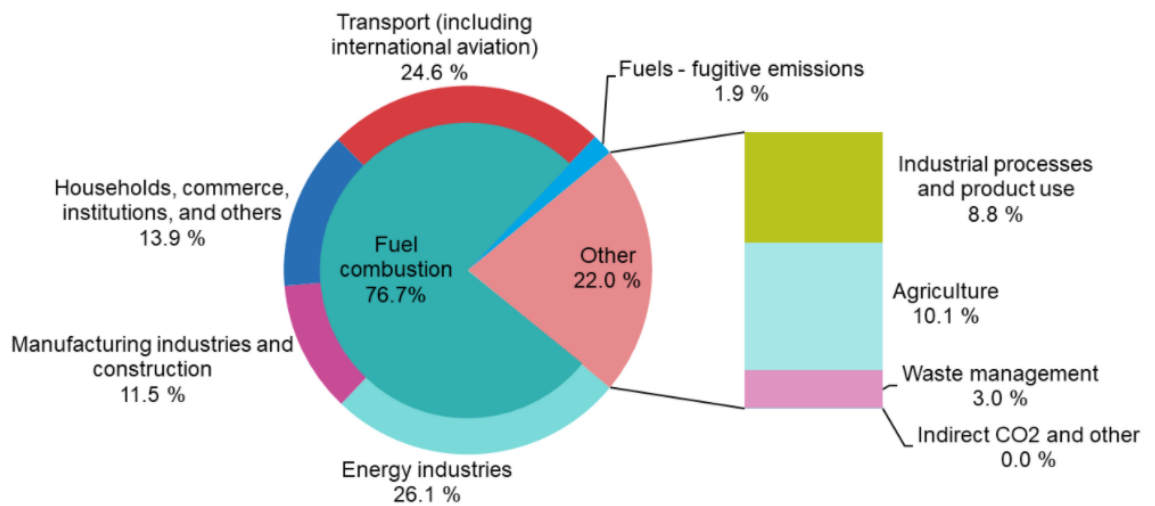


Figure 2-7 EU-27 greenhouse gas emissions by economic sector, year 2018

Source: European Environment Agency (https://ec.europa.eu/eurostat/statistics-explained/images/a/a8/Greenhouse_gas_emissions_by_IPCC_source_sector%2C_EU-27%2C_2018.png). Accessed: 12.04.2021.

Without aggressive and sustained mitigation policies being implemented, transport emissions could increase at a faster rate than emissions from the other energy end-use sectors (IPCC, 2007).

Figure 2-8 and Figure 2-9 below show that long-haul heavy goods vehicles are the most responsible for absolute freight transport CO2 emissions in the EU.

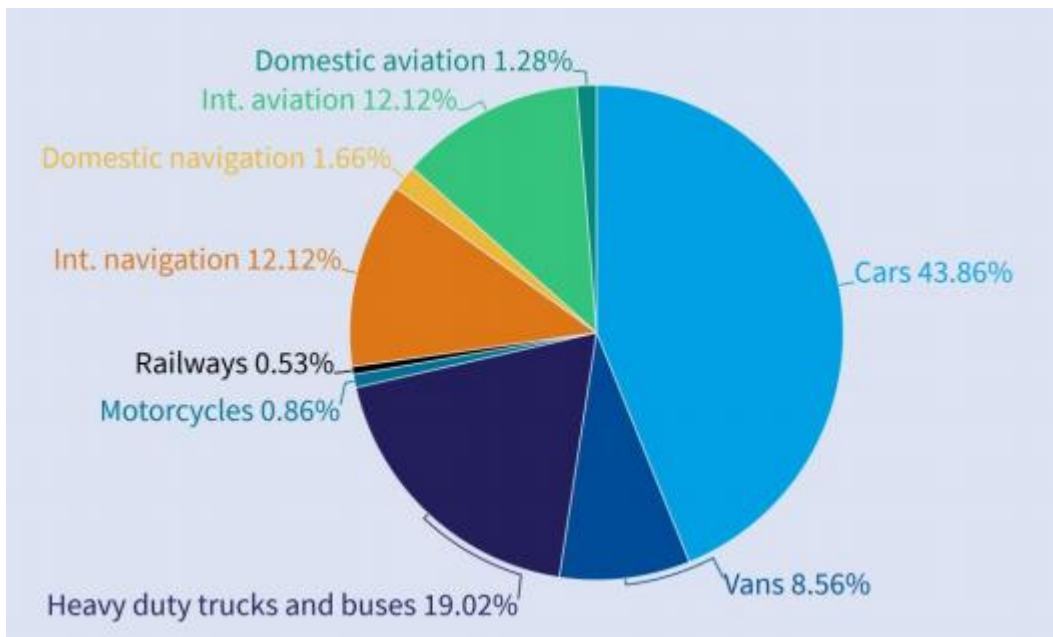


Figure 2-8 EU GHG transport shares in 2016.

Source: T&E (2018), p. 8

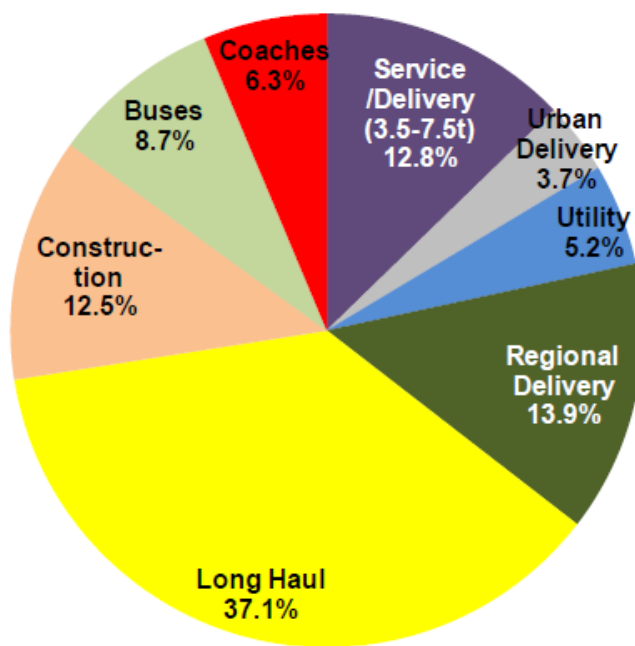


Figure 2-9 Estimated breakdown of the EU HDV energy consumption for 2010.

Source: AEA/Ricardo (2011), p. 181

CO2 emissions from HDVs rose by some 36% between 1990 and 2010, mainly due to increasing road freight traffic. Further estimations point out that unless no measures will be taken, HDV emissions would rise by 22% by 2030 (RICARDO, 2009). The EU research on CO2 emission reduction from HDVs dates to 2008, when the first report was issued. Since then, several studies on abatement potential, calculation of CO2 emission, emission abatement costs, strategies, monitoring, and certification were published. In 2019, the European Union started monitoring the reporting of HDV manufacturer's vehicle consumption and CO2 emissions.

Shipping is also going to gain on significance, although it represents only approximately 2.2 % global CO2 emissions. IMO expects the shipping sector to grow between 50% and 250% by 2050 – depending on future economic and energy developments (IMO, 2014). Marine Environment Protection Committee (MEPC) member states agreed on a target to cut CO2 emissions output by 50 % by 2050. This is, however, not a legal binding, but a framework for member states and its effect will be reviewed in 2023. It has been criticized by many environmental organizations for lack of short-term measures and not very ambitious goal (TME, 2018).

2.5.2 Greenhouse gas emissions from warehousing

Although warehousing accounts on average only for minor proportion of logistics emissions, it should be taken into consideration, as warehouse position influences length of distance travelled by the goods. When looking at single warehouse, most carbon emissions come from energy consumption of warehousing building, smaller amount is of warehousing operations, depending

on the type of warehouse and scale of operations in the warehouse. Statistics on impact of warehousing are very limited, as the warehousing buildings are part of broad industrial classification, such as offices, shops and factories (Marchant and Baker, 2015). The World Economic forum estimates that about 3% of logistics emissions originate from logistics buildings (WEF, 2009). Germany's warehousing emissions were estimated at 1% (Rüdiger et al., 2016). In 2008, warehousing buildings accounted for about 40 % of global energy from buildings used (WBCSD, 2008). IPCC (2014b) estimated a 32 % share for year 2014. In the UK, the Department of Energy and Climate Change estimates, that warehousing accounted for 2.1 million tonnes of oil equivalent, which was about 3 times less than of heavy goods vehicles (DECC, 2013b). United Kingdom Warehousing Association (UKWA) estimated that warehousing emissions in the UK are at about 3 % of total greenhouse gas emissions (UKWA, 2010). Marchant and Baker (2015) calculated that UK's share of warehousing emissions on logistics emissions are around 11%. All above estimates show that warehousing emissions vary by country (warehouse location), energy consumption, age of warehousing buildings (often related to building style and standards in given country), and development of material handling operations processes (McKinnon, 2018).

There are two main standards for assessing sustainability of warehousing building, LEED in the United States and BREEAM for United Kingdom (Grant et al., 2015). BREEAM awards points for different weighting factors such as water, waste, transport, pollution, land use and ecology, management, materials, health and wellbeing and energy. It also evaluates the warehouse on CO₂ emissions. Warehouses owned by manufacturing companies for their lifetime have generally

better CO₂ performing envelope, as they are built from better quality materials and company knows the purpose of operations inside (Grant et al., 2015). Developers mostly build functional envelope with no equipment inside and look at short-term risks and return on investment. When considering the total CO₂ performance of warehouse, life-cycle analysis must be executed, including materials, manufacturing, construction, use and disposal (Menzies, 2011). The relative proportions of embodied and operational CO₂ emissions vary by geographical location and nature of operations. Generally, when lifespan of warehouse is longer, embodied emissions are lower than operational. If assuming only 10 years of life, embodied emissions might be as high as 95 % (RICS, 2010). Rai et al. (2011) found that over a 25-year life span of highly insulated warehouse, operational and embodied emissions almost equalled. Therefore, one must consider the right balance between those two. Sometimes, operational impact can be higher. Operational CO₂ emission impact comes from cooling, heating, lighting, handling equipment and other activities involving consumption of electric energy. These activities will be described more in detail in next chapter.

Some estimations of CO₂ emissions also include activities that imply from external operations of the warehouse. Specifically, for large centralized warehouses, there is a high volume of incoming and outgoing trucks causing local pollution (Marchant and Baker, 2015). Interestingly, pollution caused by daily workers' car trips to work, can contribute to much larger emissions than operating a fully automatized warehouse (Grant et al., 2015).

2.6 Summary

This chapter introduces reader to the topic starting by different definitions and viewpoints on relationship between logistics and supply chain management. Some outline logistics as an integrated part of the whole supply chain management, other researchers and practitioners see it on the same level. Explaining human contribution to climate change, particularly logistics activities shows that it has upwards tendency due to prevailing fossil fuel consumption in transportation sector. This growth is undoubtedly significant since start of the 20th century. Therefore, an action was undertaken by governments to commonly act upon this urgent issue. Transport sector is responsible for about fifth of global carbon emissions with heavy duty vehicles as the most polluting transport mode per tonne-km. Warehousing emissions account for a fifth of all logistics activities, but there is not clear data on how warehouses contribute to total carbon emissions. It is estimated that they contribute to about third of overall building emissions. While transport innovations depend on the life span of the vehicle, ship or airplane and warehousing equipment renovation can also be, emissions can also be reduced by optimising in-house operations. Therefore, also holistic logistical approach needs to be undertaken. Total logistics emissions are not only influenced by the energy intensity of transportation and warehousing themselves, but also on the whole structure of the supply chain. The number of warehousing hubs, location of suppliers and optimised planning of movement among them can highly contribute to the whole supply chain environmental effectiveness.

Chapter 3 CO2 Reduction in Logistics Operations

3.1 Introduction

This chapter aims at identifying ways, how to approach carbon emissions reduction in logistics and how this negative environmental impact of logistics can be reduced. At the beginning, it anchors company's decarbonisation in the triple bottom line (economic, social, environmental) sustainability and what role it plays in company's corporate social responsibility. It guides through the development of sustainable thinking of companies and their corporate reporting on environmental sustainability. Further on, it focuses on describing development of green logistics and supply chain management research over the time. One of the company's carbon measuring tools, life cycle analysis and its importance of identifying logistics decarbonisation effects, is explained. In the last section, all decarbonisation initiatives in logistics operations found in literature are being outlined, described and their positive effects as well as shortcomings are being discussed. A conceptual model is being created to summarize all these initiatives in an overview of found initiatives.

3.2 Sustainability and Corporate Social Responsibility

The idea of sustainability was firstly mentioned by philosopher John Rawls, by pointing on the issue of using Earth's resources in a way that future generations can use and enjoy them (Grant et al., 2015). For business purposes, Elkington (1994) already at the beginning of 20's century wrote an article on sustainable corporation, where he mentions first attempts of companies on sustainability. A

concept of 'triple bottom line' was introduced, minimizing the negative social, economic and environmental impact of the firm (Grant et al., 2015). These three indicators became the standard building stones for corporate reporting (Papmehl, 2002). For few decades now, there has been pressure on sustainability performance of the companies. Organisations use their corporate social responsibility (CSR) activities as a way of marketing communication to their stakeholders in their annual reports (Lindgreen and Swaen, 2010). Thanks to their CSR reporting, they can also identify the improvement potential and gain indirect financial profits (Papmehl, 2002). Hence, managers have to go beyond economic profitability, they have to meet other criteria: eco-efficiency, socio-efficiency, eco-effectiveness, socio-effectiveness, sufficiency and ecological equity (Dyllick and Hockerts, 2002). Sustainable business practices have implications for every aspect of a firm's business model (Hart and Milstein, 2003).

Global manufacturing companies are most pressurized on reporting their sustainable performance. Therefore, they have the most comprehensive CSR reports. On the other hand, only about 13 % of logistics service providers include dedicated sustainability reports, the rest includes information on sustainability as part of their website (Piecyk and Björklund, 2015).

For the purpose of the thesis, more focus is being put on environmental responsibility. Transformation toward greener business model is a multi-layered process, including understanding new technologies, solutions and green thinking, followed by achieving sustainability (Rajala et al., 2016, Zhang et al., 2010). Although organizations have adapted ecologically responsible practices to meet legislative requirements, these practices can produce sustainable competitive

advantage, improving their long-term profitability (Paulraj, 2009). Greening initiatives within company can not only benefit the stakeholders but also company itself. Recent research shows that green initiatives bring competitive advantage to logistics service providers (LSPs). Subcontractors place high value on their green performance, at the same time, they do not include their own influence in this validation (Large et al., 2013).

3.2.1 Green supply chain management and logistics

Greening the supply chains has evolved within the environmental strategies that companies implemented into their corporate social responsibility. Green supply chain management (GSCM) can be defined as “integrating environmental thinking into the supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the customer and end-of-life management of the product after its useful life” (Srivastava, 2007). According to survey by PE International (1993), in the 90’s, 19 % of UK companies already had some greening strategies for their logistics operations. Srivastava (2007) in his review of environmental thinking in the supply chain management of 1500 books, articles and journals, and he found out that the articles started emerging in the late 1990’s, after the boom of research on supply chain management.

Wu and Dunn (1995) listed the logistics decisions that can have impact on the environment. According to them, the decision making starts already with purchasing of raw material, spreads across inbound and outbound logistics, marketing and even after-sales service.

Aronsson and Hüge Brodin (2006) reviewed 10 logistics, SCM and transport journals in the period 1995-2004 and they found that only 2.2 per cent (45 of 2026 articles) addressed environmental issues.

Green logistics lately became a good business practice as it can have positive impact also on financial and operational metrics of a company (McKinnon, 2015a). One of the main enablers of GSCM practices became reduction of carbon emissions (Dubey et al., 2015). GHG emissions and energy consumption became the most popular KPI indicators in world's largest logistics service providers' corporate reporting (Piecyk and Björklund, 2015).

3.2.2 Decarbonisation and life cycle analysis

In previous chapter it has been explained why decarbonisation plays a major role in overall environmental performance of a company. In order to measure the performance, the main KPI – tonnes of CO₂ reduced (or saved) is being used (McKinnon and Piecyk, 2009).

Before a company identifies strategic areas for reduction of carbon emissions, it should first look at the whole lifecycle of a product. For the vast majority of companies, however, logistics is only one of many activities and often one that emits a relatively small proportion of total GHG emissions (McKinnon, 2011). By contrast, reducing supply chain carbon emissions (Scope 3) can bring more cost benefits than reducing direct or purchased electricity-related emissions (Scopes 1 and 2) (Lee, 2011). Depending on industry the company operates in, its position in the value chain, and firm-specific factors, such as product portfolio and

technological advancements, the structure of its emissions may vary (Lee, 2011).

Without fixed governmental regulations, companies can set individual carbon reduction targets. The Carbon Disclosure Project found that 29 American companies and 20 German companies, which were large multinationals, have used an internal carbon price (Hörisch, 2013). In 2016, it was already 147 companies out of 1249 who participated, representing 23% increase from 2015. 517 companies are already using internal carbon pricing as an accounting and risk management tool (19% increase from 2015), and an additional 732 disclose plans to implement one by 2018 (26% increase from 2015) (CDP, 2016). Companies use a carbon price as a tool to help identify revenue opportunities, risks, and as an incentive to drive maximum energy efficiencies to reduce costs and guide capital investment decisions (CDP and PwC, 2013). This means, they acknowledge that future climate change will be their possible business cost and business opportunity, and they try to decarbonise whole internal processes across the company. For smaller and medium companies, however, it is not a priority, as the main obstacle is finding financial resources or time for implementing this philosophy (Mala and Musova, 2015).

Following three main steps by Lee (2011) will ease structuring the decarbonisation path: *“First, identification and measurement of direct and indirect carbon footprint is critical for mitigating supply chain risks. Second, setting the system boundary of measurement is another important issue to integrate the issue of carbon footprint into supply chain management. Third, developing a map*

of product carbon footprint facilitates identification and measurement of carbon emissions across the supply chain” (p. 1216).

Currently, there are no target-setting procedures for companies on decarbonisation in logistics, hence companies can decide themselves how ambitious targets they set (Rietbergen et al., 2015). However, there are various guidelines on the market, according to which companies or external auditors can proceed in measuring and reporting. The most important are (McKinnon et al., 2015):

- ISO 14067, Greenhouse Gases: Carbon Footprint of Products. Requirements and Guidelines for Quantification and Communication (ISO, 2013)
- Defra, 2013: Environmental Reporting Guidelines: Including Mandatory Greenhouse Gas Emissions Reporting Guidance (Defra, 2013)
- PAS 2050:2011 Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services (BSI, 2011)
- The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (WBCSD/WRI, 2004)

For manufacturers, it might not be obvious how much logistics contributes to whole carbon footprint of a product. With introduction of the environmental reporting norms and various guidelines on carbon auditing the manufacturers started focusing on details of the life cycle assessment (LCA). LCA can be defined as analysis of all the environmental impacts of a product by compiling and inventory of relevant inputs and outputs of the system, at each stage from the cradle to the grave of the product (Browne et al., 2005). A full LCA, so called

cradle-to-grave analysis, includes monitoring acquisition of raw materials, manufacturing and processing, storage, materials handling, logistics management, freight transport, use and maintenance of the product and recycling/reuse or waste management. It is a complex and time-consuming process. Despite of that, thanks to LCA, company can identify the most energy extensive parts of the supply chain, where the initiatives can be applied. For marketing purposes, on one hand it is a way of presenting the amount of CO₂ embedded in the product's lifecycle to the consumer. On the other hand, "large-scale product-level supply chain carbon auditing could cause "paralysis by analysis" delaying the implementation of carbon reduction programmes" (McKinnon, 2010).

First scientific articles on LCA started emerging in 1990's (Grant et al., 2015). One of the first ones was the article by (Böge, 1995), analysing the components of supply chain of a yoghurt pot, such as raw materials, packaging and transportation. She also suggested transport emissions improvement measures such as nearby sub-contractors, vehicle maintenance, or more environmentally vehicles. Later on, various products have been evaluated on a LCA basis, such as jeans (ERM, 2002), wine (Cholette and Venkat, 2009), canned mussels (Iribarren et al., 2010) and other food products (Roy et al., 2009). Large retail corporations started analysing food-miles, or the distance, from the origin of the product till its end consumption, in order to analyse impact of some imported products compared to domestic harvest (Grant et al., 2015). Thanks to LCA they later found out that imported products might not be as bad as it can appear, for example apples from New Zealand were less CO₂ emitting throughout their

lifecycle due to more environmentally friendly farming than in the UK (Saunders et al., 2006).

Consequently, decarbonisation of logistics must be consistent with the wider environmental strategy of the business and must be backed up by senior executives (McKinnon, 2011). Following logic path can help company to guide the process (Figure 3-1).

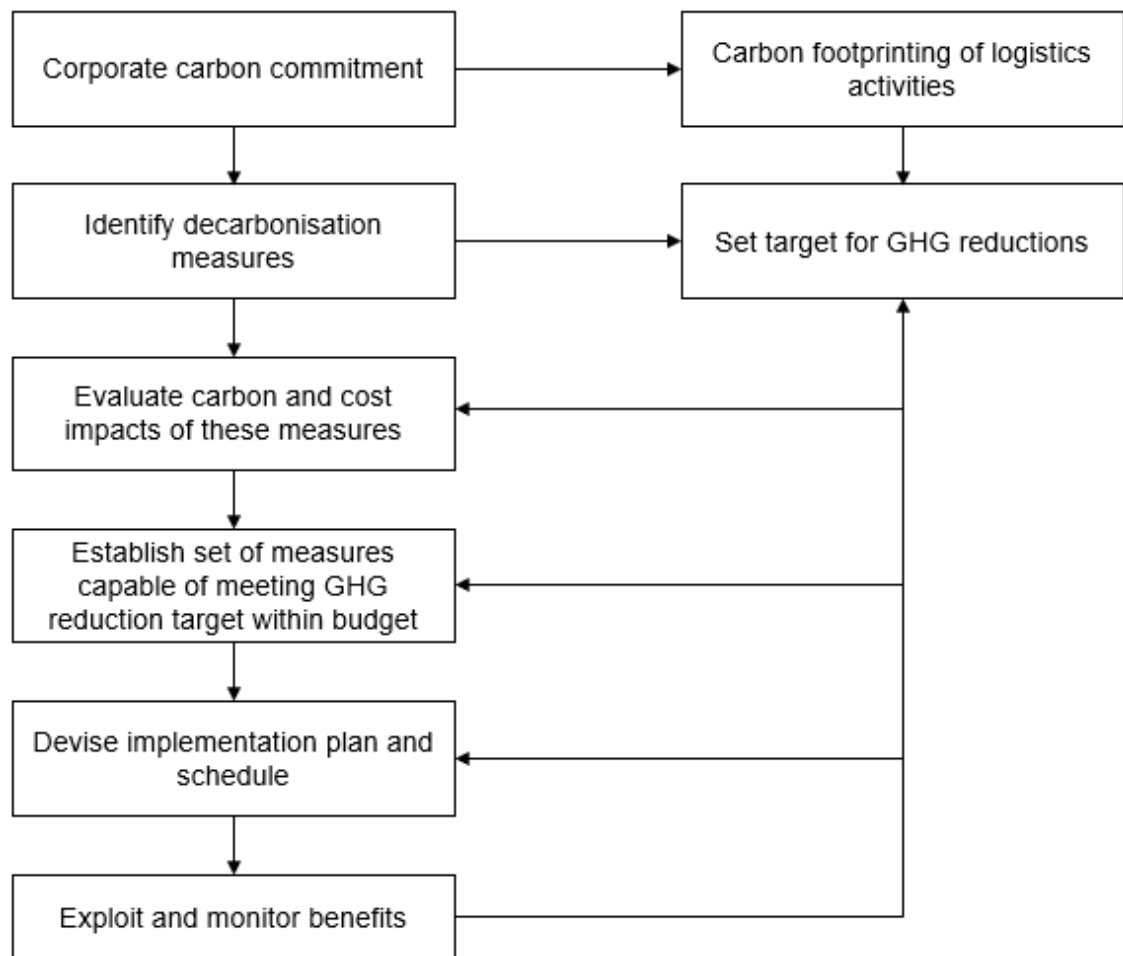


Figure 3-1 Development of a carbon reduction strategy from logistics

Adapted from McKinnon (2011)

Measuring the carbon emissions is the most fundamental part of decarbonisation strategy, as it helps to understand the most required areas as well as monitor

improvements through the time (McKinnon, 2011). It goes together with identifying the most energy extensive parts of the logistics processes.

Recently, there has been a discussion whether the product carbon auditing was accurate enough because there are different methodologies and auditing by external companies is not required (McKinnon, 2010). McKinnon (2010) points out, that supply chains of some products are often varying, causing difficulty and time constraints to precise calculation.

For more precise measurement of the logistics impact, there are following guidelines or organisations that developed methodology of transport emissions calculations:

- Standard EN 16258 "Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services".
- EcoTransIT 2010: Ecological Transport Information Tool for Worldwide Transports – Environmental Methodology and Data. IFEU Heidelberg, ÖkoInstitut, IVE / RMCON. Commissioned by DB Schenker Germany and UIC (International Union of Railways).
- GLEC Framework by Smart Freight Center, building on existing methods of SmartWay, Clean Cargo Working Group and EN 16258
- NTM (Network for Transport Measures)
- IFEU (Institut für Energie- und Umwelt Heidelberg)
- DEFRA in UK
- ADEME in France

They slightly vary in their calculations, CO₂e conversion factors and geographical considerations. GLEC Framework by Smart Freight Centre (SFC, 2020) is the latest calculation method that unifies previous knowledge and “*the only globally recognized methodology for harmonized calculation and reporting of the logistics GHG footprint across the multi-modal supply chain*” .

3.3 CO₂ Emissions Reduction Initiatives in Logistics Operations

Various studies have focused on initiatives in detail, mostly on a specific problem, initiative, or case study for an industry. This detail-based approach is very good to get a deeper understanding of each initiative. Although these papers contributed to deeper knowledge of each initiative well, they were too narrow in focus. For an overview, a wider selection of initiatives in one paper was needed.

First outline of green logistics initiatives can be found in (Wu and Dunn, 1995). Figure 3-2 shows the initiatives that they suggest across the whole logistical process from extraction of raw material until the end of the product's life cycle. They have identified most popular initiatives at that time, that can be applied in greening of the transport such as mode selection, backhaul management, consolidation. The warehousing initiatives have not been specified, however, cross-docking as most efficient way of reducing the mileage and increasing payload of trucks was mentioned (Wu and Dunn, 1995).

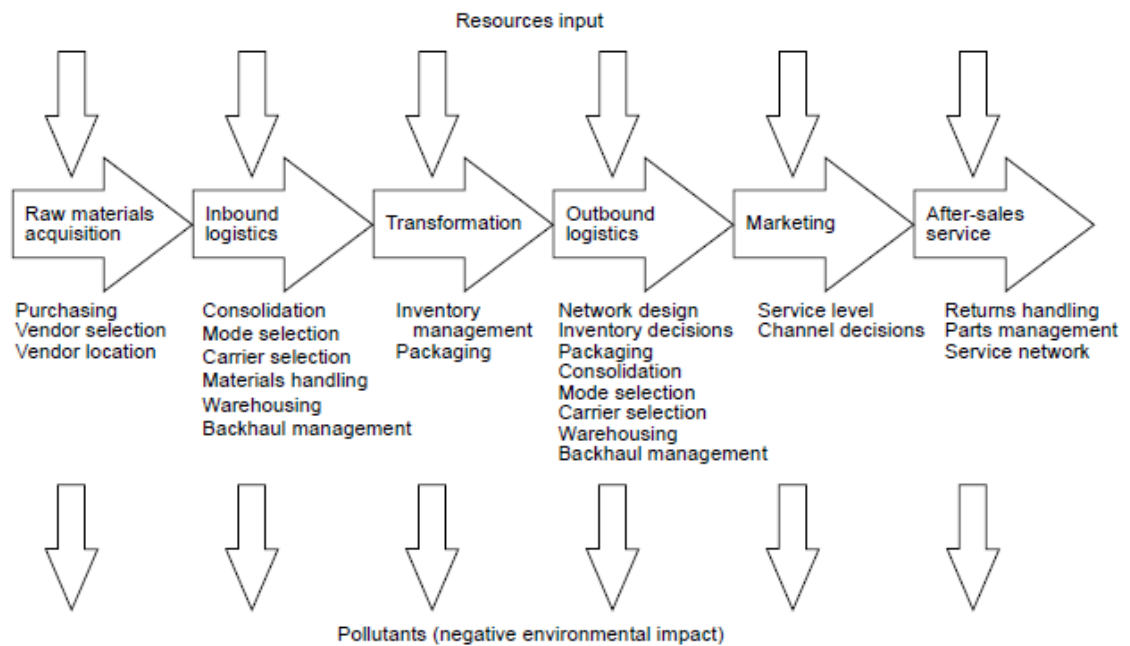


Figure 3-2 Logistics decisions that affect the environment

Source: Wu and Dunn (1995), p. 24.

In the beginning of 2000's, the research focused more on vehicle technology or distribution operations (Rizet et al., 2004). At the beginning, most articles focused on transportation CO₂ emissions, mainly truck transport. From 2008 on, more articles on CO₂ reduction in warehousing started to appear but not in such scope as the transportation articles.

3.3.1 CO₂ reduction initiatives in transport

The researched focused on CO₂ reduction initiatives in transport started much earlier than research on warehousing or whole supply chain. First research about damaging effects of freight transport emerged in 1960s (McKinnon, 2015c). It focused more on governmental policies and awareness of transport impact on the environment. Although governmental regulations and funding can in long time significantly contribute to CO₂ reduction in transport, this literature review focused rather on what the companies can currently do from their own initiative,

to achieve it. In 1980's and 1990's articles on CO2 reduction initiatives in transport started emerging more, for example (Deseey and Dobias, 1992) improvement of conventional vehicles, limiting the power of light and commercial vehicle, alternative fuels and compliance with speed limits.

Therefore, at the beginning of the search of the literature, initiatives were grouped along the terms around McKinnon's framework (McKinnon, 2007). He listed some determinants and key rations, that can influence CO2 emissions in transport (Figure 3-3).

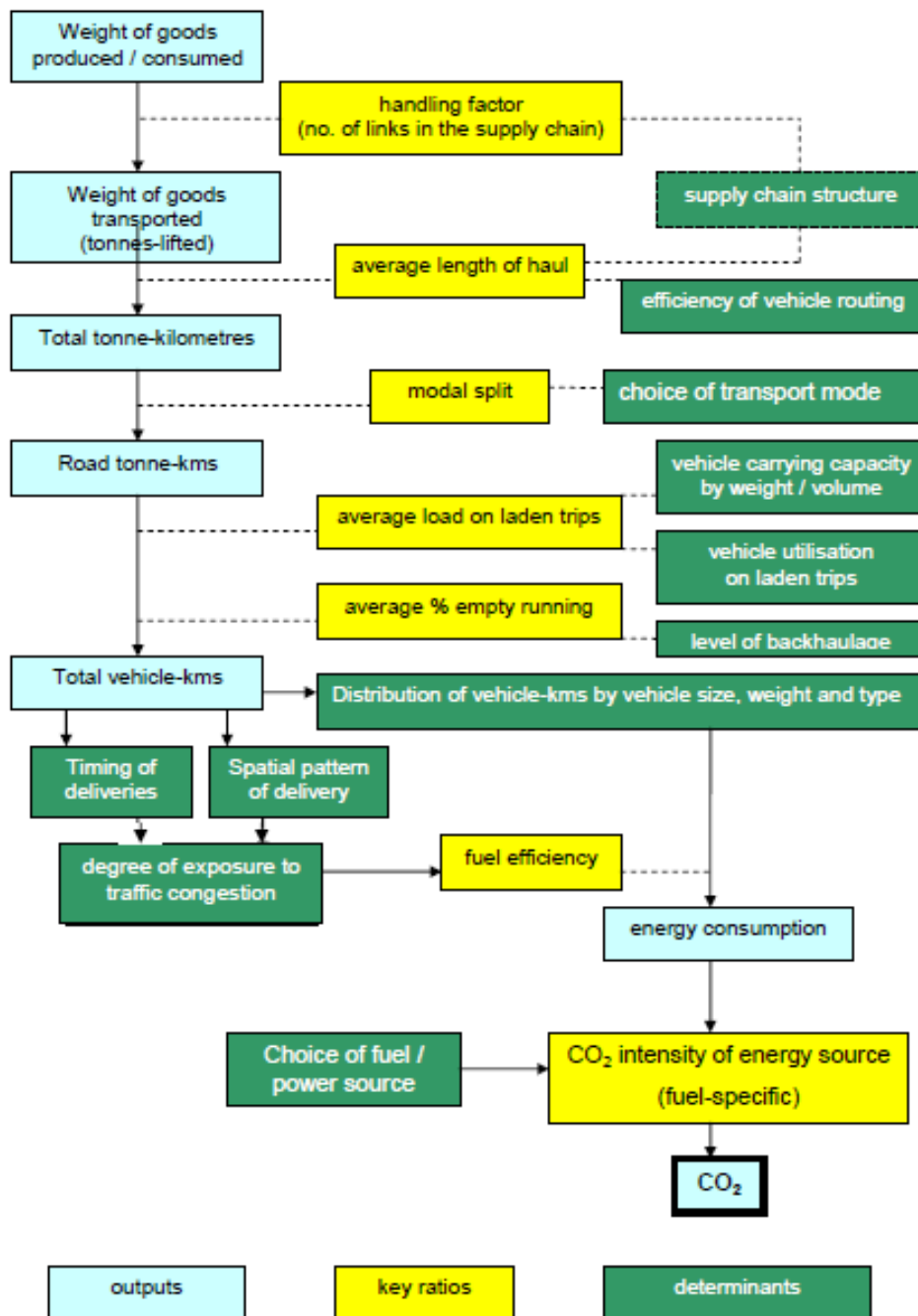


Figure 3-3 Framework for Analysing Opportunities for CO2 Reduction.

Source: McKinnon (2007).

Later, McKinnon (2011) identified more in detail all possible carbon reduction measures for freight transport, based on his previous model (Figure 11).

1. **Reduce number of links in the supply chain:**
 Dis-intermediation – bypassing agencies / nodes in the supply chain
 Greater vertical integration of processing – reduce intermediate journeys between processing plants
2. **Reduce the average length of haul:**
 More localised sourcing of inbound supplies
 Decentralise processing, storage and distribution operations
 Move production / storage / distribution facilities into more 'transport efficient' locations
 Swap arrangements - to minimise delivery distances
 Improve vehicle routing (e.g. use CVRS) / recalibrate routing packages to minimise fuel consumption
 Use telematics (possibly in association with CVRS) to determine most fuel efficient route
3. **Promote transfer of freight to lower carbon modes**
 Send greater % of freight by rail
 Send greater % of freight by waterborne services
 Relocate production facilities / warehousing to be adjacent to alternative transport network
 Invest in rail siding and / or rolling stock
 Apply for government freight facilities grants
 Develop / invest in equipment to facilitate intermodal transfers
 Reschedule distribution operations to match timetables of the alternative mode
4. **Increase vehicle payloads on laden trips:**
 Relax just-in-time replenishment schedules to permit greater load consolidation
 Increase use of primary consolidation (at expense of adding an extra link to the supply chain)
 Give hauliers / transport departments more advanced warning of traffic demands
 Promote collaborative initiatives – both vertical and horizontal collaboration
 Shift from dedicated contracts with 3PL to shared-user contracts / network services
 Suppress the 'bullwhip effect' in supply chains
 Adopt 'vendor-managed inventory' (VMI) arrangement with suppliers
 Expand the use of 'nominated day' delivery systems
 Replace the monthly 'order – invoice' cycle with a system of rolling credit
 Use more 'space-efficient' handling equipment
 Minimise the amount of secondary and primary packaging
 Stack loads to greater height (within warehouse slot height constraints)
 Reduce the height of rigid vehicles / trailers to match internal load
 Use longer and/or heavier vehicles when justified by load size / weight
 Make greater use of double-deck vehicles / drawbar trailer combinations.
 Switch from powered-to fixed-double deck trailer
 Use compartmentalised vehicles to increase load consolidation opportunities
 Increase storage capacity at delivery points – to permit delivery of larger loads
 Use of online procurement platforms ('freight exchanges') to increase opportunities for load consolidation
 Deploy load optimisation software (including agent-based systems)
 Use telematics to improve management of the vehicle fleet
5. **Reduce empty running:**
 Use load matching services (online freight exchanges / web-based procurement)
 Promote collaborative initiatives – both vertical and horizontal collaboration
 Explore backloading opportunities during purchasing negotiations
 Incorporate the planning of backloading into vehicle routing and scheduling software
 Use telematics to increase 'visibility' of the fleet and help exploit backloading opportunities
 Consolidate return of handling equipment (roll-cages / dollies) in a fewer vehicles
 Maximise use of returning shop delivery vehicles for collection of packaging material
 Relax delivery schedules to accommodate more backloads
 Improve the reliability of loading and off-loading operations to build confidence in backloading schedules
 Increase the ratio of trailers to tractors (i.e. the 'articulation ratio') to create more flexibility for backloading
6. **Reduce exposure to traffic congestion**
 Reschedule deliveries to inter-peak periods and evening / night
 Extend opening hours of premises for collections and deliveries
 Introduce unattended delivery systems for out-of-hours delivery
7. **Improve fuel efficiency**
 Development fuel management programme
 Appoint fuel champion
 Collect and analyse disaggregated fuel consumption data
 Train drivers in the techniques of fuel efficient driving (eco-driving)
 Use telematics / onboard devices to monitor driving performance
 Regularly debrief drivers on fuel performance
 Give drivers financial and other incentives to drive more fuel efficiently
 Reduce the vehicle replacement cycle to accelerate adoption of more fuel efficient vehicles
 Prioritise fuel efficiency as a vehicle purchase criterion
 Use vehicle with stop-start system
 Use vehicle with turbocharging
 Reduce vehicle tare weight
 Improve aerodynamic profiling of vehicles
 Improve vehicle maintenance, wheel-alignment etc.
 Adopt vehicles with automatic transmission
 Ensure effective tyre management / inflation of tyres to fuel efficient level
 Use supersingle tyres
 Use low 'rolling-resistance' tyres
 Set vehicle speed limiters at lower speeds
 Reduce engine idling
 Match vehicle size and weight to the characteristics of the load
 Adopt more energy efficient forms of refrigeration
 Reduce pre-loading time for refrigerated vehicles
 Power tanker pumps externally rather than from vehicle engine
8. **Reduce emissions per litre of fuel consumed:**
 Use hybrid vehicles
 Use new electric vehicles
 Use new biogas vehicle
 Use new CNG vehicle
 Use dual-fuel vehicle (biogas or LNG with conventional diesel)
 Increase % blend with environmentally-sustainable biofuel
 Recharge vehicle batteries with low carbon electricity
 Use lower carbon energy in refrigeration equipment
 Minimise refrigerant gas leakage from vehicles

Figure 3-4 List of Carbon-reducing Measures for Freight Transport

Source: McKinnon (2011), p. 7

He also adapted his 2007 conceptual model to CO₂ reduction in container transportation, where there are lot of factors (see Figure 3-5, white boxes on the right), that shippers can influence when choosing their carrier (McKinnon, 2013).

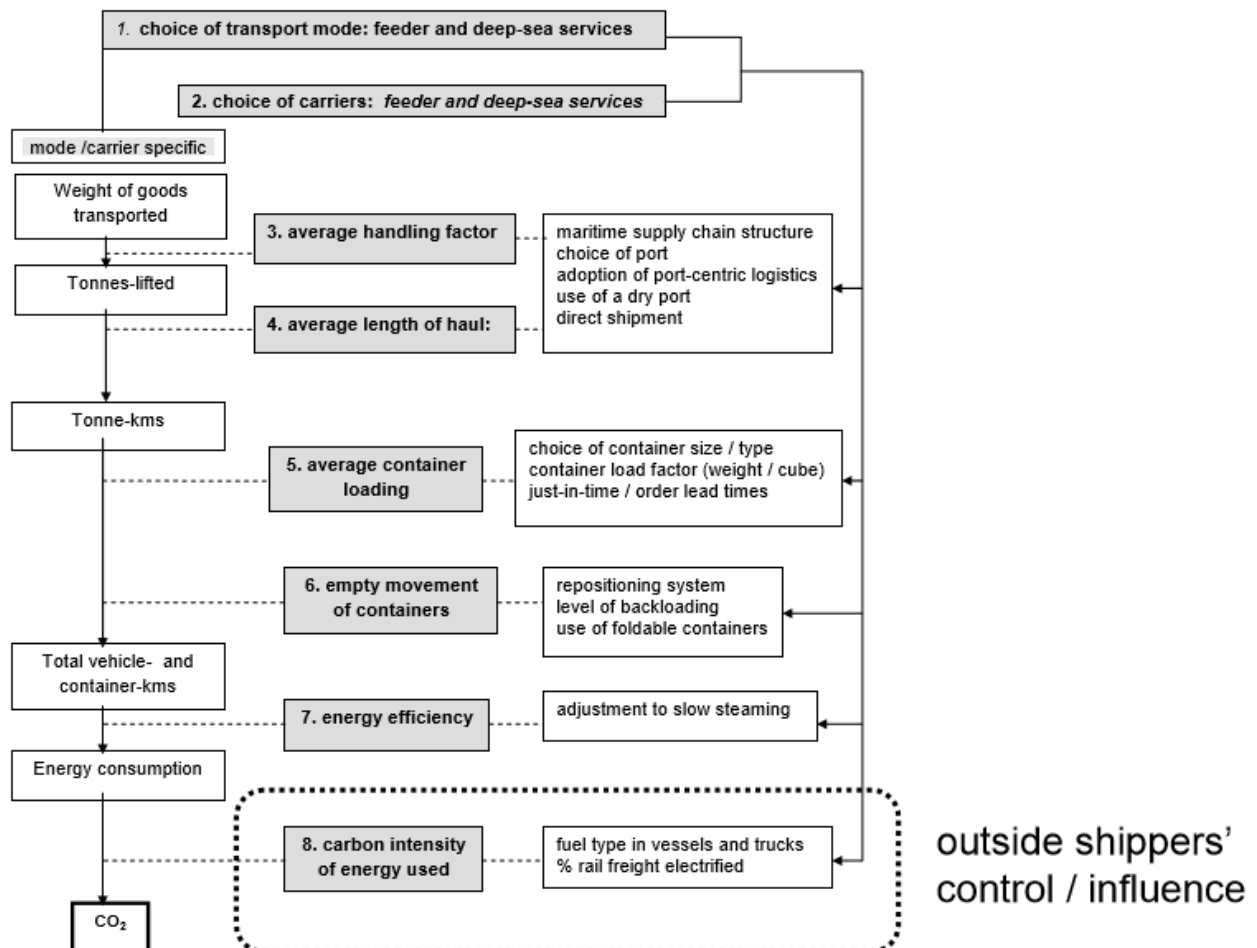


Figure 3-5 Conceptual framework for shipper's container transport decarbonisation strategy.

Source: McKinnon (2013).

Modal shift

Modal shift seems to be the most studied initiative on decarbonisation of freight transport. It is obvious that the focus has been on transport, since it involves a heavy consumption of fuel (Andress et al., 2011). Modal shift in terms of greening strategies means switching from more polluting transport mode to fewer intensive modes, e.g., road to rail, or short-sea shipping, aviation to long-sea shipping.

The most growing and the most polluting transport mode per tonne-km in the world is road freight, followed by aviation, shipping and rail freight. Truck freight and aviation have grown on the expense of rail and waterborne transport, however, aviation does not transport as much cargo volume as land transport (IEA, 2012).

Since 2000's, researchers started identifying the most efficient combinations of modal shift. Carlsson and Hammar (2002) stressed the importance of regulation of emissions in aviation, Kemp (2009) compared the environmental performance of short-haul aviation to other transport modes. Maritime transport and its CO₂ emissions performance gained interest from 2010. Eyring et al. (2010) as well as Psaraftis and Kontovas (2010) focused on externalities of international shipping and how it can affect the climate change. Increasing governmental discussions on inclusion shipping and aviation into emission trading systems from 2012 brought attention to technical and operational improvements within these modes.

As road freight transport has the most impact on the climate in terms of CO₂ emissions, most articles were written on this mode (Léonardi and Baumgartner, 2004). Some articles focus on comparison of CO₂ emissions from different modes, particularly on case study examples. Woodburn (2003) discusses shift from road to rail, Léonardi and Baumgartner (2004) summarize CO₂ reduction potential of road freight transport, Eyring et al. (2010) outline the atmospheric impact of shipping, Zhang et al. (2010) describe the contribution of air transport to global warming.

Intermodal transport gained the most significance as it is the most flexible and least costly effective substitution of road freight. It is executed by combining two

or more modes of transport using one shipping unit (container or swap body), where one mode is dominant. It is relevant especially when ports or railway terminals are not located nearby the factory or warehouse. Rail-based intermodal freight transportation systems in the European Union have been regarded as being more environmental friendly than truck-only freight systems, particularly for long-distance haulage and in terms of CO₂ emissions. Nam Seok and Bert Van (2009) compared different rail tractions to truck transport to demonstrate the emissions based on semi-life cycle analysis. They concluded that that in general rail-based intermodal freight systems emit less CO₂ than truck-only systems, regardless of the type of locomotive. For electric locomotives, “the electricity power-generating source is the definitive factor in deciding which type of train in an intermodal freight system offers the most environmental friendly alternative: if power plants use only coal or oil fuel sources, intermodal systems using electric trains could emit more CO₂ than their competitors” (Nam Seok and Bert Van, 2009).

There are other factors to be considered, such as route, energy source of the rail and type of truck engine. This was also confirmed by German study, comparing inland rail and truck networks, that for example trucks with 20 % biodiesel mixture are already competitive with railways which are using 39 % of renewable energy (Spielmann et al., 2011). International Road Union (IRU) compared 19 European routes, and concluded that CO₂ emissions decreased by 20-50 % due to using of intermodal transport instead of purely road transport (IFEU and SGKV, 2009). However, they also concluded that using combined transport (putting whole truck and trailer on the train, so called rolling highway) on European level, is rarely efficient.

On company level, generally companies decide on price of the total journey. Prices of rail / waterborne transports react slower to changes in fuel prices, than truck transport. Woodburn (2003) showed that there is an interest in modal shift in the UK, however operators need to adjust to preferences of their customers. In times of high oil prices, the truck transport is more affected than rail or waterborne (Woodburn and Whiteing, 2015). Other limitations of the companies' decisions on modal shift can be infrastructure, such as railway corridors or access to the terminals. The most significant difference in performance compared to road transport is in transit time, flexibility of delivery date and damage on goods (Evers et al., 1996). Eng-Larsson and Kohn (2012) indicate, that for shipper, rather a volume of demand and volatility of demand determine the implementation of intermodal transports, as the more stable volumes of goods shipped determine the price and time efficiency.

In the future, it is expected and required to improve communication of different country-specific railway and waterway networks to strengthen their position as alternative to road freight transport. To achieve this progress, usage of common ICT systems will be crucial for shipper's better planning. In a multimodal transport chain, it has been always a challenge to obtain real-time updates on shipment's location and status due to multiple players involved (Harris et al., 2015). With help of big data and cloud computing it should be possible to improve quality of these resources.

Vehicle load utilization

Vehicle utilization can be defined as **optimizing the carrying capacity of a vehicle**. Optimized vehicle loading was already key strategy in UK government's

first Sustainable Distribution Strategy (DETR, 1999). For companies, utilizing the space in vehicle is one of key factors of reducing total shipping costs. It can significantly improve environmental performance of the laden trip. Rizet et al. (2010) suggested that doubling the loading factor of HDV from 50% to 100% reduced the fuel consumption per 100 tonne-kms from 2.1 to 1.2 liters. Space utilization of the loading unit can bring significant reduction, e.g. completing heavy, high-density products with light, low-density products (Glaeser, 2010).

Table 3-1 shows that change in CO2 emissions caused by +/- 50% change in load from average loading factor is greater with higher vehicle capacity.

Table 3-1 Change in CO2 emissions caused by change in vehicle weight utilisation (EU ARTEMIS project)

Source: Adapted from RICARDO et al. (2019), p. 65

	Gross vehicle weight	% Change in CO2 emissions
Rigid	<7.5t	± 8%
	7.5-17t	± 12.5%
	>17 t	± 18%
Articulated	<33t	± 20%
	>33t	± 25%

Weight utilization should however not be the only KPI or determinant of capacity utilization, as also volume and density of the goods benchmark or influence the weight fill rate (Holden et al., 2016).

From the **multi-unit loading capacity** perspective, there have been studies focusing **on improving carrying capacity of trains or vessels**. In the past 50 years, the biggest progress in capacity growth was observed in container ships carrying capacity, as the large container ships achieve the highest economies of

scale per TEU/tonne-km carried (McKinnon, 2015b). The same applies also for trains, the more laden the train trip is, the better CO2 emissions result per transporting unit. Train load factor represents percentage of maximum weight of the train carrying capacity. The shorter the train and the lower its load factor, the worse CO2 efficiency (IFEU and SGKV, 2009). Further factors influencing the train or vessel utilization are port/station served, number of stops, direction of travel (import or export) and corridors (McKinnon, 2015b). Some of these determinants is hard to influence. For example, the import-export ratios between some European countries do not equal. Therefore, nowadays train operators try to set mandatory limits of booked train units and imposing penalty if the train is not fully laden (author's experience).

The third constraint is **empty running** of vehicles. It is a consequence of difficulty of balancing freight flows in opposite direction. It is expressed as proportion of empty kms to total kms driven. In 2010 on average in the EU, empty running was 24% (McKinnon, 2015b). It is estimated that this trend is improving, although the statistical evidence is not sufficient. T&E (2018) estimated truck empty running to 20%. Empty journeys, or transport of 'air' bring cost and environmental inefficiencies. In short journeys, up to about 300 km, finding shipment and reloading truck is less costly effective because driver spends much time with waiting at loading and delivery place and customers are willing to pay higher price. Thus, trucks are often running empty on return journey on purpose. Depending on delivery location, it is sometimes more cost efficient to send a truck empty to a location, for instance a rural area, where transports demand and thus freight rates are higher.

Fortunately, the ratio of partly laden or empty running vehicles is declining, thanks to gradual development of planning software, shared platforms of transport supply and demand and freight-auctions, where more hauliers have access to available cargo. For example in the UK, in recent 40 years, empty running is steadily declining despite of gradual increase of transport volumes (McKinnon and Ge, 2006).

Routing and scheduling

Optimal route and timing of a delivery can significantly contribute not only to cost aspect but also emissions. The nature of the route defines the amount of fuel consumed, thereof the amount of emissions produced (Baumgartner et al., 2008). Currently, there is various software on the market to achieve the best possible solution (Eglese and Black, 2015). Both routing and scheduling should be considered together as good route selection does not have to mean immediate CO₂ savings. Good timing of trips helps to avoid congestions and waiting, reduces idling and interrupted driving. Routing becomes more complicated when there are several customers to serve in one trip. This has been a subject of several studies and already in 1970's first book on IT systems in routing and scheduling was published (Sussams, 1971). Since then, numerous publications on this problem were written, mostly in the IT field of vehicle routing and scheduling problem (VRSP) modelling. However, these articles rather focused on minimising the costs. About decade ago, there was not much literature that links VRSP models with the green logistics issues (Eglese, 2007). Nowadays, latest software offers various options to visualise cargo movement and tracking in real time. This software can contribute to overall supply chain planning performance due to predictive analytics.

Nonetheless, since the reduction of fuel costs is linearly linked with reduction of fuel and thereof reduction of CO₂ emissions, and most of the trucks are equipped with routing software that can recognise traffic issues in real time, it can be considered as the best alternative for the CO₂ reduction from transport at no extra operational costs.

Technical improvements

The life span of trucks compared and their adaptability on innovative technology shows that truck transport is the fastest technologically developing mode. For example, the investment cycle of aircraft technology from designing of the new aircraft to recycling of the whole airplane can take up to 55 years (Woodburn and Whiteing, 2015). In the shipping, similarly, technological improvements are determined by size of the ship and type of cargo transported. Therefore, this chapter focuses more on heavy goods vehicles, however, recent shipping, aviation and rail innovations will be mentioned.

Heavy duty vehicles are responsible for about 26 % of total transport emissions in the EU (AEA/Ricardo, 2011). A comprehensive review and feasibility analysis of low carbon technologies for HGVs has been conducted by Ricardo (2009). They showed that “aerodynamic trailers, electric bodies and vehicle platooning may have the greatest CO₂ reduction potential” (RICARDO, 2009). In the UK, Ricardo (2009) concluded an analysis, which showed that 52% of energy loss is due to rolling resistance and 35% is caused by aerodynamic drag. According to Austrian research at Graz University, air resistance of vehicle is the main cause of energy loss of an articulated vehicle, which is responsible for 54% of total energy loss, followed by rolling resistance (25,2% of energy loss) (Hausberger and Rexeis, 2012).

There is a wide range of initiatives, that can be applied to reduce the energy loss and improve fuel consumption, therefore they will be divided into two areas, vehicle, and powertrain.

In this section, technological improvements on the outside of vehicle, train, airplane, and vessels will be reviewed. The engine efficiency and alternative fuels will be reviewed in next section.

Vehicle improvements

By vehicle improvement initiatives can be understood technologies that can be applied on existing fleet, such as retrofitting with aerodynamic equipment and tyres with low rolling-resistance. Long-term initiatives represent changes in the fleet for new trucks with aerodynamic shape.

Aerodynamic equipment retrofitting helps to eliminate the aerodynamic drag. This has significant impact on vehicle's fuel consumption (RICARDO, 2009). However, this has more than twice much carbon reduction potential, when applied on heavy goods vehicles over long distances, comparing to mid-size trucks in urban areas (Mohamed-Kassim and Filippone, 2010).

Figure 3-6 shows types of retrofitting on truck cabin and trailer. A case study by Department for Transport in the UK (DfT, 2010) on about 1000 tractor units with retrofitting showed, that 85 per cent of CO₂ reduction can be achieved by installation of a cab roof deflector on a tractor unit.

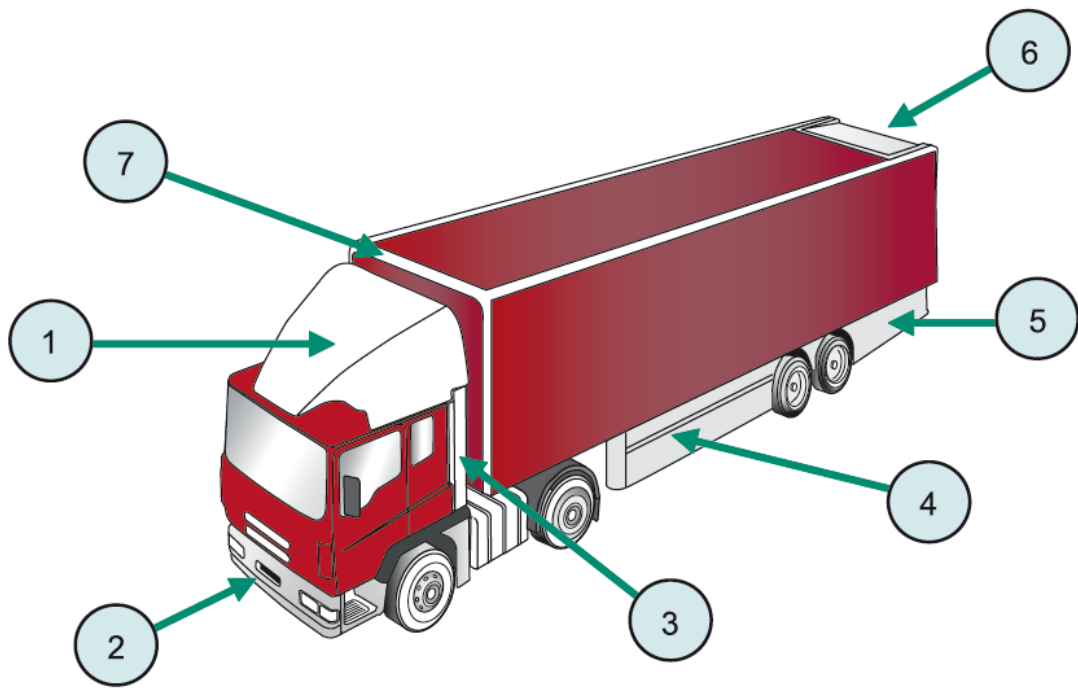


Figure 3-6 Examples of truck aerodynamic styling

Source: DFT (2010), p.12.

Key: 1. cab roof deflector, 2. air dam, 3. cab extension, 4. side skirts, 5. rear quarter panel, 6. roof tapering, 7. trailer front fairing.

While cab roof deflector is the most widely used technology already offered by truck companies as standard equipment, trailer aerodynamics needs more attention. For example, side skirts are gaining attention too, as there are few manufacturers on the market (for example Wabco's OptiFlow or Stemco's EcoSkirt). During their research project PART (www.part20.eu), TU Delft tested the additional installations on trailer and concluded that complete side skirts (SideWings) generate an average of 16 % drag reduction (Van Raemdonck, 2012). The foldable tail, placed at the back of the trailer, brought savings of 1,6 l / 100 km, however, for HGV, the dimensions are restricted by the EU regulation on maximum length of the truck (Van Raemdonck, 2012).

There have been various prototypes of aerodynamic trucks and trailers developed by main truck and trailer manufacturers, which can be found on their web sites. However, it is the demand of their customers, determined by the price, which result in their practical application. The Teardrop trailer by Don-Bur, where a trailer roof is shaped aerodynamically in a curve, has been successfully used by large parcel and retail companies such as TNT, DHL Deutsche Post, Morrison's and M&S and showed average fuel savings of 13 % with curtain side trailers and 11 % with box trailers.

Rolling resistance of tyres is caused by the contact between the tyres and the road. Manufacturers provide wide variety of tyres with low rolling resistance, which can reduce about 5 % CO₂ benefits and can be purchased at no additional cost (RICARDO, 2009). They bring more benefits on long haul. Automatic tyre pressure adjustment installations help to monitor and adjust tyre pressures depending on load weight on axles and terrain. They help to reduce the energy loss and tyre wear (DfT, 2009).

Reducing vehicle's tare weight using lighter materials can bring benefits in CO₂ savings by increased payload of the vehicle (Léonardi and Baumgartner, 2004). AEA/Ricardo (2011) estimates that it can bring 1-2 % of fuel savings per tonne when using aluminium alloy. Europe's lightest trailer BergerEcoTrail™ is made of high resistance steel formed to thin hollow sheets, that can be loaded up to 3 tons payload more than usual trailers on the market, bringing 3-5 % of fuel savings.

Longer and heavier vehicles (LHVs) or high-cube vehicles (HCVs) have been widely used in other continents but in debate at European market since many years. Hence European logistics operations depend highly on standardized

loading equipment and trailers, limitations of each country's infrastructure must be considered. The main concern remains to be modal shift from rail and sea back to road causing increased CO₂ emissions and other externalities. This was demonstrated by Palsson et al. (2017) on Swedish example, as only Sweden has gradually increased maximum weight and length regulations of HDVs. Research on German market by Sanchez Rodrigues et al. (2015) showed, that companies would be actually interested in adopting of LHVs. It is up to governments to adjust the infrastructure, so this initiative will not be considered in further research of this thesis.

Powertrain improvements

Combustion systems in Europe are highly dependent on the governmental regulation and legislation. Euro-Norms regulate levels of greenhouse gas emissions and particulate compounds. Currently, the EURO VI norm is being applied at new vehicles. EURO VI norm requires adding AdBlue chemical to the combustion system.

RICARDO (2009) and AEA/Ricardo (2011) review the existing technologies for more efficient combustion, which can result in up to 2 % CO₂ reduction. Among these technologies are piston ring for reduction of friction, electric clutch – air compression to reduce the fuel consumption, oil pump to adjust oil flow, electric water pump for cooling engine, pneumatic booster system for pumping of compressed air from breaking into the air path for faster acceleration and turbocharging. Waste heat recovery systems were evaluated between 3-6 % fuel economy benefit. Technologies by Scania, John Deere, Caterpillar were examined. They are designed to recover the excess energy from exhaust gas.

Alternative drivetrains to those of fossil fuels, such as **hydrogen** fuel cells and electric vehicles were mostly examined.

Hydrogen drivetrains could replace in the future technologies, where batteries are too heavy, such as aviation and sea freight.(Bannon, 2020b). Airbus already presented its future prototypes of commercial airplanes that target to have right technology by 2025, although experts expect this to arrive around 2040 due to safety reasons and infrastructure at the airports (Bannon, 2020a). For HGV, there is no good hydrogen fuelling infrastructure yet, the payload would be smaller due to weight of the battery, and possibilities for manufacturing are for 7.5 tonne vehicles in small batches only. Sourcing of hydrogen is also controversial topic, as it can be manufactured either from coal or natural gas, which are fossil fuels, or as a by-product of renewable biogas, but the method of electrolysis, which has high energy requirements (Grant et al., 2015). Storage and transportation of hydrogen is very costly, compared to direct usage of electricity in battery powered vehicles Bossel (2006) as shown in Figure 3-7. On the other hand, corporate enterprise Anheuser-Busch considers to exploit this technology by renting 800 hydrogen-powered trucks Eccarius and Lu (2019).

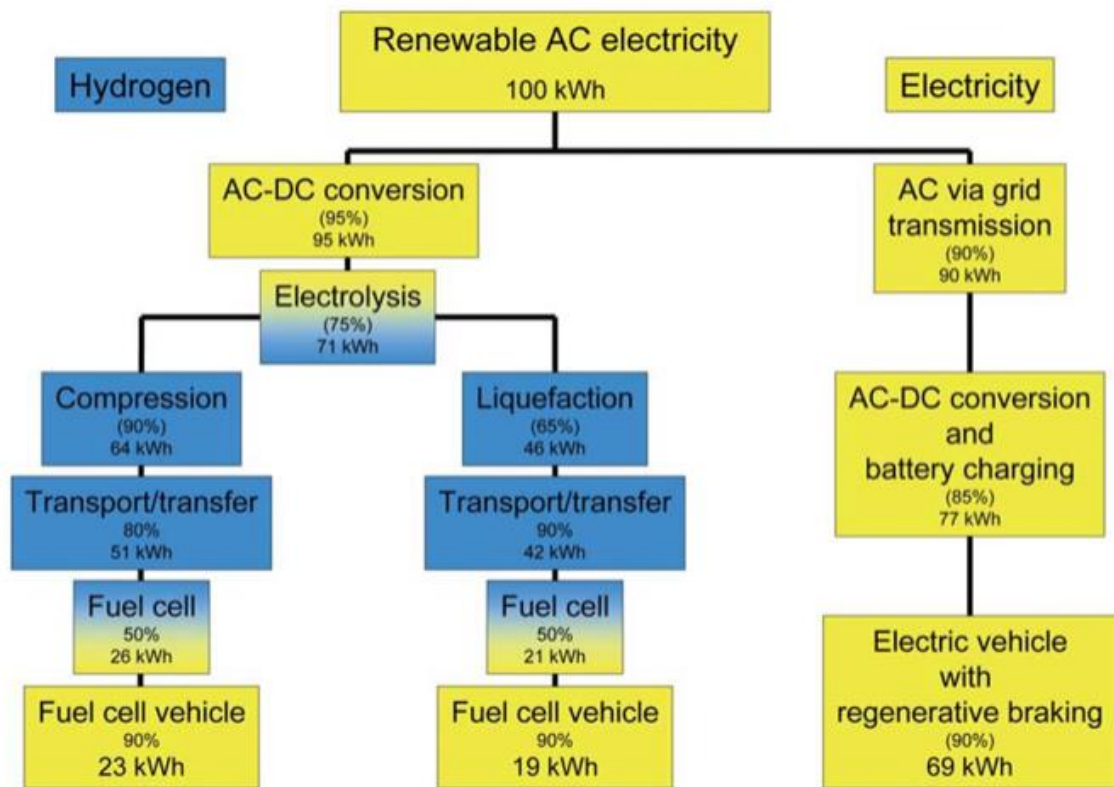


Figure 3-7 Useful transport energy derived from renewable electricity

Source: Bossel (2006).

Electric vehicles emit about 40 % less CO₂ than conventional diesel trucks, depending on the energy source (DfT, 2009). Most progress has been recorded recently by improving the range of battery and net weight of the truck. Various parcel shipping companies have been using small electric vans in urban areas. In 2017, Deutsche Post DHL Group started mass production of their own van brand StreetScooter which will be one of the steppingstones towards their 2050 zero-carbon strategy. The largest model will be able to transport 20 cubic meters of cargo (DeutschePost/DHLGroup, 2017). Benefits such as exemption from urban congestion charge, low emission and operation, and low maintenance costs have been observed (AEA/Ricardo, 2011). Downside of electric vehicles is still the size and weight of the battery. There are no commercially viable electric large HDV on the market yet (Leonardi et al., 2015). As of 2018-2019 an US

company Tesla presented heavy-duty vehicles, currently ordered in small numbers by DHL and Wall-Mart. Production is currently planned for 2021. An Austrian company Magna developed first electric truck for their in-house logistics operations that are being currently tested. Nowadays, there are many concepts brought out by other leading truck manufacturers as Daimler, VW, Volvo, who try to catch up with this development.

Hybrid vehicles contain a powertrain which combines more sources of energy to propel the vehicle (for example electric-diesel, gas-diesel). CO2 savings by electrical hybrids are also more significant in urban areas. There is still an obstacle of lower payload for heavy duty vehicle due to lower engine strength comparing to conventional diesel vehicles.

Conductive electrical transmission is being tested on German and Swedish roads by Scania, using overhead wires where the trucks can connect and disconnect, as far as there is an infrastructure on the route. These systems enable to reduce fossil fuel emissions by 80-90 % (Scania, 2015).

A survey conducted by LCRS (UK Logistics Carbon Reduction Scheme) showed that educating the members on existing technologies shows better progress in CO2 reduction (FTA, 2016).

Alternative fuels

Heavy goods vehicles run almost entirely on diesel, which brings concern to governments about transport's impact on climate change. Therefore, several alternatives, mainly biofuels and natural gas have been examined and supported by the EU.

Figure 3-8 describes the mix of main ingredients used in alternative fuels.

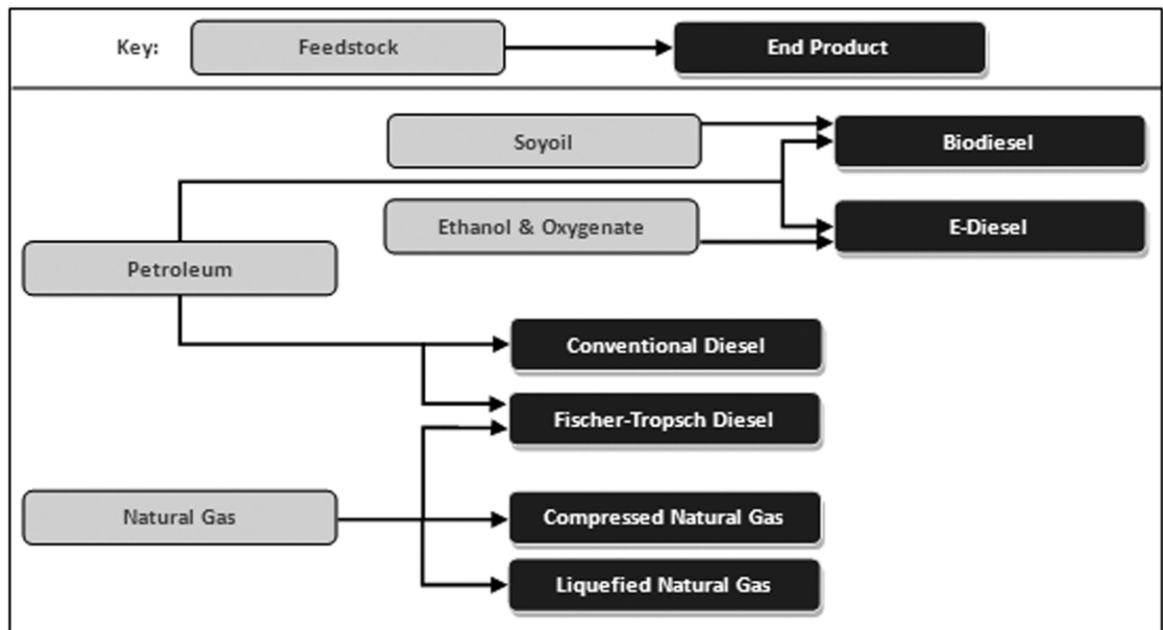


Figure 3-8 Fuel pathways from feedstock to product

Source: Mayer et al. (2011), p. 287.

Some alternative types of fuels are being currently used or tested (Leonardi et al., 2015). Biofuels are liquid or gaseous fuels produced from organic matters of plants or animals. Since 2000's biofuels of 'first generation' such as biodiesel have been widely financially supported by the EU, but there has been controversy of taking up the land originally used for edible food crops (Whittaker et al., 2011). Currently, there are projects undertaken on development of 'second generation' biofuels, which use woody crops and straw, and 'third generation' produced from seaweed (Allen et al., 2016). Most of the EU regulation supports nowadays only sustainable production of biofuels, which means no production on possible food crops fields and no production from land with high carbon stocks such as forests (Adams et al., 2015). Bioethanol is the major fuel source in Brazil. Main crop for this alcohol-based product is sugarcane. Generally, most of Brazil's production is considered as sustainable and it has been calculated that even import of

bioethanol from Brazil would meet EU CO₂ reduction targets. (Walter et al., 2011). Biomethane is a natural gaseous fuel produced mainly from agriculture waste and in smaller range from food waste.

Increased popularity of biodiesel and bioethanol is due to their ability to blend with conventional fuels, with no engine modifications (Leonardi et al., 2015). In the UK, 87 % of biodiesel was manufactured out of cooking oil in 2011/2012 compared to 51 % in 2010/2011 (RICARDO, 2013). Until 2010, biodiesel was more expensive than conventional diesel as it was produced from vegetable oils, however price of biodiesel from recycled cooking oil will be comparable to conventional diesel (Math et al., 2010). For example, company McDonald's is already using their old cooking oil for fuelling their distribution trucks.

Natural gases such as Natural Gas (NG), Liquefied Petroleum Gas (LPG) and Compressed natural gas (CNG) are only sustainable, when they do not originate from fossil fuels; when manufactured from methane, their CO₂ emission levels are slightly lower than diesel (Leonardi et al., 2015). There is also still low infrastructure for refuelling, however, UK and EU are conducting research projects about potential refuelling stations (FTA, 2013).

Meyer et al. (2011) examined total fuel-cycle analysis of alternative fuels for HGV in terms of energy and emissions and concluded that the best results gained CNG and biodiesel (B20 type in the United States results). They state that the measurements must be executed on same vehicles with the same shipments, as the data can be biased by truck payload and truck efficiency (technology as well as driver behaviour).

Currently, vehicles using alternative fuels and powertrains still have high purchase prices and there is low operational research and robust data to underpin the return on investment (Leonardi et al., 2015). For example, CNG vehicles were 20-25 % more expensive and new biogas vehicles could be 25000-35000 GBP more expensive than diesel trucks (RICARDO, 2009). Distance range of CNG vehicle is about a quarter of a diesel vehicle Burke and Zhu (2014). As the infrastructure in urban areas is increasing, it is comparable to use CNG vehicle with diesel vehicle on short routes and payback period is about 3 years.

In conclusion, there is no single best substitution of diesel. There is broad agreement that all sustainable fuels will be needed to fully meet the expected demand (IRU, 2012). For each organization, it will depend on the nature of the services and on accessible infrastructure. Recent interviews indicated that there is currently much uncertainty among carriers about the availability, distance range and infrastructural requirements of alternative fuels and powertrains and they are unsure which technology will settle down in long run (Toelke and McKinnon, 2021).

Driving behaviour training and driver incentives

Eco-driving training is regarded as the most efficient and feasible measure for fuel efficiency (McKinnon, 2015c). It includes de-speeding, more fluent driving, reduction in gear changing, less breaking and anti-idling.

Schweitzer et al. (2008) conducted a survey of 400 000 truck drivers in the US and found that drivers themselves might not be always environmentally thinking in everyday practice, however, they are aware of fuel costs and savings. Hence,

it is needed to encourage and remunerate the fuel savings. Although some of them might be environmentally concerned, there are other aspects such as time pressure in deliveries, traffic jams and other obstacles that they cannot influence.

Case studies conducted by SAFED (Safed and Fuel Efficient Driving) in the UK, showed that driving training brings 10 % of fuel efficiency, however, this might decline with the time after initial training session (RICARDO, 2009). Therefore, driver motivation, such as financial and other incentives and regular briefing on their fuel performance helps to maintain the performance over long term (McKinnon, 2011)

De-speeding is also a topic of discussion, as only 10 km/h speed reduction can bring significant results. On the contrary, the more kilometres a truck can drive per week and the more of his working hours driver can use, the more profit is gained, so this does not become very popular with truck owning companies. However, some of companies introduce maximum speed of 80 km/h. In international shipping, long-route de-speeding can bring significant savings (Corbett et al., 2009). Non-time-sensitive and non-perishable goods are the ideal cargo.

Recent research shows that in the future, also freight distribution systems will be designed with significant level of automation. 10 UK experts interviewed in 2014 reckon that stepping from human factor needs to be very advanced on safety level (Bedinger, 2014). They suggest following pathway towards future technologies (Figure 3-9).

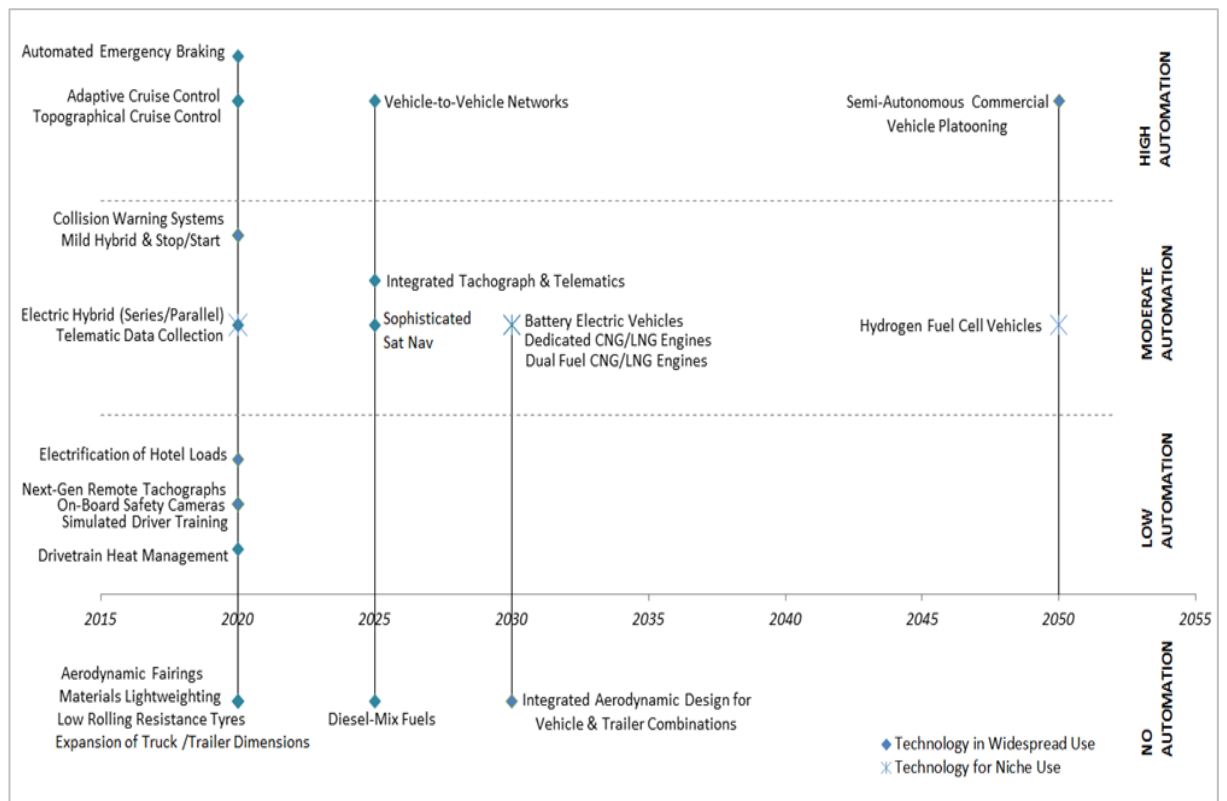


Figure 3-9 Roadmap of commercial vehicle technologies in UK, 2020-2050

Source: Bedinger (2014), p.5.

Increase of applications working on Physical Internet and cloud databases are expected to increase productivity of physical transport. Freight companies who use the software will be able to re-invest the gains to fleet modernisation (ALICE-ETP, 2019). Currently, telematics and transport management systems on company level are used to monitor efficiency of fleets. In the future, shared platforms will overtake planning and combining cargo efficiently. There has been lack of research on support of IT system on decarbonisation in freight transportation but practitioners in 60 percent of UK retail industry confirm that telematics, better transport management system and supplier management systems are positively contributing (Sanchez Rodrigues et al., 2015). They also expect more collaboration systems to appear in the future.

3.3.2 CO2 reduction initiatives in warehousing

The major CO2 reduction measures in warehousing relate to energy efficiency of a warehouse. Depending on location, lifespan, purpose, and products stored, different measures can be undertaken. Also, efficient use of resources and optimising daily operations can contribute to operational sustainability (Grant et al., 2015). As already mentioned in the first chapter, warehousing emissions can be divided into two groups – embodied and operational.

Freis et al. (2016) recently identified relevant base elements of CO2 emissions from warehousing (Figure 3-10). They suggest that it depends on level of automatization of warehouse, whether the building or the equipment consumes most of the energy. In low-automated warehouses, the focus should be on building equipment and optimizing forklift driver's work processes. In highly automated warehouses the focus should be on sourcing green energy to fuel the system, as it is expected that automated warehouses already have high-level of optimisation. They suggest that due to different usage types of a warehouse, their model is too general for a specific estimation of energy calculation during the planning stage (Freis et al., 2016).

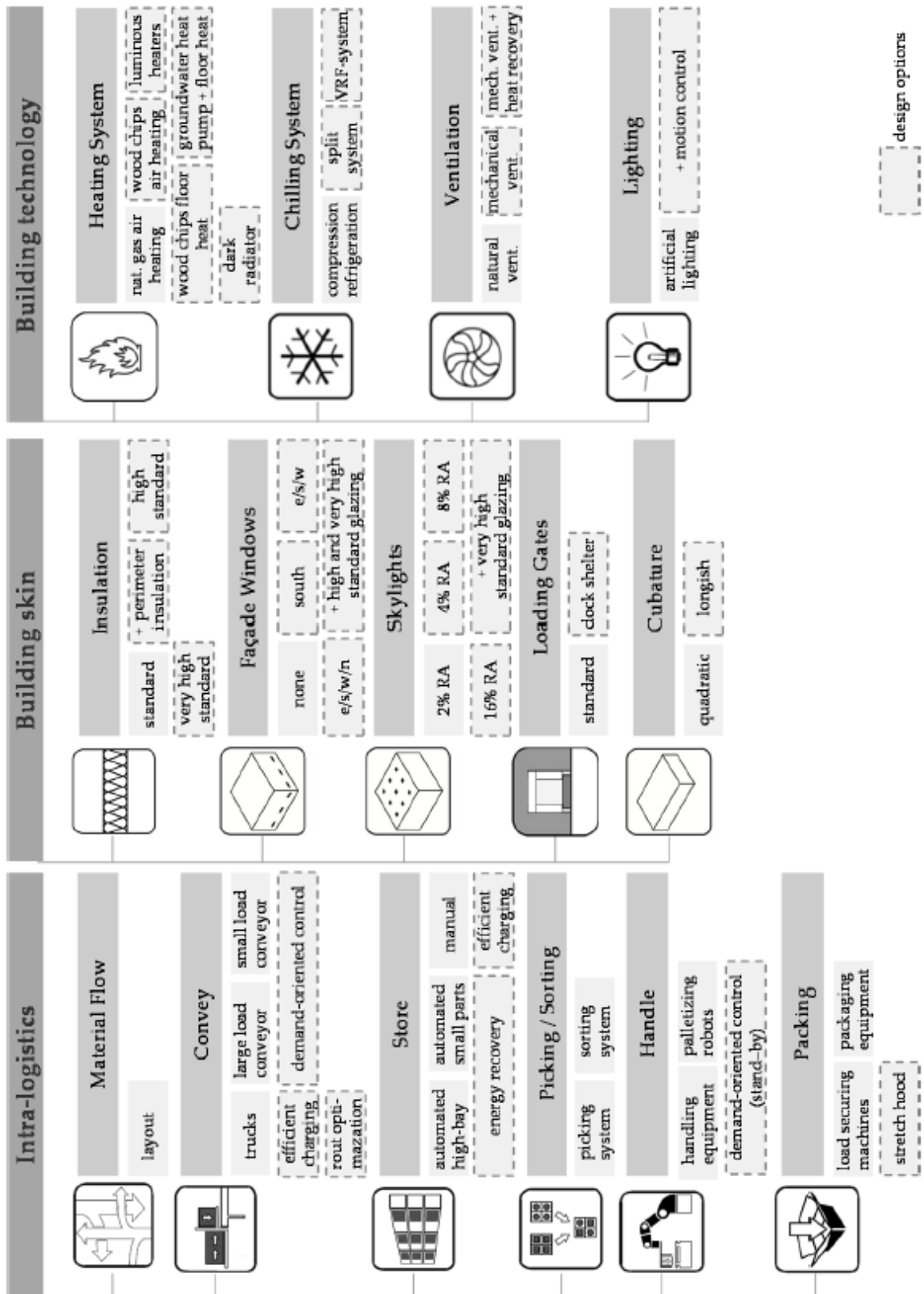


Figure 3-10 Used energy-efficient design options for the modelled base case elements of the reference building models. (RA = roof area; VRF = variable refrigerant flow)

Source: Freis, Vohlidka & Günther (2016), p. 6.

By considering all elements, overall CO2 reductions from warehousing can be achieved. This section analyses measures that were subject of previous research.

Sustainable envelope materials and design

Embodied emissions stem from the envelope construction of the warehouse, and CO2 intensity of its materials. It is also important to distinguish what scope of emissions are incorporated. Sustainable warehouse building should not only incorporate sustainable materials, but also their sourcing and construction site emissions. When comparing concrete and aluminium envelope, concrete wall contains about 20 % less of embodied energy than aluminium wall, but the life expectancy is about double (RICS, 2010). Wood has much less impact, when sourced locally and is more sustainable than aluminium and concrete (Grant et al., 2015). Insulation width and materials should be aligned with operational requirements and type of lighting and heating equipment (Rai et al., 2011). The thickness of insulation reduces energy loss, the thicker the insulation, the higher embodied energy in the insulation material (Harris, 1999). However, as logistics and storage requirements progress constantly, it is unlikely that warehouse has the same operations and equipment during its lifespan. Rather than the envelope design, the sources of energy can significantly save CO2 emissions.

Sustainable energy source

Purchasing of green energy is highly associated with operational emissions. This largely depends on source of energy in local area or by country. Despite of that,

investments in green energy have risen significantly and since 2015, the prices are lower than of fossil fuels generated energy. Many large distribution centres generate their own energy from solar panels, wind energy, kinetic energy or waste processing (Marchant and Baker, 2015). This choice also depends, whether the warehouse is automated and more energy requiring, or it still relies highly on human labour and energy consumption comes mostly from lighting and heating/cooling systems. When building own energy generators, managers mostly look at return of investment of this costly installation. For example, the cost of small wind turbine per kg of CO₂ saved is about ten times higher than that of conventional large-scale wind turbine (GBC, 2010). Nonetheless, recently governments started to promote low-carbon energy and own generation, therefore the developers can apply for funding (Grant et al., 2015).

However, the bottom line of all warehousing energy savings is its efficient operational usage. Energy efficiency can be achieved by following baseline activities (Marchant and Baker, 2015):

- Appropriate lighting
- Energy efficient heating & cooling systems
- Active maintenance and control
- Measuring building energy performance
- Efficient air conditioning

Energy efficient warehousing equipment

In distribution centres that are leased and operated for a part of a lifespan of the building, managers prefer to invest in energy saving operation equipment. In

manually operated and semiautomatic warehouses, the type of forklift used can largely contribute to energy saving. The most used forklift fuels have been diesel, LPG and electricity (Johnson, 2008). There are plenty of new technologies such as electric hybrid forklifts (AC powered are more efficient than DC powered), forklifts with hydrogen fuel cells and propane forklifts (Dukic et al., 2010). The scope of emissions measurement needs to be considered. In a more holistic view, energy output of a forklift is not the only benchmark for evaluation of the whole CO₂ reduction contribution potential, but also sustainability of its production, materials, transport, and maintenance materials needs to be considered. In real practice, LPG is more CO₂ efficient than electric (Johnson, 2008). Hydrogen fuel cells are more cost-binding and also less energy efficient to operate than accumulated energy batteries (Renquist et al., 2012). Hosseinzadeh et al. (2013) measured energy outputs of the various types during two different operating speeds. The most efficient one was hybrid technology when combining 110-cell stack with two strings of 55 Ah batteries.

Handling equipment and its usage

The similar principles of effectiveness in driving HDVs apply to forklift operations. The energy used to propel the forklift systems can be also regulated by saving unnecessary operation. For this reason, warehousing management systems (WMS) that communicate with forklifts are being used (Grant et al., 2015). There are other factors that need to be considered, such as using right size of forklift and maximising its deadlift, source, and method of refining of the fuel, sustainability of fuel cells, efficiency of fuel usage, such as maintenance, sustainable driving, and charging (refuelling) frequency. Usually, electric batteries

are being charged overnight, while hydrogen forklifts only need few minutes. Therefore, hydrogen forklifts are being employed in warehouses with 24-hour operations.

Energy efficient lighting

Depending on operations and types of racks in the warehouse, whether it is automated or man-operated, the energy consumption by lighting differs. A study by UKWA (2010) concluded that lighting uses up the most of the energy used in warehousing, accounting for about 65 % of whole energy consumption. In contrary, DECC (2013a) found that heating is the most impactful energy consumption contributor (37 %), while lighting is responsible by 29 %. Hence, it is necessary to consider various factors contributing to lighting efficiency. The most efficient light bulbs are currently LED (light emitting diodes). They consume 65-85 % less energy than halogen light and have long life span (Marchant and Baker, 2015). They also have a short payback period (Grant et al., 2015). Where possible, roof windows should be installed to allow daylight to enter the building. They need regular cleaning and maintaining, as dirt and dust contributes to lower light efficiency (Marchant & Baker, 2015). Switching lights on and off according to usage also influences the amount of consumed energy. The best efficiency can be achieved by movement sensors.

Alternative heating and cooling systems

Depending on the type of the warehouse, whether it is general cargo or perishable cargo stored inside, different heating and cooling options are available. The most sustainable appear to be wood chips, which can reduce CO₂

emissions at temperature of 17°C up to 50 % (Freis et al., 2016). Air warmth pump and ground water heat pump are other good options. In optimal geological locations, geothermal stations are a suitable solution as they provide natural, zero-carbon-intensive source. The amount of energy consumed by heating is also influenced by external temperatures, insulation and envelope material of the building (CarbonTrust, 2006). Air circulation systems also significantly contribute to energy consumed by heating or cooling systems. Unnecessary change of temperature can be avoided by installing automated gates and doors and smart separation of warehouse areas (Marchant & Baker, 2015).

3.3.3 CO₂ reduction initiatives combining transport and warehousing

This part aims to point out those initiatives that are common for the whole distribution system. Transportation and warehousing should be considered also holistically to ensure the best possible CO₂ reduction. With regular inventory optimization and reduction of driven trips, company can reduce its emissions by no additional investments needed (Tang et al., 2015). However, the role, that whole logistical system can play in environmental concerns, has not been researched much (Aronsson and Huge Brodin, 2006). Therefore, also articles on logistics optimization beyond environmental impacts were considered. Thanks to this view, new initiatives for the reduction in CO₂ in logistics were found.

Centralization of warehousing implies a change from several warehouses into one central warehouse. It brings reduction in inventory keeping and reduces warehousing emissions (Kohn and Brodin, 2008). From a holistic view, reduction in the number of warehouses significantly reduces the emissions despite the fact

that it brings an increase in tonne-kilometres of goods transported (Matthews and Hendrickson, 2002). Figure 3-11 explains the difference between centralized and decentralized distribution system.

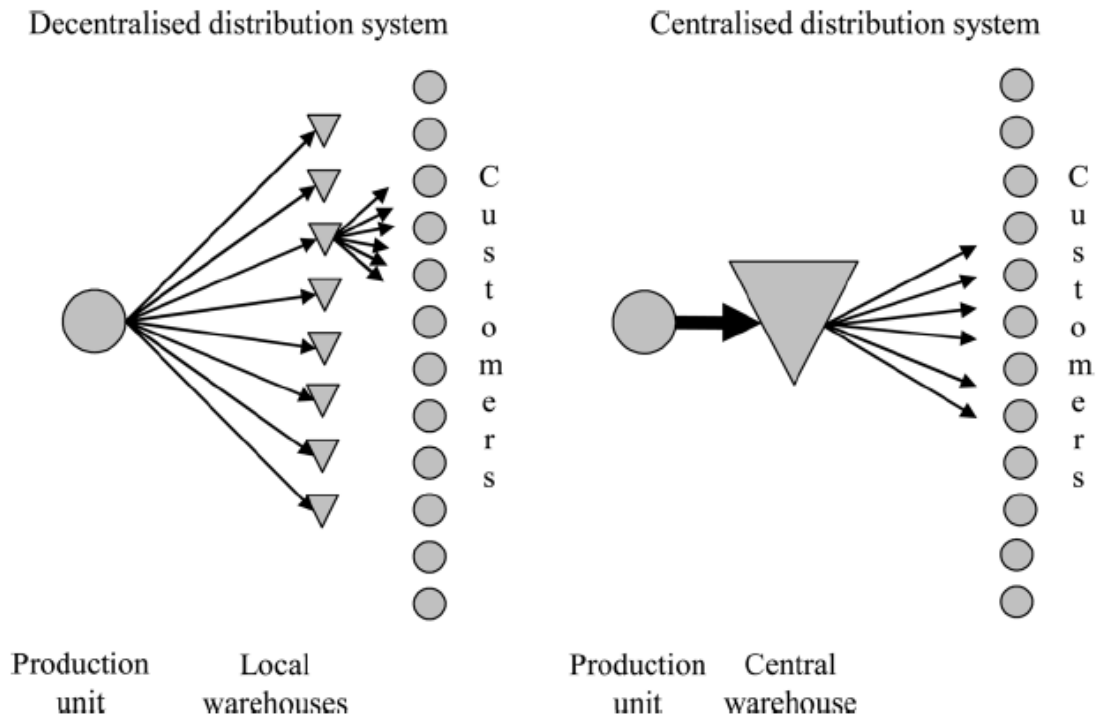


Figure 3-11 Generic illustration of transport flows in decentralized and centralized distribution systems.

Source: Kohn and Brodin (2008).

Investing in IT systems to improve computerized routing and scheduling evaluating routes to more warehouses can bring also emissions savings (Baumgartner et al., 2008). Looking at the supply chain model, managers need to decide upon trade-offs in terms of where to store the goods, how much inventory to create, when the goods should leave the warehouse and other considerations. Harris et al. (2010) focused on logistics network redesign and its environmental impact. They studied the existing Pan-European case study from the automotive industry by (Hammant et al., 1999) and extended its cost performance into environmental performance using the centre of gravity method.

They compared CO2 emissions in supply chains within 1-5 depots and found out that the most efficient number of warehouses is 3 (for the European automotive market) and noted that also vehicle optimization is crucial for CO2 reduction. These calculations were however focused on one product range, and therefore cannot be generalized for all industries. Kohn and Brodin (2008) conducted research on centralized distribution systems and their impact on environment. They focused on the distribution chain from Sweden to Belgium via a centralized warehouse in France and concluded that centralization decreases emissions as well as costs. In this research paper, they also stated that centralization enables consolidation, which has a positive impact on CO2 emissions. Also, thanks to higher capacity of a centralized warehouse, emergency orders decrease. They also identified another positive impact for the future improvements, which is bargaining power. The more transport services are procured, the more vehicles are serving the route and therefore the company may apply pressure on its logistics service provider to improve its environmental performance.

Sometimes, however, centralization might be environmentally harming, as it increases distance of journey per laden trip (McKinnon, 2003). Therefore, it is crucial to compare various possibilities of the supply chain and pick the least CO2 emitting one. In chemical industry, it was found that disintermediation, in other words allowing larger shipments to bypass distributor and deliver from plant directly to customer, eliminating handling in the hubs (McKinnon and Piecyk, 2011).

Consolidation can be understood as grouping different shipments into vehicles to utilize their carrying capacity and increase fill rate. The aim is to regroup

inbound transports in one warehouse in order to reduce the number of outbound shipments (Edwards and McKinnon, 2009). An increase of load factor of vehicles leads to a decrease of number of shipments, total fuel consumed and therefore emission savings (Aronsson and Huge Brodin, 2006). As said above, consolidation is even more efficient when using centralized logistics systems, because centralization is a source of larger volumes of shipments. Kohn and Brodin (2005) showed in their case study that it is possible to achieve positive environmental outcomes while reducing costs and increasing service quality.

From urban perspective, consolidation centres help to reduce number of trucks coming into the city (Edwards and McKinnon, 2009). City councils and 3PL providers collaborate to attract companies to unite their logistics within one logistics service providers. Following environmental benefits were observed on the UK market, which are applicable for any other country (Edwards and McKinnon, 2009):

- Improved vehicle utilization
- Using electric vehicles offered by LSP for urban transportation
- Using of bus lanes for transport and therefore reduced idling
- Recycling of packaging waste and coordinated returns

Collaboration can bring gains not only in the cost and resource effectiveness but also on the environmental level. Following challenges are tackled by collaborative striving (TRI-VIZOR and GS1-Belgilux, 2014):

- Underutilization of delivery vehicle capacity
- Empty return trips

- Suboptimal drop sizes
- Suboptimal or conflicting delivery windows
- Congestion risk
- Unpredictable drop dates and delivery schedules
- Demand variability with peaks and lows
- Suboptimal inventory rotation
- Suboptimal on-shelf availability

Horizontal cooperation represents collaboration of two or more independent companies, that can share same type of distribution systems such as types of warehouses or transport modes for their overlapping freight flows (McKinnon, 2015b). Distribution systems are being outsourced and therefore cost and emission savings are being achieved by 3PL logistics service providers. Transport units and warehouses are filled better and therefore fewer shipments are required. More companies have also higher leverage to influence environmental requirements on their logistics service providers. In the UK, there have been several examples on horizontal cooperation within the retail industry (Ramanathan et al., 2014). Palmer and McKinnon (2011) conducted a research on 27 members of Consumer Response (ECR) UK Sustainable Distribution initiative, where they collected data on their supply chain movements in one month and came to conclusion that they could save 14,6 % of kilometres on full truck movements and 14,5 % of CO₂ emissions, if they shared information about their truck flows and capacities. The savings could be also achieved by collaboration on intermodal networks by securing space fill of trans.

Vertical collaboration involves companies on different level of supply chain (McKinnon, 2015b). It can be achieved via upstream (with supplier) or downstream (with customer) collaboration within the supply chain of a company. Not only on technological level, such as implementing philosophy of manufacturing environmentally friendly products, but also on operational level (Vachon and Klassen, 2006). For example, a retailer, as a centre of the network, provides data about material flows to its suppliers to tackle challenges mentioned above.

Vachon and Klassen (2008) point out that collaboration within departments in the company can achieve distribution requirements reduction. For example, the procurement and logistics department may plan shipments and stock keeping simultaneously. This is mostly being achieved where inter-related processes are co-located on the same site, however new IT solutions in supply chain management and synchronization of ERP systems in multinational companies have significant potential. The green capabilities within supply chain management can be developed already with training and overall strategy of the firm (Bowen et al., 2001).

Importance of other supply chain activities impacting logistics system

As McKinnon (2007, 2014) points out, supply chain structure is one of determinants of decarbonisation success. Number of suppliers, linkages, customers, frequency of shipments, minimal order quantity can influence performance of freight transport and warehousing. Additionally, demand of producing factory can be adjusted to demand of customers by better supply chain planning.

Postponement of deliveries, or delay until the last possible moment enables the right consolidation quantity (Waters and Rinsler, 2016). Communication of sales and customer can imply better operations in warehousing (e.g., reduction of handling) and in transportation (e.g., reduction of vehicle capacity needed).

Vendor management inventory gives customer responsibility for inventory costs and thus reducing unused goods laying in the warehouse and consuming energy (McKinnon and Piecyk, 2011).

Flattening daily demand, or same number of transports every day reduces truck idling on parking places, shortens time on site and helps better forecast warehouse operations. Reduction of artificial peaking of transports at the beginning of the month can be supported by relaxing monthly order-invoice cycles (McKinnon and Piecyk, 2011).

Reverse logistics is probably the least studied operational component (Sarkis, 2003). Reverse logistics is associated with collection and recovering or disposal of used products (Ilgin and Gupta, 2010) with intention to reduce, reclaim, recycle, remanufacture, reuse volume of unused products in the supply chain (Govindan et al., 2012). In logistics processes this may be recycling the claimed products back into the production or reusing multiple-way pallets and packaging. It started to be researched more intensively in the beginning of 20th century, as more customer service and marketing came into consideration. Council of Logistics Management defines it as “term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes a relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials, and disposal”. It can be also

identified as “closed loop supply chain management” which gained attention in 21st century (Rubio et al., 2008). Following Figure 3-12 shows logistics processes that are included in reverse logistics.

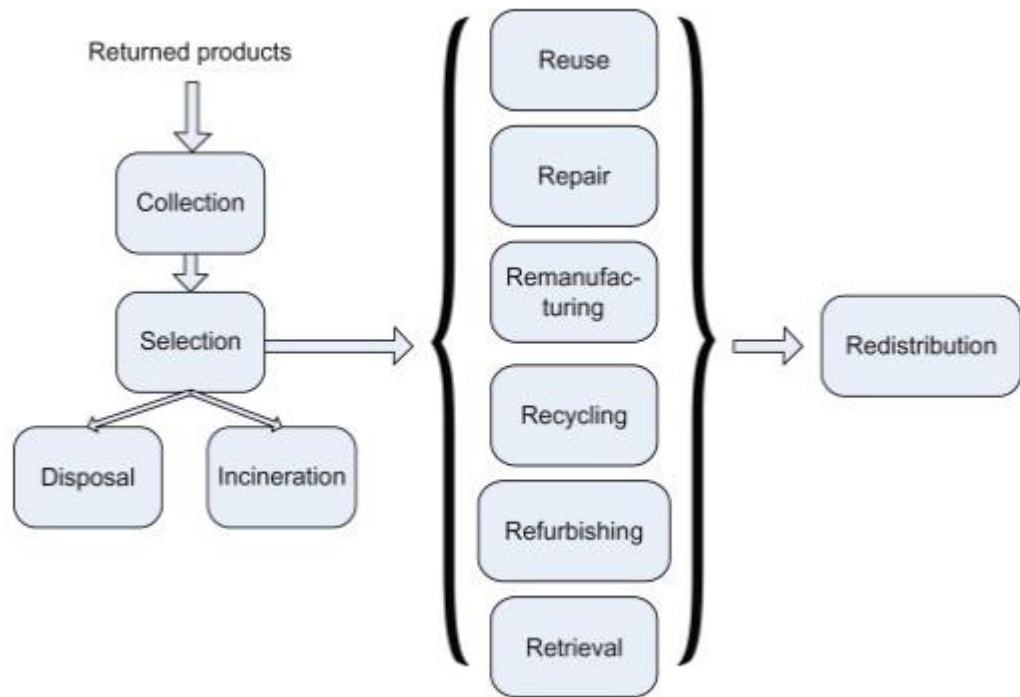


Figure 3-12 Reverse logistics processes

Source: Farahani (2011)

Choice of packaging size and form can bring economic benefits and utilize warehousing and transportation space (Molina-Besch and Pålsson, 2016). There have been numerous studies on benefits of quadratic packaging compared to circular ones.

Logistics network design can influence freight as well as warehousing costs. Moreover, placement of warehouses, hubs, ports, and transshipment points can

influence total impact on environment. As ports are placed with respect to decarbonisation of freight route, initial decision making as well as measuring the environmental effect of different options is critical (Dekker et al., 2012). Not only a well-placed hub, but also well-orchestrated green internal logistics can be a point of choice in environmental considerations of port activities. Equipment manufacturers prefer electric motors to diesel and smart port layout can reduce internal movements (Geerlings and van Duin, 2011).

3.4 Firm competitiveness and Resource-based Theory

It has been debated by academics, whether and how firms' adoption of an environmental orientation would enhance their competitiveness (Garza-Reyes, 2015). Large body of research shows the positive impact of green logistics or GSCM on internal and external performance and competitive advantage. Regarding internal advantages, the personal ideology and knowledge of leaders explicitly transfers on the employees by sharing knowledge and influencing corporate values, that reflect into collective consciousness (Chan et al., 2012). From the external viewpoint, it helps increase value for customer and competitive intensity strengthens customers willingness of cooperation (Chan et al., 2012).

3.4.1 Resource-based theory and strategic implication

Many SMEs do not acknowledge their environmental impact because they compare themselves to large corporations as too small to be able to influence anything (Ghadge et al., 2017). Where there are no mandatory regulations on

logistics carbon reporting yet, the action and persuasion must come from within the company as a strategic decision (Grant et al., 2015).

Strategy defined by Grant (1991) in this context as

“a match that organisation makes between internal resources and skills...and the opportunities and risks created by its external environment” (p.114).

Grant’s resource-based theory (RBT) confirms that a firm’s strategy is a valuable resource that guides strategic performance, resources and their capabilities determine firm’s capacity to establish a competitive advantage and knowledge is the most important resource of a firm (Grant, 1991). The competitive advantage rather than external environments is the primary source of interfirm differentials between profits of two firms.

Grant (1991) indicated that the case of making foundation of long-term strategy of the firm rests on two premises:

- First, internal resources and capabilities provide the basic direction for a firm’s strategy and in case of external environment being in flux, they are much more stable basis to define its identity
- Second, resources and capabilities are the primary source of profit for the firm

Resources of a firm are tangible, for manufacturer or forwarder they are truck fleet or a warehouse; or intangible, such as skills, capabilities, know-how. Knowledge takes longer time to develop, whereas tangible resources can be inquired in short-term. Know-how to leverage the tangible resources in the most

efficient manner makes the competitive advantage between two firms and according to evolutionary economics theory, they can outperform competitors who build their strategy on tangible resources (Barney, 2001). Intangible resources are most likely sources of firm's long-term success (Kamasak, 2017).

Lately, CSR reports have been not only a tool of external communication of company's sustainable striving but also a benchmarking tool with competitors in the same industry. It also sets internal motivation for managers to set goals and measures to improve throughout following years. Competitive landscape as well as informed customers (which corporations mostly are) add high pressure on SMEs' environmental performance (Garza-Reyes, 2015).

3.4.2 Resource orchestration perspective

From an resource orchestration perspective, SMEs can even learn from their corporate customers which was demonstrated by (Gong et al., 2018) on case study of IKEA's and Nestle's Chinese supply chain. They suggest three stages: setting up new functions and mapping the supply chains, operating internally, or identifying potential external knowledge partners and sustaining this knowledge transfer. Wong et al. (2018) suggest that lean and green practices in small companies would be achieved also in knowledge transfer on technological resources choice. Supplier and customer can share common environmental responsibilities and achieve their goals collectively (Vachon and Klassen, 2008).

It is important to say, that only resources that are well managed can create competitive advantage. Resource Orchestration Theory developed from RBT and claims that in a highly competitive and dynamic field, which for instance freight

transport market is, managers have to constantly adapt on integrating new resources, creating capabilities and achieve sustainable advantage (Hu et al., 2020). Foremost in small firms, CEOs persuasion and influence on human resource management has primary effects on firm's performance, can influence higher management strategic decision making and further empirical support on resource orchestration on mid-management level (Chadwick et al., 2015).

Freight forwarders will pick suitable measures and thereof differentiating themselves from their competitors. Core capability of transformation and upgrading is the key to keep up with competitors. Resource management is also important in fostering innovation capabilities (Sirmon et al., 2007).

Application of RBT is seen in green supply chain management view. Application of firm's strategic resources and capabilities in Thailand's electronic industry suggests top management support as one of the highest drivers of GSCM, whereas employee involvement/motivation as the lowest driver (Somsuk and Laosirihongthong, 2017).

There is a research gap of application of Resource-Based Theory and Resource Orchestration Theory on decarbonisation of SME's logistics. Applying a top-down approach, starting with sustainable supply chain management application, then green supply chain management and at the end decarbonisation as one of their building bricks, SMEs can gain a competitive advantage in educating themselves in advance or already applying market viable.

3.4.3 Challenges of SMEs decarbonisation strategy

Logistics of small and medium manufacturers, and its relative importance to business operations and strategy, influences scale of decision making in this matter. Therefore, decarbonisation measures are more likely to be applied in industries that have dominant transportation and warehousing volumes and thus costs. Many SMEs active in logistics sector find themselves are in never-ending spiral of being dependent on and exploited by larger companies, e.g., small haulier working for larger freight forwarders or manufacturer supplying for his corporate customers. This generates very low margins and puts further pressure on small firms to keep up with large ones. Not only in case of logistics companies but also small suppliers, large enterprises give managerial pressure to comply with logistical processes, keep up with fluid transactions and physical and informational flow (Gélinas and Bigras, 2004).

High investments are the most significant barrier found in the literature around SMEs (Abbasi and Nilsson, 2016). There is an ongoing balancing between long-term payoffs and short-term fixes. Large companies find it easier dealing with long-term investment risks. It is challenging for SMEs to invest in greener, often more expensive physical capital, and as SMEs are not counting on long-term return on investment (Mala and Musova, 2015).

For a small entrepreneur or CEO, it is too exhausting representing multiple roles, which are in large corporations divided into several specialists, such as sustainability manager, supply-chain manager, or marketing manager. Also, educating themselves in very specific field might be time consuming as there are

numerous **resources of knowledge**. Figure 3-13 represents multiple sources, where a manager can obtain their knowledge to form a strategy.

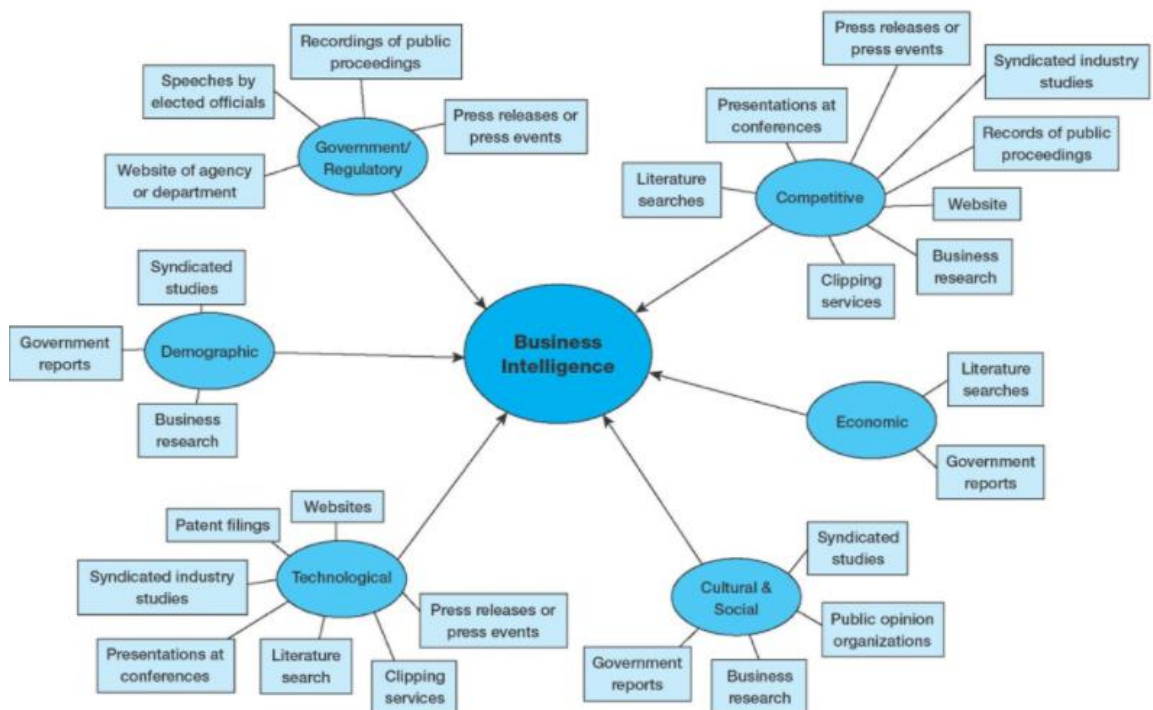


Figure 3-13 Some sources of business intelligence.

Source: Cooper and Schindler (2014), p. 9

Finding a new employee being an educated specialist in his field, is financially consuming. Not every small entrepreneur has a luxury to get educated and motivated by his large customer, although this striving is starting to emerge. Missing financial resources limit SMEs from finding properly **trained personnel** and implementing sustainability performance (Choudhary et al., 2019). Also finding internal resources or being able to pay external companies for specific trainings and development of personnel capabilities (Mathiyazhagan et al., 2014).

Lack of awareness is coming from not being educated enough in the topic. Still now, about 40% of SMEs in transport see their decarbonisation as medium to low

priority currently, 60% see it coming as long-term strategy, but only a third can currently measure their CO2 emissions (Toelke and McKinnon, 2021). Therefore it is controversial that there is an idea about the urgency, but the fundamental knowledge and tools are still missing.

Economies of experience only increase over time by gaining skills and practice. In this context, the long-established corporations have generally better starting position as they have organisational routines that they perfected over time, however innovative small companies can use their advantage of fast learning and change management as they are less dependent on old processes (Grant, 1999).

Next challenge is negative impact of **adaptation to customer's processes**. Getting integrated their physical and information flows according to the large customer might disturb their management styles (Gélinas and Bigras, 2004) and sometimes also environmental sustainability by being forced to change the warehousing location or fleet size, delivering just-in-time or using less green transport modes. Small hauliers are often finding new customers and thus constantly changing parameters in company's processes and balancing priorities (Wu and Pagell, 2011).

Geographical location and infrastructure can limit SMEs in terms of possibilities of choosing greening measures. Companies located in developing economies face lower number and quality of intermodal infrastructure, charging stations and come to delay in investment (SFC, 2016). Underdeveloped environmental legislation not only does not force companies to act and governments offer lower support in financing projects (Ghadge et al., 2017).

3.5 Creating a Conceptual Model Based on Literature

As many initiatives on logistics or SCM decarbonisation were found, an overview is created to summarise all possibilities in one figure. This will enable to sort the initiatives for further empirical research for the respondents into categories of their operations. To some extent some researchers already have shown this, focusing more on transport, warehousing, or specific industry. Therefore, it is important to compare these studies, find similarities and joined them to one unified model.

3.5.1 Existing conceptual models on the topic

One of the first comprehensive studies assessing the CO₂ reduction initiatives was brought by (WEF, 2009). This study assessed 13 supply-chain decarbonisation opportunities on their feasibility and emission abatement potential. Some of them could be already applied to logistics sector.

- Clean Vehicle Technologies
- De-speeding the Supply Chain
- Enabling Low Carbon Sourcing: Agriculture
- Optimised Networks
- Energy Efficient Buildings
- Packaging Design Initiatives
- Enabling Low Carbon Sourcing: Manufacturing
- Training and Communication
- Modal Switches
- Reverse Logistics / Recycling
- Nearshoring

- Increased Home Delivery
- Reducing Congestion

Although number of academic articles focused on decarbonisation strategies have been issued in recent decade, only one book on this topic, Green Logistics by McKinnon et al. (2015), first edition McKinnon et al. (2010) was found. This publication introduces the green logistics field and gives wide range of options how to perform greener. However, when assessing the environmental impact of the logistics, it includes various environmental externalities of logistics and warehousing, such as noise pollution, water pollution, congestion, and air pollution by particulate matters. It divides greening initiatives by their strategic and operational feasibility. In some chapters the decarbonising potential of measures is described but although it brought large contribution to knowledge in this field, it is lacking a more comprehensive summary of all current decarbonising strategies. In this book, two main conceptual models can be found. The first one suggests measures on decarbonising the transport sector and the second one on warehousing. They were used as initial outline of the model on decarbonising logistics operations.

McKinnon's Analytical framework for green logistics, basing on his earlier research (McKinnon, 2007) which was then later developed as shown in Chapter 3.3.1, brings an overview of key parameters that influence the green performance of logistics, from which some conclusions of possible CO₂ reduction initiatives may be drawn. More specified initiatives are found, as mentioned in previous chapter, in the further work on decarbonising strategies of freight transport, where

the joint project of Heriot-Watt University and EPSRC and FTA identified long list of initiatives and narrowed them down into 38 measures (McKinnon, 2011).

In warehousing, less comprehensive research in terms of conceptual models on decarbonisation has been done. In Green Logistics book (McKinnon et al., 2015) the model by Marchant and Baker (2015) shows measures that can be done on warehouse envelope and equipment.

3.5.2 Conceptual model from literature review for further framework

Initial conceptual model aims to provide an overview of all initiatives that have been found in various literature sources and gathering multiple terms and definitions in short wording. This cluster of initiatives sorted into two main categories will serve as a baseline for further empirical research. It becomes visible that the CO₂ reduction strategies in logistics can be very complex, thus company cannot focus only on few initiatives and forget other possibilities. It also shows that some issues can be solved within transport mode or within a warehouse, but that also cross-department projects can be incorporated. Figure 3-14 summarizes key initiatives that were found in initial literature review.

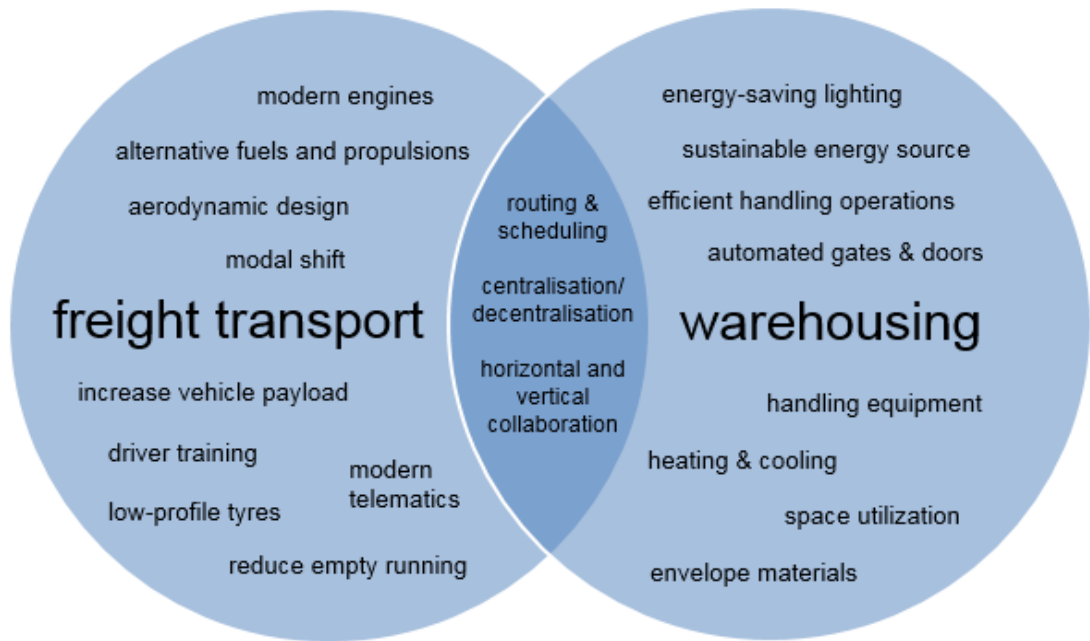


Figure 3-14 Conceptual model derived from the literature

Source: Author.

Whether all initiatives and to what extent are used in practice, is shown in further empirical part of the thesis, Chapter 5, and Chapter 6. This conceptual model helps to formulate themes for interviews into clusters and initiatives incorporated into survey. After conducting and analysing the empirical findings, the model is refined. Practitioners will be able to see the whole scale of initiatives at once. Initiatives, that are used in the practice more significantly, will be highlighted to allow non-experts to orientate themselves quicker in practices that are currently most applied.

3.6 Summary

Logistics and warehousing are only partly regulated by governments. This chapter introduces sustainability and corporate social responsibility in logistics context. Green supply chain management thinking has evolved over the past 10 years and companies started to reduce, measure, and report their emissions. Different tools and approaches for measuring CO₂ emissions were stated. After measuring emissions from different activities, companies can identify areas of improvement. Second part of this chapter lists logistic decarbonisation initiatives and explains more in detail their benefits, functionality, readiness, and limitations. It discusses also various models that were issued in logistics publications and identifies a gap in the literature. Further literature gap is identified when searching for theory that supports SME's reasoning how they can benefit from decarbonisation of their logistics as papers on Resource-Based Theory and Resource-Orchestration Theory connected with wider terms of GSCM or sustainability are only very recent, and no authors applied these theories on decarbonisation of SMEs. A conceptual model based on literature review of all known initiatives concludes this chapter to be further reviewed by practitioners on its contents, usage in practice and gaps in literature.

Chapter 4 Research Methodology

4.1 Introduction

This chapter guides through the researcher's understanding of the world, and paradigmatic stance of this thesis. Basing on the philosophy, the design is chosen to guide the whole research process from the start to beginning. Topic choice is explained and justified. Later, methodology and its relationship of paradigms guides into the last section, choice of methods. At the end, reliability and validity are being defined.

4.2 Relationship Between Researcher and Researched Subject

Before starting of the whole research process, researcher needs to realize the way he views the world and his position to the researched problem. Understanding research paradigms guides researcher to right choice of methodology and later, research methods.

4.2.1 Research philosophy and research paradigms

A researcher's understanding of the world shapes the whole philosophy of their research. Philosophy is the system of concepts which people refer to in explanations of the events and occurrences of their lives. (Gale, 1979). The subject-matter of the philosophy of knowledge is the analysis of procedures and logic of scientific explanation (Losee, 1993).

Losee (1993) defines four views of the philosophy of science:

- As a formulation of worldviews that are consistent with or based on important scientific theories
- As exposition of the presuppositions and predispositions of scientists
- As a discipline in which the concepts and theories of the sciences are analysed and clarified
- As second order criteriology (ex. what procedures should scientist follow, what conditions must be satisfied, what is the cognitive status)

As Saunders et al. (2016) confirm, developing a research philosophy is a reflexive process, which goes hand in hand with research design and methodology chosen. The researcher's background will influence their understanding of the nature of the social world. That and the nature of the researcher himself will indicate of the guiding paradigm. Collis and Hussey (2013) define paradigm as:

"...a philosophical framework that guides how a research should be conducted" (p. 43).

Paradigm tells us what reality is like (ontology), what the relationship is between the researcher and the reality (epistemology), and what methods can be used for studying the reality (methodology) (Punch, 2014). Ontology relates to being, thus what is real in the world. In social sciences, it is examined, whether reality is given or existing, vs. reality constructed, produced and reinforced by humans (Lincoln and Guba, 1994). Epistemology relates to knowing, where the questions evolve around whether the reality is perceived as fundamental knowledge, assumptions, or current feelings about the surroundings. The key feature of paradigm is, that it is *"incommensurable, that means paradigms are inconsistent with each other*

because of their divergent assumption” (Bryman, 2012). While this can be strictly said about positivism vs. phenomenology, later in this chapter, there are paradigms with similar epistemology or ontology, but at least one of more specifics are opposing each other.

The paradigm will guide them to find their research methodology, as well as ontology and epistemology (Lincoln and Guba, 1994). Ontology asks if the nature of reality is objective, constructed or subjective. Epistemology deals with nature of knowledge and what is the way in which reality is known to us. Second key epistemological issue is the relationship between the researcher and researched (Ritchie et al., 2014).

The two extremities of paradigms are known for social science, and business studies – positivist and phenomenological (in some literature mentioned as interpretivist).

Positivism believes that the objective reality exists and the function of science, including social science, is to describe and explain the reality in the form of the universal laws. The researcher does not affect the reality. The researcher involves a deductive process and explanatory theories to understand social phenomena (Collis and Hussey, 2013).

Phenomenology bases on the meanings that people bring to situations and understand the behaviour. Social reality is in our minds, it is subjective and multiple (Collis and Hussey, 2013). Researcher is active, interactive, and cooperative. Social reality is affected by investigation. On the contrary to positivism, it involves an inductive process, with interpretive understanding.

In the earlier nineteenth century, positivism was predominant paradigm. It started emerging in social studies, as scientists tried to measure and quantify social problems. Even in psychology, scientific, 'measurable' results were preferred. In earlier twentieth century, new approaches were discovered, as market research and political research started using empirical analyses. In the second half of the twentieth century, positivist perceptions started to be questioned and criticized. With the industrial revolution and capitalism, researchers turned more to observing social phenomena (Collis and Hussey, 2013). There was a split view in the field, between qualitative and quantitative researchers (Punch, 2014). New schools emerged. More recently mixed views are considered as correct, as the empirical meets theoretical, hence business studies cannot exist without underpinning the theory with reality. Table 4-1 below shows the relationship between the paradigm and its ontology, epistemology, and methodology. Methodology translates the ontological and epistemological views into design and methods of the research.

Table 4-1 Paradigms vs Ontology, Epistemology and Methodology

Source: Sarantakos (2013), p. 30.

	Postitivism	Phenomemolgy
Ontology	Realist / objectivist	Constructionist
Epistemology	Empiricism	Interpretivism
Methodology	Quantitative	Qualitative

There are differences within various types of paradigms, however, some of them tend to have more in common with positivism and other one with phenomenology, as shown in Table 4-2.

Table 4-2 Key features of the positivist and phenomenological paradigms

Source: Mangan et al. (2004), p. 567.

	Positivism	Phenomenology
Basic beliefs	The world is external and objective	The world is constructed and subjective
	Observer is independent	Observer is part of what is observed
	Science is value-free	Science is driven by human interests
Researcher should	Focus on facts	Focus on meaning
	Look for causality and fundamental laws	Try to understand what is happening
	Reduce phenomena to the simplest events	Look at the totality of each situation
	Formulate hypothesis and then test them	Develop ideas from induction of the data
Methods include	Operationalising concepts so that they can be measured	Using multiple methods to establish different views of phenomena
	Taking large samples	Small samples investigated in-depth or over time

Modern business research of last century evolved into using relativist viewpoints, combining both paradigms. Relativists acknowledge that the truth is determined through consensus of different viewpoints. Quantitative data must be completed by explanation of the behaviour of objects, ex. managers. Lincoln and Guba (1994) analyse various alternative paradigms in qualitative research, such as constructivism, hermeneutics, feminism, critical theory, cultural studies and sexualities and queer theory. In the Table 4-3 below, Saunders et al. (2016) compare diverse research philosophies in business and management research. They compare them also on the level of axiology. Axiology is a branch of philosophy dealing with basic beliefs of the researcher, such as ethics, aesthetics and religion (Lincoln and Guba, 2011).

Table 4-3 Comparison of five research philosophies in business and management research

Source: Adapted from Saunders et al. (2016)

	Ontology	Epistemology	Axiology	Typical methods
Positivism	Real, external, independent	Scientific method	Value-free research	Typically, deductive, highly structured, large samples, measurement, typically quantitative methods, but a range of data can be analysed
	One true reality (universalism) Granular (things)	Observable and measurable facts Law-like generalisations	Researcher is detached, neutral and independent of what is researched Researcher maintains objective stance	
	Ordered	Numbers Casual explanation and prediction as contribution		
Critical realism	Stratified/layered (the empirical, the actual and the real)	Epistemological relativism	Value-laden research	Retrodictive, in-depth historically situated analysis of pre-existing structures and emerging agency
	External, independent	Knowledge historically situated and transient	Researcher acknowledges bias by world views, cultural experience, and upbringing	Range of methods and data types to fit subject matter
	Intransient	Facts are social constructions	Researcher tries to minimise bias and errors	
	Objective structures Casual mechanisms	Historical casual explanation as contribution	Researcher is objective as possible	
Interpretivism	Complex, rich	Theories and concepts too simplistic	Value-bound research	Typically, inductive
	Socially constructed through culture and language	Focus on narratives, stories, perceptions and interpretations	Researchers are part of what is researched, subjective	Small samples in-depth investigations, qualitative methods of analysis, but a range of data can be interpreted
	Multiple meanings, interpretations, realities Flux of process, experience, practices	New understandings and worldviews as contribution	Researcher interpretations key to contribution Researcher reflexive	
Postmodernism	Nominal, complex, rich	What counts as 'truth' and 'knowledge' is decided by dominant ideologies	Value-constituted research	Typically, deconstructive - reading texts and realities against themselves
	Socially constructed through power relations	Focus on absences, silences and oppressed/repressed meanings, interpretations and voices	Researcher and research embedded in power relations	In-depth investigations of anomalies, silences and absences
	Some meanings, interpretations, realities are dominated and silenced by others Flux of process, experience, practices	Exposure of power relations and challenge of dominant views as contribution	Some research narratives are repressed and silenced at the expense of others Researcher radically reflexive	Range of data types, typically qualitative methods of analysis
Pragmatism	Complex, rich, external	Practical meaning of knowledge in specific contexts	Value-driven research	Following research problem and research question
	Reality is the practical consequences of ideas Flux of process, experience, practices	'True' theories and knowledge are those that enable successful action Focus on problems, practices and relevance Problem solving and informed future practice as contribution	Research initiated and sustained by researcher's doubts and beliefs Researcher reflexive	Range of methods: mixed, multiple, qualitative, quantitative, action research Emphasis on practical solutions and outcomes

4.2.2 Paradigms in logistics research

Business and management researchers do not agree about one best philosophy (Knudsen and Tsoukas, 2003). Logistics research accounted many discussions on what paradigmatic viewpoint to use, hence qualitative or quantitative data might be examined. There are different possibilities how to approach the problem, either to quantify the correlations of occurrences or to examine the behaviour of managers.

Mentzer and Kahn (1995) analysed articles in *Journal of Business Logistics* in years 1978-1993 and they prove that positivist method, survey, dominated. Frankel et al. (2005) investigated articles in the same journal between 1999-2005, and found six main methods: surveys, interviews, observations, focus groups, case studies, experiments, literature review, and content analysis. Sachan and Datta (2005) examined articles in *Journal of Business Logistics*, *International Journal of Physical Distribution & Logistics Management* and *Supply Chain Management: An International Journal* between 1993 and 2003 and they also confirmed that positivism still dominated. Halldórsson and Arlbjörn (2005) reviewed articles in the same journals but between years 1997 and 2004, to see if research in supply chain management differed, and found that only 8 of 71 articles used solely qualitative methods.

Carter et al. (2008) expressed idea about the 'paradigm shift' in supply chain management research, from quantitative data, to qualitative data. Frankel et al. (2005) suggest, that using more qualitative methodology fills in the 'white space' of the logistics research. They acknowledge that using only qualitative data can be dangerous for the objectivity of the research. The same point was emphasized

by Näslund (2002), he argues that advance logistics problems might be often ill-structured, messy, real-world problems. Therefore, case study and action research are the emerging methods used in logistics research.

Other author suggests that methodologies are being mixed. "The trend in management research generally is increasingly using methods and approaches which provide a middle ground between the contrasting positivist and phenomenological paradigms and perspectives. Methodological triangulation, using quantitative and qualitative methodologies, increasingly provides multidimensional insights into many management research problems." Mangan et al. (2004). Mixing the methodologies for example surveys (quantitative results) and interviews (qualitative results) is a more profound form of triangulation (Olsen, 2004). Regarding logistics research analysis of articles in Journal of Business Logistics between 1999-2005, by Frankel et al. (2005), more than one third of articles included two or more methods, most typically, surveys that were seconded with interviews. They claimed that authors often chose a primary data collection with help of surveys and used other method like interview to avoid bias, increase theory development and improve data collection (Frankel et al., 2005).

Logistics research is relatively new discipline, and it continues to evolve as it becomes recognized by organizations. The interface between academics and practitioners will continuously contribute to maturing of the discipline. Researchers agree that "...logistics discipline is diversifying its research efforts and expanding the array of issues addressed" and that they are "responding to the evolution of the discipline by expanding their efforts to conduct applied research" (Craighead et al., 2007).

4.2.3 Paradigmatic stance of the thesis

When choosing the paradigmatic approach, the researcher should reflect on following assumptions (Creswell, 2014):

- The issue or concern to be addressed needs to be considered fully and the research needs to be designed that best matches the problem.
- The researcher needs to consider his or her skills and experience and assess which approach best complements these.
- The researcher needs to consider the audience to whom the findings from the research will be addressed.

Before starting any research, researcher should find a basic research approach at the start of the study. Thinking of research questions, researcher might find out that some point to one approach and others to the other direction. Kitchin and Tate (2013) suggest to focus on the approach that *best matches* researcher's views. Reflecting on the epistemology and ontology of the two main paradigms, the phenomenological paradigm was a more obvious choice for researcher. Philosophical phenomenology agrees that relation between perception and its objects is not passive (Lincoln and Guba, 2011). Founder of phenomenology, Husserl (1859-1938) argued that subjects (humans) are involved in object (world) (Kitchin and Tate, 2013). From the ontological perspective, the reality is known to the researcher and he is part of the reality in daily job in the field of logistics. However, reality is mostly not biased by opinions, as in many business activities, cost analysis needs to be undertaken to act upon a measure. The researcher already studied the logistic field, wrote Master Thesis on green logistics, and worked in the field of freight transport therefore the general reality is known to

them. Logistics field that will be examined, consists of individual managers, that are responsible for decision making and strategies. By choosing the philosophy, definitions in epistemology of interpretivism and pragmatism correlate. The interpretivist viewpoint says: "Humans govern the logistics systems, and unless they are managed extremely well or for some reason are willing to subordinate themselves to the needs of holistic logistics or supply chain management systems, they will exert an influence on the practice of the systems" (Gammelgaard, 2004). However, for interpretivism, inductive research follows data collection first, and detail research later. Pragmatism is very practically oriented but suggests that previous deeper knowledge is necessary to understand the phenomenon, thus it supports deductive research. Getting more into detail of logistics practitioner's thinking is essential for finding out possible gaps in the researched topic. The choice of CO2 reduction measures might be based on numbers, but managers can decide upon personal experience. Positivism excludes the detail of people's inner thinking (May, 2011).

By following the definitions in Saunders et al. (2016), pragmatism is the closest philosophy to practically oriented research, as in the end, it is aimed to improve practitioner's knowledge and support decision making in decarbonisation projects. However, it concerns also experience as a tentative hypothesis about what our actions should be. It also asks about truth and sensemaking of practitioner's actions (Baker and Schaltegger, 2015). It helps to engage practitioners to promote positive change. It believes that "ideas do not exist as timeless and pre-existing perfect forms, but instead are formed contingently and experimentally" (Barnes, 2008), thus dependent on occurrence and conditional. Thus it examines the real-world problems by providing both theoretical

understanding and practical solutions (Frazier, 1981) In pragmatism, can never be enough rational, critical discussion in this complex natural and political reality (Pihlström, 2008). The attributes of good research topic are closely linked to the researcher and his interests. Saunders et al. (2016) point out that capability, necessary research skills and genuine interest in the topic lead to best research projects.

Researcher studied green logistics in automotive industry and collected data by interviewing logistics plant managers in Czech Republic and Slovakia on sustainability of their logistics systems. In the master's thesis, interpretivist approach was undertaken, trying to understand managers by conducting in-depth interviews and case studies of six manufacturers. Only very few measures were undertaken, therefore it reflected in further need to help companies from all industries to gain deeper knowledge and motivation.

Pragmatism is known for application of mixed methods, combining qualitative and quantitative data (Morgan, 2007). A deductive and predictive approach is applied, where theory is formulated and then tested on real world and as the world is constantly changing, it should be re-tested and re-evaluated after some period of time (Frazier, 1981).

4.3 Research Design

The design describes how the researcher conducts the work. Basing on (Sarantakos, 2013) following steps of the design were chosen:

- 1) Topic and methodology
 - selection of research topic
 - selection of methodology
- 2) Methodological construction of the topic
 - framing of research questions
 - literature review
 - conceptualization
- 3) Sampling procedures
 - choice of setting, key informants, study groups, events
 - methods of data collection
- 4) Data collection
 - entering field, collection data, re-defining
 - checking of soundness of data
- 5) Data analysis and interpretation
 - analysing data
 - aligning research process
- 6) Reporting
 - preparing a report for discussion

4.3.1 Methodologies – qualitative and quantitative

Closely linked to the whole paradigm is methodology as “...an approach to the process of the research, encompassing a body of methods.” (Collis and Hussey, 2013). It is a coherent set of rules that can be used to observe a phenomenon within a framework set by epistemology and ontology (Kitchin and Tate, 2013). There are several methodologies associated with one of the two main paradigms. However, some of the methodologies are adaptable for use under either paradigm. Bryman and Bell (2015) suggest, that when researchers combine qualitative and quantitative research, it does not mean that they are breaking paradigmatic philosophy, as the interaction is only at superficial level and within a single paradigm.

Quantitative research generally starts with a research theory, which has been already previously developed, forms hypotheses and rigorously analyses quantitative data (Holton and Burnett, 2005).

Qualitative research typically starts with observation of the phenomena by field visits, where researcher “observes phenomenon in natural setting where he begins to frame an understanding” (Golicic et al., 2005). Literature review commences throughout the whole research and is not separated into a single stage. In the second step, researcher uses methods to describe the phenomenon by viewpoint of respondents.

Following Table 4-4 summarizes the advantages and disadvantages of using only one type of data or analysis and helps research realize the gaps that need to be filled in during the entire research period.

Table 4-4 Advantages and limitations of qualitative and quantitative research

Source: Adapted from Creswell (2015), p. 191.

Qualitative research	
<i>Advantages</i>	<i>Disadvantages</i>
Provides detailed perspectives of a few people Captures the voices of participants Allows participant's experiences to be understood in context Is based on the views of participants, not the researcher Appeals to people's enjoyment of stories	Has limited generalizability Provides only soft data (not hard data, such as numbers) Studies few people Is highly subjective Minimizes use of researcher's expertise due to reliance on participants
Quantitative research	
<i>Advantages</i>	<i>Disadvantages</i>
Draw conclusions for large numbers of people Analyses data efficiency Investigates relationships within data Examines probable causes and effects Controls bias Appeals to people's preference for numbers	Is impersonal, dry Does not record the words of participants Provides limited understanding of the context of participants Is largely researcher driven

Deductive approach starts with reviewing appropriate literature to develop a conceptual model. While researcher may use a typically qualitative research

method, interviews, the results are not used to form a theory, rather they help to understand and refine the results obtained from quantitative data. Figure 4-1 embarks on explaining logic footsteps of an inductive and deductive research.

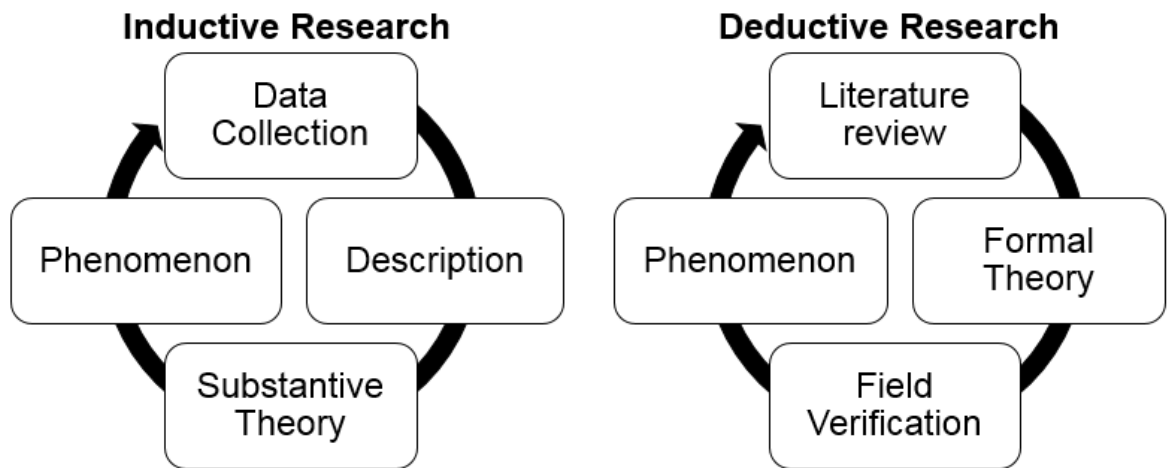


Figure 4-1 The Balanced Approach Model

Source: Adapted from Golicic, Davis & McCarthy, (2005, p. 20).

A deductive research will be applied, where conceptual and theoretical structure is developed which is then tested by empirical observation (Collis, 2014).

4.3.2 Literature review

A literature review is "...the selection of available documents (both published and unpublished) on the selected topic, which contain information, ideas, data and evidence written from particular standpoint to fulfil certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed" (Hart, 1998).

Literature review has twofold purpose. Firstly, it is used for organising the ideas around the topic and defining the narrower scope of the research. Secondly, it

helps to critically review what is the current state of the academic knowledge in the subject, its limitations and how the own research can contribute to the current state of knowledge (Saunders et al., 2016).

The first step, broader topic green logistics was already known to the researcher, therefore the focus was put more on CO2 emissions mitigation in logistics. Using keywords CO2, carbon and greenhouse gasses combining with reduction and improvement and with freight transport, supply chain, logistics and warehousing, articles suitable for this research topic were found. These articles helped researcher to gain overview of how relevant these topics are in terms of global impact across manufacturing industries, logistics service providing industries, geographical impact, and impact of small vs. large firms.

Secondly, more specific articles that focused on specific measures, were grouped into themes, per transportation or warehousing or combining both initiatives. Then they were grouped using EndNote program, into categories, that were later to be used for framing the conceptual model.

Following sources were used to obtain the broadest possible knowledge:

- University of Plymouth library
- articles using journal databases (Emerald, ScienceDirect, EbscoHost...)
- specific books, most significant 'Green Logistics' (McKinnon et al., 2015)
- conference proceedings and working papers
- reports and reviews
- internet (web sides of organizations, or institutions)

Evaluating the collected literature from the complex bibliography is a critical step to identifying relevant literature for the selected topic (Sekaran, 2016). The best way for evaluating the journal article is to read the abstract, introduction and conclusions. Good articles help to broaden the spectrum by citing other authors writing on the similar topic in the literature review or introductory chapter. Books are usually more generally named; therefore, table of contents help to get the insight. After that, the researcher gets an idea of comparability and relevance.

4.3.3 Initial conceptualisation

Under mixed methods, a conceptual framework is being used (Creswell, 2015). A model is a representation of a system that is constructed to study some aspect of that system or the whole system. There are three types of models found in business research (Cooper and Schindler, 2014):

- **Descriptive models** are used for more complex system, visualising more variables and their relationships.
- **Predictive models** applied for forecasting future events.
- **Normative models** used for informing about what actions should be taken.

In this thesis, a normative model has been chosen. The construction of a model should keep in mind all possible variables influencing the phenomena.

4.3.4 Mixed methods in research cycles

In the following section, the research methods used in this thesis will be defined, specified for this research and the advantages and disadvantages of using these methods will be outlined. This thesis will use mixed methods design, adapted from Bryman and Bell (2015). As explained above, mixing the methods does not

collide with philosophical direction of the research. Bryman (2012) states that since the beginning of 2000's the mixed methods research gained on significance. Balanced approach in supply chain management research can contribute to richness of the data and avoiding delimiting the scope of their inquiry (Golicic et al., 2005). Mixing the methods not only brings deeper understanding of the problem, but also eliminates the bias that both methodological approaches can bring.

Mixed method research involves combining both qualitative and quantitative data. It does not mean combining multiple qualitative data, or multiple quantitative data. That form is called multimethod research, not mixed method research Creswell (2015). It can be used, when the research question cannot be explained by only qualitative or only quantitative research. (Sekaran, 2016).

Some researchers, however, argue against mixed methods research. First argument is that the research methodology is rooted in epistemological and ontological commitments, therefore methods should comply with the rules too. Second argument, paradigm argument is that research paradigm is also superficial to the methods, but others agree that methods are not linked directly with paradigms.

There are three types of mixed method designs (Creswell, 2015):

- **Convergent design** represents collecting and evaluating quantitative and qualitative data at the same time and merging the results of both sets of data analyses with purpose of comparing them.

- **Explanatory design** uses first quantitative methods and then qualitative methods to help explain the quantitative results in more depth.
- **Exploratory sequential design** is the opposite of explanatory one, meaning that first qualitative data will be analysed, which helps to design an instrument to measure variables in the study, and then the quantitative instrument, intervention or variables are used.

This research is a mix of exploratory (initial stage) and explanatory (subsequent stage) design. Exploratory research is used to generally observe the industry's development stage of decarbonisation in the first paper-based questionnaire. Research focuses on specific type of managers, therefore there is no need to widely explore the population or question as in exploratory design. Explanatory research is the main body of this thesis which then elaborates on results from the quantitative surveys. An example of mixing qualitative and quantitative methods is shown below (Figure 23).

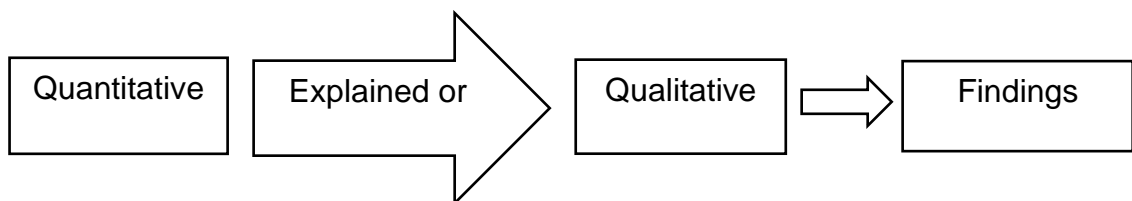


Figure 4-2 Mixed method explanatory design

Adapted from Bryman and Bell (2015)

Following procedures are to be used to obtain the results (Creswell, 2015):

1. Collect and analyse quantitative data
2. Examine the results and determine what results will need further exploration in the second, qualitative, phase
3. Conduct qualitative data collection and analysis to help explain the quantitative results

Wadsworth (2012) argues that *“despite a current ‘mixed methods’ truce, (we are) continuing having... differences in ... human ‘inquiry preferences’: writ small in individual psychology and writ large in the often equally seemingly mutually-exclusive multi cultures of specialising schools of social, political, economic and methodological thought, their philosophies of knowledge and ever-expanding profusion of methods, techniques, associated literatures and proponents”* (p. 51).

However, the argument against mixed methodologies used under one paradigmatic stance bases on epistemological commitments, which are incompatible between paradigms. Therefore, the choice of methods, despite pre-considerations at the beginning due to recommendations in the literature, was also adapted to this specific research development, considering how well the research questions have been already answered. In literature, this term is also called “research cycles”.

This thesis is showing a need to come back and reviewing the researched topic from different angles and due to dynamic changes in the industry, addressing it

to small and medium sized firms for the most urgent application. Therefore, following research cycles were undertaken, as shown in Figure 4-3.

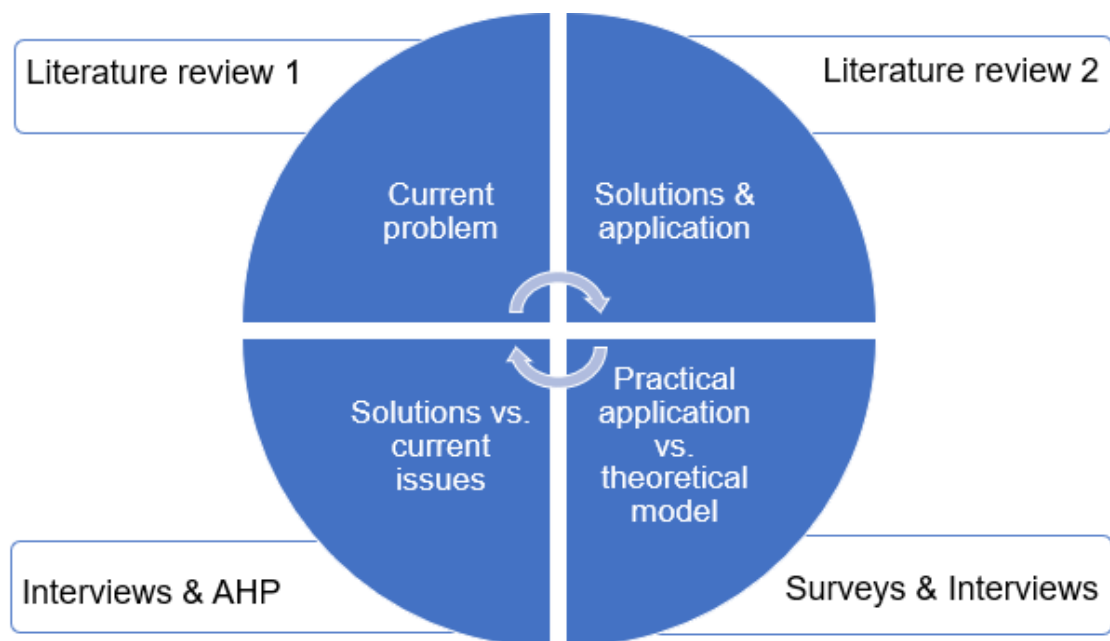


Figure 4-3 Research cycles with mixed methods

Source: Author

4.4 Research Ethics

In philosophy, ethics is described as establishment of right or wrong (Allen and Muurlink, 2019). Basic principles of ethics are protecting communities and individuals and their environments to increase sum of good in the world (Israel and Hay, 2006). It has become increasingly important to consider ethics of research involving humans, mentioning extreme research tactics in medical research in the mid-20th century, not getting consent of research subjects on the performed methods (Milgrim's experiment with emotional stress of participants doing electric shocks in the US, mind manipulation and radiation exposure in Canada, Nazi's experiments in Europe).

Social science researcher should ask themselves two questions (Mertens and Ginsberg, 2009):

“What is the ethically proper way to collect, process and report research data?”

“How should social scientists behave with respect to their research subjects?”

While first questions cover topics as confidentiality, accuracy, best intentions of the researcher. Methodologically, researchers must feel confident that they depicted reality in ethical manner. The second question guides researcher to realize how to build trust to their research subjects, remain respectful, avoid harm, keep dignity, and equal treatment of research subjects. At the end, ethics should be not only considered during data collection and analysis, but also in the way results are used (Roth, 2005).

4.4.1 Ethical approach of researcher

Early publications studied honesty and trust, and on the contrary, consequences of lying, deception and failure to disclose scientific findings (Diener and Crandall, 1978). Fabricating and falsifying data or results or engaging in plagiarism have nothing to do with good science (Allen and Muurlink, 2019). However, one third of scientists admit they slip into grey area from time to time (Steneck, 2006).

Criteria for qualitative research are connected with research ethics and they are trustworthiness based on credibility, dependability, transferability and confirmability (Rudolf et al., 2008). Trustworthiness can be enhanced by basing

on already established theory and literature review, equivalence of research topics, e.g., pre-testing it on survey or alertness on already existing background assumptions. A study can be developed from a formal theory or semi-developed conceptual structure (Lee, 1999).

4.4.2 Ethical treatment of participants

Each research design has its own sensitive content topics and methods that could possibly harm respondent and therefore it needs to remain sensitive. For example online survey can create unfortunate and stressful feelings for the respondent (Allen and Muurlink, 2019). In research analysis of interviews, rejecting body language and hesitating voice can also indicate that researched subject feels uncomfortable to state some details of his work or experience. The researcher should, where possible, inform potential participants in advance of any features of the research that might reasonably be expected to influence their willingness to take part in the study. Where the research topic is sensitive, the ethical protocol should include instructions for the informed consent procedure and consent should be obtained in writing. If sensitive questions are asked, researcher should have an option to skip the question, and this should be also considered in the data analysis.

The principle of respect and confidentiality protects participant from causing harm to his organisation and thus harm to his career and reputation (Heggen and Guillemin, 2012). Researcher might have an aim that is not coherent with the participant's world view and therefore communication of transparency and equal positions is vital to methodological and ethical rigor (Aluwihare-Samaranayake, 2012).

4.5 Reliability and Validity of The Research

One of the main principles, as well as issues of quantitative and qualitative research are their reliability and validity. Although they sound like synonyms, they have different meanings in concern of evaluations of methods. Validity presumes reliability because, if measure is not reliable, it cannot be valid (Bryman and Bell, 2015).

According to definition in Sarantakos (2013), method is **reliable**, “...if it produces the same results whenever its repeated and is not sensitive to the researcher, the research conditions or the respondents. Therefore, it is a measure of objectivity, stability, consistency and precision.” (p. 104). There are several methods of testing reliability of quantitative research (Sarantakos, 2013):

- Stability reliability – whether a measure produces reliable findings when it’s applied at different points of time. For example, if consumers preference on buying designer goods might have changed over time due to his financial situation (Bryman and Bell, 2015).
- Representative reliability – if a measure will be reliable if employed in other groups of subjects, other than the original.
- Equivalence reliability – if the measure brings consistent results across indicators. For example, where more than one researcher is involved in categorizing data and they may bias the results by subjective judgement (Bryman and Bell, 2015).

On the contrary, qualitative researchers use measures of reliability rather to prove that the data is large enough, that the sample is variable and diverse, and use rather concepts such as applicability, credibility and auditability (Sarantakos, 2013). Qualitative researchers discuss the relevance of reliability and validity because the testing criteria might not have considered the possibility of altering meanings. It can, however, test it on external and internal criteria. External reliability evaluates, to which degree a study can be replicated; internal reliability is applicable when there are more observers, to check if they agree upon their observations (Bryman and Bell, 2015).

Validity refers to the issue of whether an indicator that is devised to gauge concept really measures the concept. Internal validity means, whether there is a good match between observations and theoretical ideas they develop, external validity represents the degree to which findings can be generalized (Bryman and Bell, 2015).

In quantitative research, there is a number of ways how to test validity (Bryman and Bell, 2015):

- Face validity – reflects the content of the concept in question. For example, by asking managers with experience to act as judges to determine, whether the measure reflects the concept.
- Concurrent validity – employs some criterion, that shows if cases differ. For example, if criterion 'job satisfaction' refers to real satisfaction with a job position or only not being satisfied to be absent from work.

- Predictive validity – measures future criterion rather than a contemporary one. For example, if a respondent is likely to engage in a certain activity in the future.
- Construct validity – researcher deduces hypothesis from a theory. For example, if people who are working in routine jobs are less satisfied due to automated technology.

Assessing of nonresponse bias of results brought by surveys is crucial for validity and reliability of results. Wagner and Kemmerling (2010) analysed articles published in three logistics journals (International Journal of Physical Distribution and Logistics Management, Journal of Business Logistics, Transportation Journal) between 1998 and 2007 and observed, that 44% of papers did not discuss nonresponse bias, which can influence the generalizability of results in case of nonresponse.

Qualitative researchers argue, whether validity is applicable, because the testing methods include measurements (Bryman and Bell, 2015). They can test the validity, same as the reliability on internal or external aspects. Qualitative data are subject of bias and therefore validity needs to be justified even more carefully. This rigor can be accomplished by having sound methodology, a protocol or a guide to an interview, documentation of collected data and appropriate analysis of the data (Brod et al., 2009).

4.6 Summary

Researcher understanding of the world shapes his philosophy. Philosophy can be shaped by pre-assumption about the world or by real observations. The guidance to research steps is provided by phenomenological stance of the

research. Paradigms differ by their ontology (how reality is perceived), epistemology (relationship of the researcher to the researched subject) and methodology (what set of methods can be used in given paradigm). In logistics field, positivist paradigm with quantitative methods prevailed in 2000's. Nowadays there is a shift to phenomenological paradigm, exploring qualitative data. This research bases on phenomenological paradigm. The paradigm influences further research design and research methodology. This way researcher decides if he goes the inductive way or deductive way. Deductive research in this thesis is guided by literature review, grounding the topic in an economic theory, conceptual model being reviewed by multiple methods. As the research is predominantly qualitative, research ethics plays a role in data collection and analysis. At the end reliability and validity are defined generally as well as with regards to quantitative research. In quantitative research it is even more important to rigorously question further criteria as credibility, trustworthiness, dependability, and auditability.

Chapter 5 Questionnaires with Practitioners

5.1 Introduction

This chapter is the first one of three empirical chapters that are focusing on the current situation of the CO2 reduction initiatives that are being used by logistics practitioners. The main purpose of conducting questionnaires, was firstly to explore current logistics and sustainability practices' situation, interest, barriers, and motivations to decarbonise their logistics activities and secondly to underpin the current and near-term usage of initiatives found in the literature.

During the studies, two questionnaires were conducted. While the first, paper based one, which was conducted at the beginning of the studies, was more extensive, exploratory, and brought researcher more insight into the industry, the second and more recent one was aimed solely at specific CO2 reduction measures. At each questionnaire, their design, administration, size, and quality of samples are described. Also, limitations and reliability and validity bias are discussed after each questionnaire type. A comprehensive analysis of both data sources helps to describe current happening in the industry and continues to refine the conceptual model based on literature. At the end, concluding remarks and contribution of both surveys are given.

5.2 Use of Questionnaires in Business Research

Surveys have been the most used methodology in empirical research in social sciences (Mentzer and Kahn, 1995). A survey is a detailed and quantified description, it counts and describes a population (Sapsford, 1999).

Questionnaire is a distinctive research instrument of the survey, where group of different people (respondents) answer prearranged set of questions (Zikmund, 2000). Mostly, surveys are conducted as one-time data collection, but they can also be collected multiple times to describe the evolution of the problem. The questions are usually arranged to self-administered questionnaires, face-to-face interviews, or observations. The survey is very popular in business research, because it allows to collect both quantitative and qualitative data on many types of research questions (Sekaran, 2016). It also allows collection of large amounts of data in an efficient manner (Kotzab, 2005). As already stated, survey seems to be important method in logistics research. Mentzer and Kahn (1995) found that survey was 'methodology of choice' in logistics research, analysing articles in *Journal of Business Logistics* between 1978 and 1993. Kotzab (2005) reviewed 223 articles in *Journal of Business Logistics* between 1993 and 2003 and identified that 99 articles used survey. He then divided those types of surveys in different types and found, that postal questionnaires dominated (83 out of 106 questionnaire approaches). A lower percentage occurred in article by Larson and Poist (2004), where mail surveys were found in 60% of articles in *Transportation Journal* between 1992 and 2003. Following example in Table 5-1 shows types of questionnaires analysed by Kotzab (2005).

Table 5-1 Types of Questionnaires in JBL Research

Source: Kotzab (2005) p.129.

Questionnaire					
Self-administered			Interviewer-administered		
Online		Postal	Delivery & collection	Telephone	Structured
Email	Website				
1	2	86	4	9	4
93			17		

Prior to the internet era, following methods were used: personal interview or administration by trained interviewers, telephone surveys conducted by trained interviewers, and mail or postal surveys completed solely by respondents (Grant et al., 2005). This research uses internet-based survey therefore more will be explained on this method.

Web-based surveys arise with the widespread use of internet in 20's century and they mitigate the limitations of self-administered questionnaires (Grant et al., 2005). At the beginning of 2000's, the importance of internet in surveys gained on attention, as already two thirds of UK's small and medium enterprises had daily access to the internet, and in the US predicted hypergrowth of e-commerce (Brown et al., 2001). Various authors compare advantages and disadvantages of mail surveys compared to web-based surveys. For example, Cobanoglu et al. (2001) compared fax and web-based surveys in a university setting for response speed, response rate and costs. Although the response speed of surveys by fax was faster by one day, the response rate of web surveys was about twice as high (26.27% for mail, 17.0% for fax, and 44.21% for web surveys) (Cobanoglu et al., 2001). Ilieva et al. (2002) see the response time as the greatest advantage, as the data collection can take under a month. As the internet access spread out

since the 2000's and it is part of every household and business, web-based surveys became medium of choice for researchers (Grant et al., 2005). Web-based surveys nowadays can be executed via various web-sides, where they also offer analysis and evaluation based on received responses. They offer zero to low fees, depending on the analysis required. Response rate is considered higher than of postal surveys (Griffis et al., 2003). Faster response speed is also a big advantage, as shown by Cobanoglu et al. (2001), who sent out fax, postal and web surveys to 300 respondents. Web surveys were 64% faster than postal surveys. They also limit the bias caused by researcher's focus on respondent in terms of anonymity of respondents.

Usually, the researcher contacts respondents by introductory email, containing the link to the survey. A deadline can be given. It is required to send second, and if necessary, third wave of emails to remind respondents to answer the questionnaire to increase the response rate. Usually, respondents react immediately, or not at all (Grant et al., 2005). At this stage, it is already crucial to add contact where they can ask for explanation, if something is unclear. There is a higher risk of uncompleted questionnaires, when too long and complicated. Another disadvantage of too long surveys might be, that respondents do not complete the survey carefully and fill out quickly answer types 'do not know' or 'not applicable'. These responses should be sorted out before analysis. However, there is another risk of turning down the questionnaire or using 'do not know' answer when question is unclear. Therefore, standardized wording and clear questions can eliminate nonresponse bias. The questions and they clearness should be tested with some general practitioner, who knows the terms of the field of study, before they are handed out to respondents. For more complicated

surveys, there is various software available that can analyse quality of response by recording every click of respondent in a time frame, average time spent per question, or stage, at which respondents quit answering (mortality rate), for example SPSS 11.0 or QSR N6 V6.0 (Grant et al., 2005). For more simple surveys, such as the one in this thesis, specialised websites such as surveymonkey.com, can be used.

Other nonresponse bias might be a relevance of the topic to the manager position in a company and amount of effort and time invested in filling out of the questionnaire (Frohlich, 2002). Therefore, it is recommended, that in the introductory email researcher asks the recipient, that if they do not feel suitable for responding, they can forward it to other manager in the company, which is more qualified for the survey. The quality of the population sample must be assessed, before the generalization is made (Wagner and Kemmerling, 2010). In summary, it is very likely that response rates will be higher if targeted on the right population and if the questionnaires are easy and quick to fill in. Personalizing the survey and providing small incentives can also contribute to higher response rate (Tenforde et al., 2010).

A population in statistical terminology is a set of subjects, usually individual people but it can also be objects or institutions (Sapsford, 2016). Sample is a subset of population where subjects have common key characteristics. Survey sampling helps to organise a population to a narrower group of respondents that are more relevant to the topic. Main purpose of sampling is to reduce the amount of work put into analysis and sorting out irrelevant responses when given the survey to a wider population. There are two ways of sampling; probability

sampling and non-probability sampling. Probability sampling uses randomised process of selection. It is mostly used in social research when the size of population is large, and it must be divided into sub-samples. The main issue of this sampling is, that it requires randomisation on a sample and at the same time the mean of sample must be equal to the mean of population (Kish, 1965). Non-probability sampling, on the other hand, focuses purposively on finding suitable respondents. Either researcher decides on respondents with assumption that they are representative to the sample, or he asks the members of the sample to recruit other members, called snowball sample (Cooper and Schindler, 2014).

5.3 Paper Form Questionnaire

The questionnaire was undertaken on 3rd-4th July 2013 at venue of Pfenning Logistics in Heddeshheim, where Open Day of Green Freight Europe Initiative took place. At that time, it was the main organisation in Europe gathering logistics service providers, manufacturers, NGOs, and consultants on national and international level. This event was a yearly gathering of about 60 members and new companies that were interested in joining in. On the first day, both existing members and new companies could participate. Second day was organized for members only. The main aim and topics of this questionnaire were:

- To find how CO2 reduction initiatives are applied in current practice
- To discuss initiatives found in the previous literature
- To identify drivers and barriers of their implementation
- To evaluate them in terms of time and costs of implementation

These aims were e-mailed in research proposal to the organizers, as well as presented to respondents when talking to them personally. A summary of the results was sent to the organizer afterwards. As the members event was themed around sharing knowledge, one of which was workshop on chosen best practice measures, this survey complemented the theme of the conference.

This questionnaire can be found at the end of this theses in Appendix A.

5.3.1 Design and administration

Printed version of the questionnaire was handed out on first day before noon during two breaks between speeches, which took about 15 minutes every hour and during lunch break. It was a good opportunity to access a group of about 5 people standing together and explain them the purpose and contents of the questionnaire. Subsequently, it was mentioned that questionnaire is anonymous, but if anybody is interested to get access to results, they can leave an e-mail address. The questionnaire was handed out to all participants, with exception of those who said they were not suitable, e.g., academics or NGO employees. They had whole day and eventually next day to fill it in. On the next, open day, some new interested companies approached the event and participated in workshops. If the faces were unknown, they got approached in the breaks but here the return rate was lower, as the event was not organized in one large room, but rather small rooms divided among various workshops.

The printed version consisted of five parts, each on one side. First part consisted of multiple-choice question, where only one answer was required. Second part consisted of general questions about attitude of company towards CO2

reduction in logistics, which was summarized into 17 questions. There were various types of questions used. Most of the questions had a choice of yes or no, or had questions to be answered with digits, such as year, number of employees and budget. Open ended questions were used in the next three sections. Third, fourth and fifth part had common goal, to identify initiatives used by the company and evaluate them by time and cost of implementation. These initiatives were found in the literature review and were sorted in two groups, operational and strategic as suggested by first edition of Green Logistics book in 2011 (McKinnon et al., 2015). They also identify drivers, further plans but also list those initiatives that they tried and failed.

5.3.2 Sample

For this survey, stratified sampling was used. Selection of representative companies and experienced practitioners reduces the validity bias. The total number of participants who came to the conference is the actual population for this survey. Around 50 organizations visited 1st day and about 40 organizations visited 2nd day, of which about one third were visitors of 1st day too. Not all participants were relevant for this survey, as there were a few some representatives of IT companies, environmental consultants, academics, and non-governmental organizations. On the first day, the survey was handed in to all relevant companies. It was easy to access participants, as they were grouped to three afternoon workshops. Some of them already filled in the survey by the end of the day, the rest was reminded to bring it back on the next day. By the end of the 2nd day, 16 questionnaires were collected. The researcher separately asked those, who did not hand it in yet, to try to do so. Some members promised

to fill the Word document online. 19 e-mails were sent a week after the event, only 3 replies came back. After a reminder, one more reply came back. Table 12 shows the percentage of responses to the questionnaire.

Table 5-2 shows that out of 51 organisations that were participating, 35 companies were rated as relevant because they came from industries that were able to respond to the questionnaire. The remaining participants were consultants, universities, NGOs, or local governmental bodies. The event ensured that it will be possible to take a big picture of the current practice, as the participants were listed on the event's website ahead of the event.

Table 5-2 Paper-based survey: number of responses relative to total

Source: Author

Population	51 organisations
Relevant respondents (sample)	35 companies (70%)
Number of responses returned by relevant respondents	16 (46%)
E-mail survey (out of further 19 respondents)	3 (16%)
Responses after e-mail reminder	1 (0,05%)
Total (actual respondents to relevant respondents)	20 (57%)

First chapter of the survey was asking about the professional role of respondents as well as size of company and industry they are coming from. Most of the respondents were from middle management (10) and high management (7). Most of them (14) were enterprises with above 1000 employers, with more than 10 million EUR yearly turnover and multi-continent presence. However, mostly managers from European branches were present, as the organization deals with Europe. 8 companies were carrier and freight forwarder (only two of them were purely carrier). 3 were only shipper without own fleet, 3 were warehousing companies, 1 ICT provider and 1 NGO organization. Some of the companies, who were freight forwarder, also chose answer warehousing company and/or carrier.

5.3.3 Analysis

The aim of the first questionnaire was to conduct an exploratory research based on initial literature review and to collect as much information as possible on current situation in CO2 reduction in logistics and identify operations and

strategies as extensively as possible. Out of 16 responses that were handed in, two were evaluated as not suitable, as they were filled in only at first page. For many open-ended questions, the best method was content analysis.

First section contained 6 general questions about respondent, which are described in previous section on sample analysis.

Second section was focused to find out more in details about current actions and in practice and experience of responding managers in this narrow topic.

Experience of implementation, budget, and employees

Almost all companies have already implemented at least one of CO₂ reduction initiatives, only one answered none, and one did not answer. Four companies started earlier than in 2008 (5-10 years ago, 1985, 2005 and 2007), 2 in 2008, 2 in 2009, 1 in 2010, 2 in 2011, 3 in 2012. This shows that about half of the representatives were in or came to already experienced company environment, one quarter were already having some current experience and one quarter were under two years of experience, thus starting with first projects. Four companies did not answer this question. Almost none of the companies stated a budget for their implementation as this is, for most of them, a very sensitive information to give. This was also expected and not required from the form of the questionnaire, as in paper-based questionnaire, there is a risk of not all questions being filled in. On the other hand, companies that just started exploring these initiatives, might not have dedicated budgets for these projects yet. Only two companies mentioned current annual budget of the CO₂ reduction initiatives (200.000 €, respectively 500.000 €). These were also companies with

the longest experience. One company answered 'zero'. The question of how many employees were involved in CO2 reduction initiatives, was answered as follows: 1-5 employees at 6 companies, 5-10 employees at 2 companies, 5 of them stated 50-100 employees and one company had even more than 100 employees involved. This question seemed to be understood in different ways as it did not specify how direct, and at which level the involvement was. It is possible that some respondents understood the awareness or company-wide trainings already as an involvement. This was answered by freight forwarders with longer experience.

Drivers and barriers of implementation

The part on drivers and burdens of CO2 reduction in logistics was formulated as multiple-choice. A respondent could choose more than one answer. All the companies were motivated by customers. Majority of them saw it as a social responsibility (14), and as a tool for good reputation or marketing strategy (13). Twelve of them reckoned it was also cost saving. None of them seemed to be driven by any NGO, although nowadays many companies cooperate with NGOs. One respondent surprisingly stated a self-believe in better tomorrow. The largest burden are partners that are hard to persuade (11), and low budget or high up-front investment (9). This shows, that at that time, about half of managers were still not aware of cost-saving effects of CO2 reduction strategies. On the other hand, 15 managers felt positive feedback and good support from high management and partner companies, one commented that it is not always the case. A third of the companies already included some of the CO2 reduction initiatives in long-term contracts with their partner companies.

Collaboration with partners

Most of the companies do not share the costs of implementation with their partners, rather carry them on they own. Only two share joint investments in innovative technology within long-term contracts. One company wrote in an actual example of reducing costs with their competitor by sharing loading capacity and multimodal cooperation. For a half of the respondents, some initiatives brought simplification of inter-company process and second half of them did not change processes at all. 14 companies are willing to share their experiences with the competitors, one said they are not and three did not answer. This section underpinned willingness of companies to cooperate not only on horizontal and vertical level but also with their direct competitors. The last question of this section aimed to identify the situation in Europe and differences in the readiness of CO2 reduction implementation. There were no Eastern European companies at the event, therefore the response could be biased by one-sided viewpoint of the respondents. In comparison to Western Europe, in their eyes, Eastern European companies are “more sensitive”, “hesitating, with less focus on sustainability” and “with worse infrastructure and financial resources”. They do not see Eastern European companies willing to improve their CO2 emission performance due to “language barriers” and “a lot of small and medium enterprises with little budgets”.

Initiatives in transportation

Third section focused on initiatives in transportation. All companies completed this section, at least partly. At the beginning, respondents were asked in which modes of transport are they operating. The most of companies use road

transport, the least use short sea. 6 companies filled in also intermodal. In the first question, the respondents reviewed most and least applied initiatives by their business. This section led to identify current state of usage on operational and strategic level. Operational initiatives are possible to implement shortly with short-term budgets and strategic initiatives usually come from high-level management and take longer to apply. This division in two categories was originally planned for a conceptual model, but as later found, complexity of the project and duration of continuous improvement goals are relative depending on resources, industry, and company size.

Table 5-3 shows count of the answers next to the measures. Mostly commonly used measures are loading efficiency and modal shift. Least applied are handling and routing and scheduling and in long-term technological improvements. The ratio between count of operational and strategic decision making seems to be the same.

Table 5-3 Transportation initiatives on operational and strategic level

Source: Author

Transportation initiatives	
Operational (count)	Strategic (count)
Handling 6	Modal shift 10
Short-term technological improvements 7	Long-term technological improvements 6
Routing and scheduling 6	Fleet renovation 7
Loading (payload and backhauls) 10	Alternative fuels 7
Energy efficiency in driving 8	

Open question “What were the drivers?” represented motivations behind the implementation of decarbonising strategies. Respondents included

environment, main company strategy, to support CO2 reduction target, CO2 and cost reduction, easy implementation and short payback, continuous improvement. The survey also asked how popular the initiatives from literature review will be. Listed were alternative modes of transport, increased modal shift, more alternative fuels, own reporting, reduced speed, new packaging systems, network optimization with the help of latest IT technology, and aerodynamics of the truck-trailer combination. The question of sorting of above-mentioned initiatives by implementation time was completed only by the few ones. Routing and scheduling ranged first. Alternative fuels rather last. One respondent commented that “they can’t be clearly sorted as most run parallel”. Ranking by cost of implementation included least cost requiring initiatives loading (payloads and backhauls), routing and scheduling and handling. Most cost imposing was fleet renovation. One company stated that the CO2 reduction initiatives are not cost requiring, thus cost saving. New contributions to the model would be filling up pallets considering volume and weight trade-off (combination of heavy and light loads) and offsetting of CO2 emissions.

Six companies tried to pioneer some initiative or at least they thought they did it. They implemented lightweight trailers, more train usage to Russia, paper pallets instead of wooden pallets and innovation of flexible trailers that can transport sea freight containers, wheel alignment, Mega trailer development, LNG trucks, electro scooters in parcel deliveries. 4 companies recognised that they did not pioneer anything and 2 did not answer. Most of these companies implemented these initiatives with success, hence 10 of them did not fail at implementing them. Two have also failed, one of them mentioned failing at

testing LNG trucks and came therefore back to diesel trucks. Two of companies did not answer this question.

Initiatives in warehousing

The fourth section on warehousing was answered only by 5 respondents. The rest left out this section, 6 of them specifically wrote, that it is not applicable to them, as they do not own or operate a warehouse. Two of respondents admitted while handing-in that they did not have time or motivation to come that far. 3 of them operated only on standard, non-refrigerated warehouse and two of them did have all kinds of warehouses, including refrigerated, semi-automatized and automated warehouse. Only four of them completed the section on listing initiatives that they already implemented. Table 5-4 shows the count of each initiative. The most popular operational initiatives were efficient usage of existing equipment and space utilisation. The most used strategic initiatives were alternative energy sources and purchasing of sustainable equipment for the future.

Table 5-4 Warehousing initiatives on operational and strategic level

Source: Author.

Warehousing initiatives	
Operational (count)	Strategic (count)
improving operations 2	sustainable building envelope 1
material use (forklifts etc.) 3	sustainable equipment purchasing 3
waste management and recycling 2	alternative energy sources 4
space utilisation 3	generating own energy 2
operational energy use 2	energy efficient heating and cooling 1

Only three out of these five respondents finished completing the warehousing section. The best drivers for them were cost efficiency, marketing advantage, cost and CO2 emission reduction. One company plans using alternative energy sources in the future, this company did not fill in the initiatives listed in Table KL, it means it has probably not implemented any of those before. Three companies agreed that the least cost requiring initiatives are improving operations, space utilisation and waste management. The most cost requiring was sustainable building envelope, sustainable energy purchasing and generating own energy. None of respondents suggested any initiatives that were missing as well as none of the respondents tried to pioneer any CO2 reduction measure in warehousing. Nobody seemed to fail any initiative in warehousing.

Initiatives combining transport and warehousing

The fifth and last section listed three initiatives that are common for warehousing and transportation. Only 6 companies (42 %) finished the survey with this last section and only one responded thoroughly. There might be two reasons, one

of them the extent of the survey. Second one might be relative novelty of these topics, as the listed initiatives were easily identifiable at the first sight. First and second question were meant to observe the complexity of the supply chains, by asking, on average how many warehouses the product needs to pass. This was to distinguish, whether the company was suitable to answer the below questions. If the company had only few warehouses, combining different logistics chains was not applicable. Two companies answered one, one replied two, third one answered 45 in Germany and 70 across Europe. One of the two companies who stated only one warehouse, replied in the previous warehousing section that it operates 100 warehouses around the world and 45 in Germany. Hence, it was quite difficult to draw any conclusions from this section. Two companies are using centralisation, two have consolidation in place and three have already done some collaboration projects. One company who previously stated they have many warehouses, has not crossed any of above initiatives. This means, either there was lack of interest, finances, or time to pay attention to these measures. As in previous sections, the main drivers were cost reduction or cost savings to the logistics system by improving network efficiency, avoiding empty capacities, and using collaboration for enabling shift of warehousing activities from Europe to Asia. Further plans were listed only by one company and that was to automate optimised planning from strategic too tactical and operational with real time information. Any missing initiatives were answered only by two participants saying 'no'. It is probably because most of these respondents answered that they have neither pioneered nor failed any of these initiatives. Only one mentioned that they pioneered IT system that calculates optimised network taking collaboration, consolidation, and routing into account.

This section especially did not enable researcher to generalise the answers for the whole sample and therefore the section should be topic of further research, possibly a deep interview with logistics or sustainability manager.

5.3.4 Bias and limitations discussion

The main limitation was the size of the questionnaire compared to given time for completion. It was too comprehensive to be completed in 15-minute breaks, considering the fact, that managers wanted to network with other participants as well. This fact increased validity but reduced reliability and generalisability of last section focusing on solutions in the whole logistics system. There were two types of respondents, those who finished most of the questions and those who filled only parts that could be answered quickly. One participant finished after 2nd part with comment that he did not have time and lost motivation to finish. Therefore, the response rate of some sections was not cohesive. Five practitioners responded the most comprehensively, as they took time in the evening after the first day of the conference and handed in the completed survey on the next morning. A couple of respondents came afterwards with comments on the too narrow layout, as they wanted to write more but did not find enough space next to the question. Other respondents commented that questions were not so easy to reply quickly and required longer thinking. Some questions did not apply to some respondents, for example, if they only operated in transport or only in warehousing. It is possible, that some respondents purposively skipped questions such as budget, failures, and other confidential information. After the survey was sent out to the rest of them by e-mail, only three answers arrived although more respondents gave in the visit card with promise to answer.

The reason behind that might be lack of time at work to complete such an extensive range of questions. The last section showed already 42% non-responsiveness and therefore it cannot be generalised. It can be only concluded that it was not applicable to companies who did not provide overall logistics services, or they have not applied such measures yet and will progress in the future. The bias caused by improper data analysis were limited by summarizing each question to excel spreadsheet.

Analysis of non-responsiveness bias, reliability and validity of this questionnaire helped researcher to re-evaluate survey type needed to find all initiatives. Wide range of question type, size and length brought a conclusion that there is a need of more simple survey. As not every respondent filled in the survey carefully and in detail, and not all initiatives were identified, external validity of the research is limited in the initiatives section. A new, simple questionnaire had to be recreated. The researcher also reconsidered paper form of the questionnaire to online-based website. Open questions were left out for analysis purpose. Further information on implemented initiatives will be obtained more thoroughly by telephone interviews.

5.4 Web-Based Survey

Consequently, a web-based survey was conducted in November 2018, to collect more targeted responses and fill the gap in response rate of previous paper-based survey. As the analysis of previous survey showed, the aim to identify the most used initiatives and finding new suggestions could not be completed, as the questions were placed at the end of the already long survey.

5.4.5 Design and administration

The questionnaire layout stems from conceptual model, where CO2 reduction initiatives in logistics were summarized. The aim of this questionnaire was to complement the first questionnaire where it had gaps. It helps to identify initiatives which are currently in use, are being planned within 5 years or not being planned at all. The questionnaire was built not to take up more than five minutes of respondent's time. This was successful, as the average response time was three minutes. It was created using a website SurveyMonkey that enables to collect and evaluate data in real time. This survey was structured into 6 slides. The whole survey can be found in Appendix B. First page was informative, it included aim of each section and instructions how to fill in the survey. It could be pre-set that respondents could answer only one option or fill in 'other – please specify'. They could only proceed to next section when previous section was filled in. When they wanted to jump back, it was enabled to them to do so. Second page aimed to obtain general information about the respondent, although it was already pre-defined by the sample choice. This tool eliminated option that the respondents would forward the survey to less qualified colleagues. Also, in this section, there was an option of 'other – please specify' at each question. The third, fourth and fifth section were already focused on CO2 reduction initiatives in transport, warehousing and combined. They were structured into a matrix, where at each initiative the respondent could choose one of three options: currently using, planning to implement within 5 years or not planning yet. Also, each row, or initiative, needed to be filled in to proceed to next section. At the end, a thank note together with researcher's emails address for further requests and research results, concluded the survey.

5.4.6 Sample

This survey was conducted about two years after the first one. Contacts obtained by the conference were also used for sending out e-mails with the survey link. It was assumed, that some of contacts might be obsolete due to job position change or leaving the company. Therefore, the email addresses needed to be updated and completed. If available, respondents were reevaluated by LinkedIn and websites of the companies. Ten more contacts from global enterprises were added to the sample ensuring larger sample size. Number of respondents are shown in Table 15.

Table 5-5 Web-based survey: number of responses relative to total

Source: Author

Population	51 organisations
Relevant respondents (sample)	41 (80 %)
Number of responses 1 st round	7 (17 %)
Number of responses 2 nd round	2 (0,5 %)
Total (actual respondents to relevant respondents)	9 (22 %)

In the first round, six responses were received on the first day and one response on the second day. In two weeks, a second e-mail was sent to remind respondents to fill in the survey. After the second round, two more responses were received.

5.4.7 Analysis

Most of the analysis of this survey was with help of SurveyMonkey, where it is possible to evaluate and download the data to excel spreadsheet.

First section containing the general information on companies confirmed the reliability of the responses as they were senior managers of global companies. Detailed figures summarizing the responses and percentage of each answer are part of Appendix C. In most questions, respondents chose pre-defined answer. In two sections, they answered other. For position in the company, they completed project manager, transport collaboration senior manager, sustainable performance director and QESH manager. Almost half (44 %) of the companies were freight forwarders and 11% were manufacturing companies. The rest added parcel & pallet freight business, pallet pooling company, retail and logistics service provider. Nobody responded to question 7, which was optional.

The main part aimed to find initiatives that are being used or are in planning to use within 5 years or they are not planning it yet. Transportation section showed that the most used initiatives being modal shift and increasing vehicle payload, responded by all practitioners. Each of all initiatives is being used by at least three practitioners, therefore it can be concluded that all initiatives from literature are known to practice. The most planned initiatives within 5 years are alternative propulsion, low rolling-resistance tyres and improving aerodynamics. About the same count of respondents replied at these initiatives, that they are not planning them yet. One practitioner suggested missing measure which was network optimization and consolidation of transports. This suggestion, however, can be added to category routing & scheduling and consolidation in further section. Figure 5-1 summarises the analysis of responses. The transportation section was filled in by all respondents.

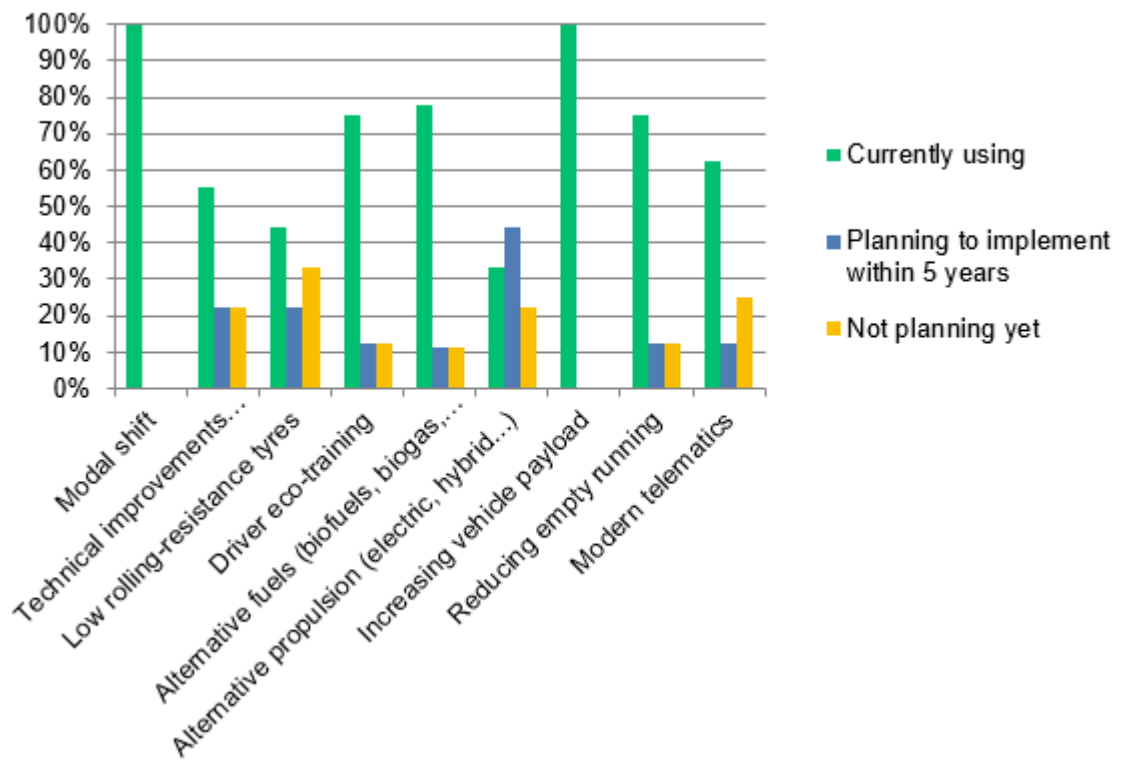


Figure 5-1 Transportation CO2 reduction initiatives from web-based survey

Source: Author

In warehousing, eight participants answered, and one skipped this section. In this case, all initiatives have been already implemented (Figure 20). All responding companies have been using energy efficient lighting. The next best used measures were optimised handling, sustainable energy source and efficient handling and layout of warehouse. The most surprising result brought building warehouses in sustainable way. Only three companies responded that they have sustainable building envelope design and materials. Two companies are planning on building warehouse with sustainable envelope and surprisingly, three companies are not planning it yet. The same number of companies is thereof also not planning to use automated gates and doors yet. Nobody suggested any other measures that they implemented and that were not

mentioned.

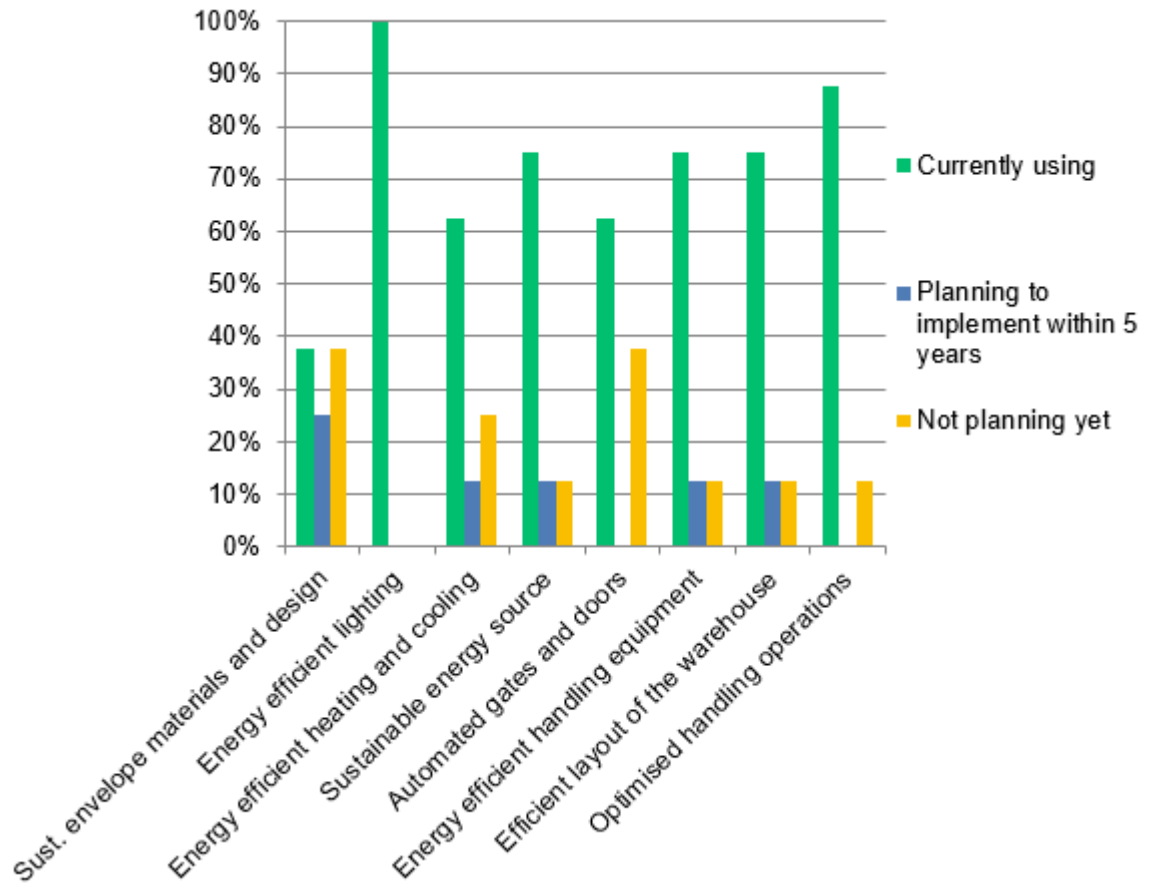


Figure 5-2 Warehousing CO2 reduction initiatives from web-based survey

Source: Author

All respondents filled in last section which was dealing with whole logistics system, combining transport and warehousing (Figure 21). All of them already consolidate their cargo. Most of them have centralised warehousing, one is planning it and one was not considering it yet. Horizontal or vertical collaboration is being used by half of the companies and planned by two of respondents. Off-peak loading hours were not in place at half of respondents, only three had this measure in place. None of respondents gave any hints of missing initiatives.

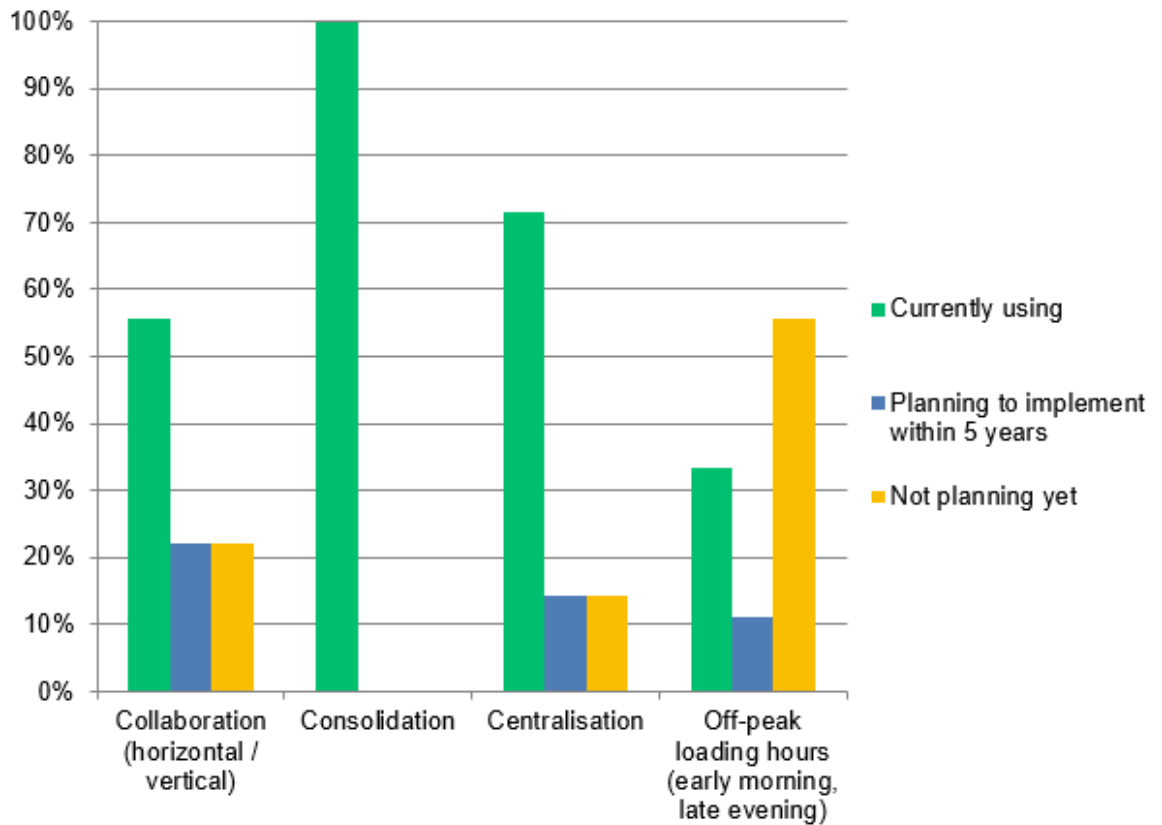


Figure 5-3 Logistics CO2 reduction initiatives from web-based survey

Source: Author

5.4.8 Bias and limitations discussion

As with many web-based surveys, the main limitation is the sample size and response rate. When dealing with low response rates, the significance level of sample size must correspond with strong association to the topic (Forza, 2002). The relatively small sample size had to prove its external validity on response quality. Nonresponse of 78 % shows low interest of practitioners on web-based survey despite of sending reminders and relatability to the researcher. The time when it was undertaken should not influence non-presence of practitioners. It is possible that end of November was already the busiest time to finish yearly

targets. Reliability bias was avoided by contacting practitioners directly connected to sustainability or logistics measures, who were senior managers of multinational companies. Although the ratio of contacted freight forwarders to manufacturers was the same (18 and 18), actual respondents were of 44 % freight forwarders and only 11 % of respondents were manufacturers. The rest of respondents defined themselves as service providers, thus they could be given a separate group of logistics service provider not owning vehicles or facilities. As this is a part-time research, this survey was not part of any bigger project and therefore respondents were not associated with any organisation or project, other than Plymouth University research and therefore they did not see big potential in future collaboration. The reliability was tested on criteria based on Sarantakos (2013). If this survey was sent out at other point of time to given respondents, they would most probably respond the same way, as the survey was based on the company activities rather than opinions of respondents. If however survey would be sent five years later, more projects, higher budgets or higher experience of practitioners would increase number of measures they could have taken. As this survey is based on hard facts, there is a low bias based on subjective judgement. Also, using SurveyMonkey as a tool enabled easy and quick export and summarisation of the data collected. Therefore, bias of analysis stemming from manual input mistakes can be excluded.

5.5 Contribution to Decarbonisation Framework

Paper-based survey mainly analysed current market situation at the beginning of the research, preparedness of companies for their logistics decarbonisation paths, as well as expectations for the future. Suggested topics could refine the model: **reduced speed (or de-speeding), new packaging systems, combining light and heavy cargo for truck utilisation, network optimization with the help of latest IT technology, and aerodynamics of the truck-trailer combination.** These findings were then added to literature review findings in Section 3.3 which improve both transportation and warehousing decarbonisation and were considered for further refining of conceptual model.

5.6 Summary

The first survey enabled to draw initial conclusions on the industry knowledge, happening, strength of reliability of contacts responses and initial information in CO₂ reduction initiatives in logistics sector. Second, more recent survey looked more specifically of each initiative and could draw conclusions, which initiatives are the most or the least likely of used and what is the outlook for the future. Comparing both types of surveys, following conclusions can be drawn. With the first survey, information about general situation of business-as-usual scenario was given. In 2013, there were most of respondents already experienced with some greening measures, with 5-10 years of implementation of at least one initiative. They had also on average 5 employees dealing with this topic. The companies viewed decarbonisation as necessary tool for marketing purposes, cost reduction and general responsibility for sustainable acting. They were also

disappointed of low responsiveness of their customers, but when already implemented, they received positive feedback from inside of the organisation but also from customers. For half of respondents these initiatives also implied simplification of intra-related processes. In general, it can be concluded that large-size companies have more expertise in CO2 reduction initiatives. From mid- and small sized companies' viewpoint, the initial cost of implementation plays a big role. Western Europe seems to have more funding and thus also more experience. From both surveys it can be evident that modal shift is the most widespread measure, although short sea has been the least used green mode of transport. Further on, eco-driving and efficient loading prevail as the second most used measures to decarbonise logistics processes. Companies tend to modernise their fleets if costs of alternative fuels and propulsions decrease. Hence, alternative systems to diesel are gaining on importance. In warehousing, efficient lighting systems are mostly widespread. When the warehouse envelope does not embody the greenest technologies, operations, and layout as well as sustainable energy contribute to overall reduction of emissions. Consolidation of cargo using right number of warehouses and trucks during the trip from source of origin to destination is widely used across different types of companies. Centralised warehouses and collaboration are gaining on significance. It can be also concluded that further findings need to answer the question why some initiatives are not so popular although they also contribute to CO2 reduction in some extent. Therefore, deeper interviews with practitioners will be suitable to draw final conclusions.

Chapter 6 Interviews with Experts

6.1 Introduction

Interview is the last method used in empirical part of this thesis. The main purpose of using this method was to internally validate findings from literature review and surveys, and to discuss the CO₂ reduction measures in a more focused context. The respondent's choice was determined by very advanced sustainability reports and good name in the industry. Depending on the interviewee's practice and involvement, as some initiatives are also done on operational level more in detail, the measures were described. They were necessary to complement the findings from the previous questionnaire of more quantitative character by understanding the qualitative reasoning behind the initiatives that are actual for the industry and to see how wide the industry's knowledge of these initiatives is. Telephone interviews with practitioners were also verified with the text in their CSR reports. Following the steps of Grounded Theory helps to uncover end of 2020's best practice of two global freight forwarders and one global manufacturer. Hence, the viewpoint from both sides, manufacturer, and logistics service provider, is being brought. The bias that implies from using this method, as well as sample size summarize this chapter.

6.2 Interviews and Grounded Theory

The interview is the personal interaction mostly on one-to-one basis, where the interviewer gives questions and interviewee answers them. They give the researcher the opportunity to probe deeply, uncover new clues, dimensions that

are based on personal experience. The interview offers participants more possibility to express their views on the topic.

The aim of the interview is to understand the interviewee's 'world' and the researcher might influence the result. Other purpose is to generate new information, and compare it to known information, or confirm or deny it (Brod et al., 2009). It must be realised, that the information provided might be confidential or commercially sensitive, therefore researcher must offer anonymity Easterby-Smith et al. (2001).

Prior to the interview, the invitation with description of the topic is sent. The interviewee is briefly informed what he can expect in the interview, and therefore has time to reflect on the subject and prepare for the interview. This type of the interview is called semi-structured interview, when the topic is outlined, but the questions are not prescribed. The questions will be formulated as open-ended questions, which cannot be answered with 'yes' or 'no' or a short factual answer (Collis and Hussey, 2013). If the respondent tends to answer with one word, the researcher will use further questions to elaborate on that answer. Structured interview contains given sets of questions but also needs probing. Some examples of probe questions are listed in Table 6-1 below. On the contrary, in unstructured interviews, interviewer does not list planned sequence of questions. Unstructured interviews are used mainly in identifying factors that need further in-depth investigation (Sekaran, 2016).

Table 6-1 Examples of probe

Source: Adapted from Collis and Hussey (2013).

Characteristic	Probe
Clarity	Can you give me an example of this? What do you mean? Can you explain that again?
Relevance	How do you think that relates to the issue? Can you explain how the factors influence each other?
Depth	Can you explain that in more detail? Can you give me more examples?
Dimension	Is it possible to look at this another way? Do you think that is a commonly held opinion?
Significance	How much does that affect you? What do you think is the most important? Would you change your opinion?
Compassion	Can you give me an example when this did not happen? Can you give me an example of different situation? In what way does your opinion differ from views of other people?
Bias	Why do you hold this opinion? What might happen that could change your opinion?

Most common type of interview is telephone interview. The main positive of this method is, that it is convenient for both interviewer and interviewee. They can easily set the meeting, which can be rescheduled. There are no travelling costs included, therefore rescheduling the interview or no appearance of the participant do not affect the response rate. The interviewer can guide the interviewee to answer the questions in the most informative way and not to deviate from the topic. To obtain the best possible outcome, experts from higher management or managers focusing on specific topic should be interviewed. They possess the best knowledge of the problem and are daily involved in decision-making; hence they remember better what has been done recently in the specific area.

The negatives are that the interviewee's answers cannot be generalised. They represent either industry, or countries they are present in. To avoid bias, the probe questions should be asked.

There are many methods how to analyse the data from interviews. Lincoln and Guba (2011) states seven ways of analysis - Grounded Theory, schema analysis, displaying concepts and models, classical content analysis, content dictionaries, analytical induction, and ethnographic decision models.

After reviewing of possible ways how to analyse interviews, Grounded Theory was the most appropriate. For the purpose of this thesis – refining the conceptual models, the best way is to analyse chunks of texts into set of themes and concepts and then to identify how these things are linked to theoretical model (Lincoln and Guba, 2011).

Grounded Theory evolved in 1960's as a way of challenging the hegemony of quantitative research by verification through precise instruments and standards. "It could be viewed as preliminary exercise through which researchers could refine quantitative instruments before the real work began. Presumably, quantitative researchers tested existing theory as prescribed by the logico-deductive model." (Charmaz, 2000). It is mostly used to validate models from literature with expert informants to analyse secondary data. The researcher becomes more "grounded" by collecting verbatim transcripts of interviews as they pick key phrases. This can be achieved by coding, where researcher pulls real examples from the text. The codes are written as the text flows, and the codes are, unlike in quantitative research, interpreted by researchers own language. By code notes, researcher can summarize her ideas about the meaning of the text

(Ryan and Bernard, 2000). Data collection and analyses are interrelated and concurrent; researcher starts analysis already when first bit of data is available (Brod et al., 2009). Grounded Theory does not specify the data collection methods, but the purpose is, that data is extensive, rich and with thick description (Charmaz, 2000).

Collecting the coded text results in comparisons, is a major technique. It can compare (a) different people, their views, situations, actions and experiences, (b) data from same individuals with themselves over a period, (c) incident with incident, (d) data with category or (e) category with other categories (Glaser, 1992).

In Table 6-2, Charmaz (2000) gives an example of coding from a statement.

Table 6-2 Example of Line-by-Line Coding of an Interview Statement

Source: (Charmaz, 2000)

Line-by-Line Coding	Interview Statement
Deciding to relinquish	And, so I decided, this pain, fatigue and stress accruing during her workday, isn't a way to live. I don't have to work...So It was with great regret and not something I planned, I turned in my resignation. It was the best thing I ever did.
Accounting for stress	
Weighing the balance	
Relinquishing identity	
Making identity trade-offs	

Some authors criticized this method as too 'straight forward'. In summary, they argue that there are limits to entry of subject's world, it relies upon viewer's job position as expert observer, and posts set of objective procedures on which the

analysis rests. They suggest rather to use narrative analysis, which is an approach where people make stories to interpret the world, for example by questions like ‘How do you make sense of what is happening?’ instead of ‘What is actually happening?’ (Bryman, 2012). Charmaz (2000), however, argues, that when refining quantitative data, the use of Grounded Theory makes more sense than narrative analysis. It needs to underpin findings of what is happening in large scale and bring it to more specified level by expert work experience, rather than using subjective opinions.

There are different ways of sampling strategy in grounded analysis. For instance, Strauss and Corbin (1998) elaborate on three levels of strategy for sampling data; open, axial and selective (Table 6-3).

Table 6-3 Data sampling process recommended by Strauss and Corbin (1998)

Source: Adapted from Easterby-Smith et al. (2001)

Coding practice	Theoretical sampling strategy
Open	Indiscriminate sampling, sample that provides the best opportunities for collecting relevant data
axial	Sample that provides information about properties of the categories, as well as information how they relate to each other
selective	Very focused and deliberate sampling, sample fills in gaps in core categories and refines the story

The transcription of the recorded interview should be as accurate as possible, avoiding simplification or reconstruction of sentences. It must include basic features as pauses, repairs and overlaps (Silverman, 2011).

Easterby-Smith et al. (2001) suggest following steps, when analysing the data collected:

1. Familiarisation – re-reading (or re-listening) the data transcripts (or recordings) and putting notes wherever additional information needed and reflecting on whether the answers can respond the research question and bring a point
2. Reflection – whether the research supports current knowledge, whether it challenges it, if previously unanswered questions are answered and what is different from existing research
3. Conceptualisation – a set of concepts is drawn to understand what is going on, expressed by simple codes.
4. Catalogue concepts – if concepts tend to occur more often, then they should be transferred into a database as categories and sub-categories.
5. Re-coding – highly interactive process of going back and checking whether there are some incidents, for example if there are individuals interpreting what seems to be the same concept.
6. Linking – explanation of patterns between concepts, developing theoretical codes, or conceptualization. Linking key variables to more holistic theory.
7. Re-evaluation – if researcher feels that more work is needed in some areas, for example if analysis may have omitted some factors

6.3 Interview Design and Administration

The interview was a follow-up to the simple web-based surveys which were used as plot of the questions, that was based on the initiatives mentioned in the surveys. Potential contact persons for the survey were invited to participate in the interview. Reasoning behind the choice of this sample is described in survey sample section. The possibility of participation at the interview was mentioned at the end of introductory email of the survey. However, nobody replied to this option at the beginning. Following this, respondents of the survey who either responded positively that they finished the survey or who were interested in further research or research results, were separately invited to the interview. A reply to their emails included topic, structure and length of the interview and guarantee of anonymity. Participants were informed about the confidentiality and anonymity in the data evaluation. Participants were asked to reserve thirty minutes for the interview. Four companies agreed upon participation. In the end, fourth participant from warehousing sector could not take part on the interview, and due to time constraints, this call could not be postponed.

Prior to the interviews, the researcher did not know any environmental initiatives that were implemented in the specific companies. Researcher read only briefly main web sides of the companies on general activities of the company and more thoroughly sections of CSR reports that included environmental sustainability. This helped to reduce the number of unnecessary questions and save time at the beginning. The respondents were called on landline or on conference call phone number. At the beginning of the interview, researcher reminded interviewees on the main aim of the interview which was identifying current and potential CO2

reduction initiatives in transport, warehousing and combined and potentially find new initiatives. Also, they were asked if they agreed upon recording the interview for the analysis reasons. All respondents agreed and from this moment, the whole interview was recorded by a mobile phone app TypeACall and then transcribed to word document. Interviewees were guided by conceptual framework of CO2 reduction initiatives that were found in the literature.

Addressing the aim of using this method, interviewees were asked to develop reasoning and motivation behind the measures that they have undertaken. They were asked probe questions, in case the answer was not explanatory enough. If they tended to jump from one topic to another, they were left to finish talking about the specific initiative but were subsequently guided back to the main plot. The interviewer skipped a topic if it initially was on the list but was already mentioned by the practitioner without guiding. Complementary questions, such as “Can you give me an example?” or “Do you also look at...”, were also formulated specifically either for freight forwarder or manufacturer perspective to see the depth of the knowledge. At the end of the interview, interviewees were asked if they wanted the transcript for further elaboration and corrections. None of the participants insisted on this kind of verification. They were also asked whether they wanted the results of complete research. The response was positive from all sides.

6.4 Sample

All the companies who took part were of global corporate presence. Freight forwarders were two of top 5 European forwarding companies according to

several rankings online. The manufacturer was one of leaders in clothing industry. The interviewees were heads of sustainability on either global or European level with growing market share. All companies were certified with ISO 14001 and gained recognition for their environmental performance. They were known for achievements such as pioneering biodiesel trucks in Sweden, collaboration portal in Netherlands and greenest warehouse building in Belgium. They have all mentioned environmental performance of their logistics activities in their CSR reports. One of the managers was also active as advisor for EU organisations dealing with environmental issues of transportation. All participants are members of non-governmental organisations in sustainability and green logistic. The interviewees were purposely selected as experts to be able to elaborate on as many initiatives in the practice as possible.

6.5 Analysis

For analysing interviews, Grounded Theory was used. The main seven steps of Easterby-Smith, Thorpe, and Jackson (2001), familiarisation, reflection, conceptualisation, catalogue concepts, re-coding, linking, and re-evaluation were kept. After transcribing the interview to a word text, it was carefully re-read, and eventually first main points were realised already during re-reading. Also, the researcher reflected upon each answer if it was sufficiently answering the given question. Subsequently, a method of coding was used. Firstly, key words for initiative were outlined by making them bold directly in the text. As there were different synonyms for initiatives, for example innovative design of vehicle could be understood as aerodynamic design, the main coding groups remained the initiatives from the conceptual model based on literature and surveys. Keywords

of each answer were picked up and grouped next to each initiative. A chart was created to group the answers into the topics and find common properties of each initiative. The codes were formulated to pick up the main issues and simplify complicated and long statements, that were leading to a more explicit conclusion. Examples for such formulations are stated below.

Interviewee 1 (further as FF1 = Freight Forwarder 1):

*“You know we have thousands and thousands of customers that book with us and sometimes they book a full truck transport, I mean one trailer and that is dedicated to this one customer. And sometimes, the customer fills this trailer, example, we have to pick up 3 times a week, but it is not necessary that the customer has fully packed the trailer. There can be some interspace in this. Then we discuss with customer: Is it necessary that we have 3 trailers? Could we **reduce** them to 2 trailers, and they are **utilised**? Then we will **increase the vehicle payload** and we also decrease the cost and the environmental cost of the transports.”*

Interviewee 2 (further as FF2 = Freight Forwarder 2):

*“For example, we also use **windows for day light**. This reduces the energy consumption for lighting. Also, we use boilers that are **heating with old broken pallets**. This heat goes to pipeline systems and heats rooms where usually workers would be cold.”*

Interviewee 3 (further as M = Manufacturer):

*“Yes, when tendering new carriers, we push for **LNG and CNG vehicles**, if it's an option. That is part of our tendering strategy. Also, in city logistics we support **electric vans, electric bikes**. Traditionally our logistics was post driven, but it is moving towards other private companies, that can compete with postal services. In two years, the service will be on about equal level. The costs will be also on about the same level.”*

Re-coding and re-evaluation were implemented later, by comparing the statements to the CSR reports and other documents such as press releases which were published on companies' web sides. This technique ensured there was no initiative, that has been applied by the company, forgotten. When some

incomplete information would require going more into detail and could not be responded thoroughly, more information was researched in the CSR report. For example, one stated that “in France, we had a customer who wanted us to buy hybrid (forklifts), but I don’t know exactly why. I would have to speak with my operation manager.”

Analysis of freight transport section

Table 6-4 summarises the analysis of the transportation section and deals as a tool for drawing conclusions. As mentioned above, coding categories were chosen by initiatives in previous literature review and surveys.

Table 6-4 Coding interviews, Part 1: Transportation. FF = freight forwarders, M = manufacturers

Source: Author.

Coding category	Properties	Examples from the interview	Examples from CSR
Modal shift	FF1: Transit times of greener modes are longer, only if customer agrees	FF1: of course, it can take 1-2 weeks longer than by road	FF1: reporting our external carbon footprint per transaction, transport mode and customer
	FF2: improving container routing from port	FF2: some of them are willing to compromise costs vs. emissions	M: actively seeking solutions in our supply chain to reduce all unnecessary airfreight
Technical improvements on truck and trailer	M: implementing rail and short-sea transports FF1: Mostly EURO 5 engines	M: yes if it fits our distribution programme and budget FF1: encourage our partners to buy newer trucks, engage with manufacturers to find new designs; we tested all kinds of aerodynamics on own trailers	FF1: In 2015, nearly 75 % of our partners met the highest European standards
	FF2: tested some aerodynamics	FF2: all kinds of aerodynamics	
	M: using LNG, LPG	M: we push for LNG and LPG it is part of our tendering strategy	
Improvements on tyres	FF1: Checking tyre pressure; Liquid against puncture M: not in use as they do not own trucks	FF1: we use telematics to regularly check tyre pressure M: low-rolling-resistance tyres and adding some fluid to the tyres	FF1: A tyre sealant that reduces pressure loss considerably, and at the same time minimises punctures and breakdowns
Eco-driving training	FF1: Complementary for all partnering companies FF2: only own fleet M: No own fleet	FF1; All own drivers are trained; subcontractors must have eco-training, if not they can lose contract with us FF2: few our own drivers that we have employed	FF1: Since 2010, an average fuel consumption from our own trucks improved by 7 %
Alternative fuels	FF1: LNG FF2: Biofuels M: LNG, CNG	FF1: we use mostly LNG, now we have 20 trucks, next year we want to double the number, where we know there are fuelling stations FF2: mainly biofuel, mainly in Sweden domestic groupage transports M: when tendering new carriers, we push for LNG and CNG vehicles	FF2: The initiative to realise HVO 100 (hydro-treated vegetable oil) could have a nationwide basis
Alternative propulsion	FF1: Depends on customer and costs M: electric vans	FF1: in next 5 years we expect the costs of electric vehicles to go down	FF1: We are currently testing electric vans for a very large drugstore chain in Germany
Increasing vehicle payload / Reducing empty running	FF1: optimisation of vehicle	FF1: we use different sharing platforms to optimise our vehicle space; we make sure to optimize space in the truck, not to transport air	FF2: Managing idle capacities, space consolidation M: we encourage material vendors...to ship the pre-cut pieces to our finished

	FF2: increase vehicle payload	FF2: We discuss with customer, is it really necessary to have 3 trailers instead of 2?	goods manufacturers, it cuts down on CO2e emissions related to transporting the materials
	M: avoiding transport of air	M: working on marrying up reversals	
Modern telematics	FF1: different data from truck to improve it's performance	FF1: I evaluate mostly km driven and fuel consumption	FF1: Extending use of Telematics and FleetBoard, which decreases fuel consumption
Other suggestions	M: not in use as they do not own trucks FF1: sharing platforms with freight forwarders	FF2: We use telematics to regularly check tyre pressure FF1: as I said, we cooperate in Netherlands on LEAN platform	M: testing and assessing multiple box designs... without compromising performance attributes for transport
	FF2: Think of payload utilisation in terms of scheduling	FF2: we have to pick up 3 times a week...is it really necessary that we have 3 trailers? Could we reduce them to 2 trailers, and they are utilised?	
	M: packaging design	M: develop best possible packaging not to transport air	

In freight transport initiatives, freight forwarders were more experienced, as they owned or booked the fleet directly. They seemed to have at least some experience in each measure as they could comment on each initiative by making examples from their best practice. Comparing the two freight forwarders, it is interesting to observe that they were not doing the same initiatives in the same extent, hence one was expert in one initiative more than other one. Sustainability report of FF1 contained more examples and was comparable to almost all manager's answers. The common property was, that they both were good at initiatives that were feasible and easy to implement and that were longer on the market, such as modal shift, improving vehicle payload, tyre pressure control, eco-driving, EURO V and higher engines and telematics. Smaller scale was observed at initiatives that were more complicated to implement and did not bring fast return on investment, mentioning electric vehicles, aerodynamic design, gaseous propulsion. They intend to stay prepared for further development in this area within 5-10 years. Freight forwarders who were interviewed do not seem to

apply many aerodynamic adjustments on trucks yet. However, they have already tested it. In the logistics solutions they get often influenced by customer's wish, but also are proactive on optimising routing and scheduling for customer's benefit. This was very interesting point for the interviewer and interviewee (FF2) was asked to elaborate on this.

M: "Yes, but actually, it would be more convenient for you to book 3 transports and you get paid for each transport, each part load, but now you make them to reduce them, so you do not earn as much per pallet or per tonne."

FF2: "Sort of...Another thing that you can look up in our CSR report is transport lanes, travel distance that the customer has. We have described an example from a customer where they had some exports out of China, from Shanghai to Europe and they transported all their containers to Rotterdam and then to different destinations in Europe. Looking closer at where we then transported these containers, we saw that we could reduce the transport distance and, they could travel quite far from Rotterdam. They could be discharged in other parts of Europe. If the destination was for Great Britain, we discharged containers in closer harbours, and we could reduce the cost and also CO2 emissions for specific customer."

Manufacturer focused on using greener transport modes such as rail and short-sea and tried to avoid air freight as much as possible. They did not really influence their freight forwarders on technical improvement on the fleet, or driver training but they pushed LNG and LPG in tendering strategy. They also supported electric vans and motorbikes in urban deliveries. One interviewee expressed satisfaction

with current development of prices of electric vehicles. An initiative uniting all of them was reducing empty running and optimising vehicle payload. In one CSR report a concern about speed of the innovation was expressed as due to volatile transport prices and short-term relationships there is lack of needed progress. They discuss the fact, that customers with bigger transport budgets perform sort of due diligence process which includes environmentally responsible measures when tendering new carriers. Manufacturing company confirmed that they add plus points for partners with greener performance when tendering.

Throughout the whole interview, respondents were guided by measures from the literature and at the end of each section they were asked, if they know any initiatives that were not mentioned yet. They have responded with further suggestions, as sharing transport platforms with other companies, even competitors to increase the vehicle payload, which was not explicitly mentioned in transport initiatives but can be included in collaboration part. Very good initiative is to encourage customer to rethink the regular pick-ups in some periods, when the trucks are not filled up properly, and reduce number of truckloads per week. Manufacturer went beyond what freight forwarders can influence and that was redesigning packaging to reduce empty space in the truck. Therefore, this measure was later added to the literature review in Chapter 7.

Analysis of warehousing section

Warehousing initiatives were solved in both freight forwarders and manufacturer's best practice. The interviews brought better understanding to what companies are currently doing because there has been not much literature on this topic. Table 6-5 summarises the analysis of warehousing initiatives.

Table 6-5 Coding interviews, Part 2: Warehousing. FF = freight forwarders, M = manufacturers

Source: Author

Coding category	Properties	Examples from the interview	Examples from CSR
Sustainable envelope materials & design	FF1: sustainable materials pay off later	FF1: We use specific materials that are bit more expensive, often because this investment will imply lower running cost when it is in use	FF1: our locations are built to some of the most demanding national standards...investing in more expensive materials with longer lifecycles
	FF2: Complying to highest standards	FF2: We have own department, which gives us format of new building technology that we should use	FF2: Green roofs, green walls and landscaping
	M: building of green warehouses	M: We just built a new warehouse that is very ecologically strong	M: the warehouse is a rack-supported building, moving away from a traditional structure requiring steel and concrete
Energy efficient lighting	FF1: LED, automatic switch on and off	FF1: We implement LED lights in as many warehouses as we can, in 2015/2016 it was 30 %.	FF1: When the use of natural light is not possible, 100% LED lighting dims and illuminates as required through the presence or movement of employees....automated illumination and low energy light bulbs.
	M: natural light where possible, LED when no windows		M: An experimental daylight delivery system captures daylight and, through a cable network, helps light the inner reaches of the facility.
Energy efficient heating & cooling	FF1: automated temperature controlling	FF1: In most building we have appliances for fine controlling of temperature.	M: The aquifer thermal energy storage system (ATES) acts as a "heat battery:" with this system, the heat from summer is used to warm the building during the winter and the cold from winter will cool the summer.
	M: heating by reusing old pallets	M: We do only implement different heating and cooling system that operate on a need basis.	FF1: Increasing installation of solar power in our premises
Sustainable energy source	FF2: Purchasing green energy depends on country	FF2: The main obstacle is cost... in some countries, sustainable energy is more expensive. In countries like Germany or UK, where there is majority of renewable energy, we do (purchase it).	M: geothermal energy system with seasonal storage of cold/warm groundwater is supplemented with wind, solar, small hydro and biomass energy
	M: generating own energy from five different kinds of sources	M: We cooperated with 3rd party who built windmills on our site.	Not mentioned.
Automated gates & doors	FF1: in all most of facilities	FF1: Yes, in many warehouses.	
Energy efficient handling equipment	M: not mentioned		
	FF1: electric and hybrid forklifts	FF1: Mostly electric and hybrid. FF2: We usually have electric forklifts and when you charge	FF2: When a traditional stacker crane stops, its kinetic energy is turned into heat. With a

		these batteries, they produce the heat. You need to insulate the air when you charge them...We put converter to use the warmth of these batteries for heating.	regenerative braking system, that heat is captured and used.
Efficient layout of the warehouse	FF2: layout adjustment according to stored cargo	FF2: Yes of course, at every facility we look at most efficient operations.	M: Vehicles, that serve within the facility or transport employees are designed for minimum impact on the environment. FF2: All aspects of the logistics network are optimized to be simple, flexible, and scalable.
	M: optimised movements within high rack systems	M: we use high rack systems, and monitor movements	M: very best characteristics of smart automation and employee teamwork to create a performant logistics ecosystem FF2: Managing idle capacities (space consolidation)
Optimising handling operations	FF2: continuous improvement of handling operations	FF2: at every facility we look at most efficient operations	M: Outbound containers are loaded using special extendable conveyors, called 'man riders' allowing employees to ergonomically optimize the fill-rate of trailers, reducing emissions, and increasing speed
Other suggestions	FF1: roof top windows FF1: Heating with old pallets FF2: converter for warmth usage from charging forklifts M: Incentives for green commuting M: use software for smart movement monitoring	FF1: We also use windows for day light. This reduces the energy consumption for lighting. Also, we use boilers that are heating with old broken pallets. This heat goes to pipeline systems and heats rooms where usually workers would be cold M: it does not end with building a green warehouse, we continuously improve our energy efficiency, use software for smart movement monitoring, check conveyor belts layout, route design	M: Employees who commit to commute to work by bike at least 50% of the time are provided with a free bike.

The analysis showed that also warehousing initiatives mentioned by interviewees do not differ from literature. Interviewed companies are very active in keeping the state-of-the-art technology at their warehouses. As mentioned in previous chapter, warehousing is mostly running on electric energy and therefore reduction in energy consumption yields in CO2 emissions savings. Although warehouses have long life span, one practitioner mention that they rather look at

quick repayment, for example: "... it could be different kinds of initiatives how to build, but it needs to be short return on investment, 5-10 years." Depending to what scope companies measure their CO2 emissions from warehousing, commuting transport mode of employees to the office also can contribute to overall footprint. Therefore, encouraging employees to use green modes such as train or bicycle can contribute to a positive improvement. This was one of the suggestions outside the conceptual model but can contribute to overall impact. Improving existing facility together with heating up old pallets, installing as many rooftop windows as well as software for evaluation and improvement of cargo movement within the warehouse finalised the suggestions.

Combining transport and warehousing was the last category to analyse. Freight forwarders tended to jump to this section already from freight transport themes, therefore the section was complemented by the remaining initiatives at the end. Following Table 6-6 shows how the three interviewees progressed on their supply chain practices.

Table 6-6 Coding interviews, Part 3: Combined. FF = freight forwarders, M = manufacturers

Source: Author

Coding category	Properties	Examples from the interview	Examples from CSR
Collaboration	FF1: Knowledge support of subcontractors	FF1: We started last year to share some capacity. It is critical for us to increase partnerships.	FF1: we are now focusing on collaboration with customers to bring down emissions. This collaboration can take many forms, from working on alternative transportation routes to implementing new technology...
	FF2: Collaboration with partners	FF2: I mentioned LEAN in Netherlands, and other transport platforms where we can offer or find cargo	
	M: not yet but interested in the future	M: No, not yet, only with our transport partners. But we are strongly interested in it in the future. We started last year to share some capacity. It is critical for us to increase partnerships.	M: We wish to increase collaboration ... to find transport solutions focusing on the reduction of carbon emissions and general environmental impacts.
Consolidation	FF1: depends on location of warehouses and production sites	FF1: sometimes you consolidate the goods, therefore reduce the number of trucks because if you send it directly it will add CO2 emissions and sometimes it can be the other way around. Depends on the locations of warehouses and production sites.	FF1: Consolidation is, on the other hand, our main contribution to reducing the environmental impact of transport emissions.
	FF2: yes, it saves costs	FF2: it's a way for earning money, that we can consolidate goods from very many different clients on one trailer	
	M: one hub to reduce transport emissions	M: it depends on specific shipments and lanes	
Centralisation	FF1: Constantly evaluating locations of warehouses	FF1: we consider how to merge the sites, one out of two or do we have to build a new one that is larger, better equipped	M: Lying at the centre of a 500km radius in which 60% of Europe's buying power is concentrated, the facility is fed by an infrastructure of canals, railways, and highways.
	FF2: yes, in urban areas		
	M: in the centre of demand	FF2: in areas with traffic problems, it is better to build consolidation centre	
Off-peak loading hours	FF1: yes if customer asks for it	FF1: This is customer-based solution. Of course, it needs to be in line with customer facilities, they need to be open.	No examples
Other suggestions?	M: not mentioned None		

The most widespread measure was collaboration with partners, such as logistics service providers educating their subcontractors, or collaboration with their clients

on reducing the number of transports. Collaboration among manufacturing companies will gain on significance in the future, as the interviewee was interested in making a software for sharing of capacities. Consolidation of cargo is the main tool of transport companies to reduce their costs. If a consolidation centre is in the centre of gravity and location is near demand, it makes sense to build a centralised warehouse. In the discussion on whether it is better to build a centralised or decentralised warehouse, one respondent answered that it depends also on geographical location. Off-peak loading hours do not seem to be considered, when collaborating with customers, hence freight forwarders do it only if they are asked.

6.6 Contribution to Decarbonisation Framework

Many practical examples of initiatives from survey were found in the practitioner's interviews. These experts already took part on surveys so it could be expected that they do not refine the model much anymore. However, there were still new recommendations for warehousing such as **roof top windows, using old pallets for heating** (equipment recycling), **heating with forklift battery loading, software for smart movement**. The trend is also moving towards **collaboration - transport disposition platform sharing, better scheduling of customer's deliveries to increase payload, and alternative packaging**. Interviews showed wider consideration of the **supply chain structure**. Therefore, a further literature review was conducted on the mentioned suggestions from managers and added to the last part of Section 3.3 as they are supply-chain related. These initiatives also form surrounding of logistics decarbonisation framework, as supply-chain management has direct influence on logistics operations.

Interviews helped understanding of current trends of decarbonisation and closing the loop of the supply chain. These measures suggest also investigating repurposing equipment or bringing added value services to their clients by better orchestrating their resources to add competitive advantage as a freight forwarder.

6.7 Bias and Limitations Discussion

Reflecting on limitations of this interviewing method, which were mentioned in Chapter 4, several points could be concluded. These interviews proved the argument that the data obtained from interviews cannot be widely generalised due to limited number of interviewees. On one hand, the three companies do not represent the overall situation on the market, as they were those having the resources, departments dedicated to these solutions and they are taking the leadership. On the other hand, to obtain the best possible information about how the innovations have adapted on the market, the best practitioners had to be chosen. Two freight forwarders who were interviewed can represent global best practices of their industry, as they received various awards and they directly compete in bringing the best innovation to the market. Not only them but also their customers determine the scale and scope of decarbonisation measures. It was mentioned in several parts of the interview, that customers participate on investment and they are also drivers of those initiatives that would not necessarily mean cost reduction for the freight forwarder. The main weak point for generalisation was interviewing only one manufacturer. Talking to more manufacturing companies from different fields of activity would enable to see which initiatives are specific for each industry. From a garment manufacturer

viewpoint, owning several large distribution centres brings focus on CO2 reduction initiatives in warehousing rather than in transportation. It would be interesting to interview companies who own and operate their own vehicles, to see whether they implement different initiatives than freight forwarders and to compare the scale and scope. The other question is whether it would be necessary to include not only sustainability manager, but also logistics manager to the interview, as logisticians have more insight into daily operations.

The thirty-minute duration of the interview enabled to summarize all initiatives with detailed comments. However, history behind decision making, calculations of return on investment, and other background information was not provided at each initiative. The risk of bias by avoiding asking on personal opinions was reduced by asking about what company is doing right now or planning in near future. This information provided facts. Of course, some planned projects might not come to a realisation but at least this information brings insight into current practice's considerations. The bias of incomplete information was avoided by finding complementary information in CSR reports and websites of participants.

6.8 Summary

Interviews brought more detailed description of initiatives that are being used within the companies. Analysis shows that most of the initiatives found in the literature are being used in practice. Initiatives that are going to happen within 5 years is electrification of truck transport and software tools to enable collaboration among companies. There are few gaps in the academic literature such as special liquid used inside of tyres to avoid pressure loss and a warehouse heating

recycling old pallets or excess heat from loading of forklift batteries, or forklift with regenerative energy from breaking. Main limitation in practice is the willingness of customers to support the co-financing of the projects with their service suppliers. On one hand, hauliers expect their customers to participate on unusual decarbonisation measures, on the other hand the manufacturers would like to have suppliers with already high level of innovation in place. Companies hope for short time return of investment, but some initiative seem to pay off only long-term, therefore they may not become a priority for managers. Therefore, it is of transport company's interest to implement CO2 reduction measures within their truck fleets ahead of the specific customer requirements to obtain long-term partnerships with market leaders. One freight forwarding company admits in their CSR report that even if they were able to monitor and book the greenest transport modes and use the most efficient routing and warehousing, the price could not be competitive, and they would lose majority of contracts that help them to re-invest the profits into sustainable innovations. Interviews helped understanding of current trends of decarbonisation and closing the loop of the supply chain. These measures suggest also investigating repurposing equipment or bringing added value services to their clients by better orchestrating their resources to add competitive advantage as a freight forwarder.

Chapter 7 Criteria for Choice of Decarbonisation Measure in Logistics

7.1 Introduction

This chapter is a follow-up on research in past two years which leads to further exploration on the decision making in the practice. As mentioned in previous chapters, in past decade, there have been no formal obligations of companies to reduce their logistics carbon footprint. Most large corporations have their focus on the economic, social, and environmental sustainability and logistics is a small part of this agenda. Accordingly, there are not many dedicated group managers involved in these projects. There is already awareness of importance to act also in small enterprises, but the methods for execution are lacking. Majority of companies do not have skills and knowledge to calculate their CO₂ emission from transportation to determine their opportunities and measures Transporeon (2021). Thus, it is hard to find relative importance of each measure. If a company starts greening their logistics processes, it requires changes in operational capabilities and assessing different greening initiatives (Wang and Chan, 2013). At the beginning, managers face different decision-making thought processes, asking themselves: “What are current priorities? How to decide upon the most efficient initiative with limited knowledge? “. This chapter explores these processes more in detail and aims to find the top priorities in today's manager's decisions to round up the framework on decarbonisation measures. With help of

further multiple-criteria questionnaire and software, the most important criteria will be listed and discussed.

7.2 Updated Literature Review and Current Research Suggestions

Since start of this thesis, further projects have been completed, among the most significant, Centre for Sustainable Road Freight (CSRF) with a 5-year grant from EPSRC (2012-2017). It has focused on single decarbonisation measures in road freight, in topics such as modelling the cost-effectiveness of decarbonisation measures, optimising long-haul transportation, driver behaviour, human factor in vehicle design, decision support in logistics and alternative fuels. This research further contributed to understanding of relative contribution of these single measures. Hence, the initiatives in Chapter 3 of this thesis were revisited and missing information was added.

Further need on deepening knowledge of small and medium carriers was recently confirmed by Toelke and McKinnon (2021), by results from several surveys and interviews conducted with about 800 European carriers. This project was undertaken in collaboration of Kühne Logistics University and Smart Freight Centre together with members of transportation platform Transproeon. It confirmed, that in year 2020, still around half of carriers have insufficient knowledge, motivation, calculation capabilities and belief in implementation benefits. This body of research confirms actuality of this thesis's research motivation and usability of the conceptual framework.

With increasing fleet size, there is growing motivation and capabilities. There are not only company size differences, but also geographical differences. Results show that government backed programs that are existing in countries such as Netherlands and France may correlate with the current knowledge and importance view. To find, in what extent the carriers would benefit from further knowledge sharing, they identified main internal and external factors promoting uptake of carbon-reducing measures.

Utilization of assets in freight transport and warehousing gains on importance in terms of IT systems, therefore this theses' framework was updated towards the trend of holistic approach. Nowadays, countless start-ups, that are offering solutions for goods flows utilization across end-to-end supply chain processes, are emerging. They offer logistics utilisation solutions from material sourcing up to return shipments. These lead to absolute reduction of demand of freight capacities. The competition to win the market leaders for customers has strengthened in the past year.

Similarly, to this thesis ALICE and Smart Freight Centre developed a framework based on McKinnon (2018), see Figure 7-1.

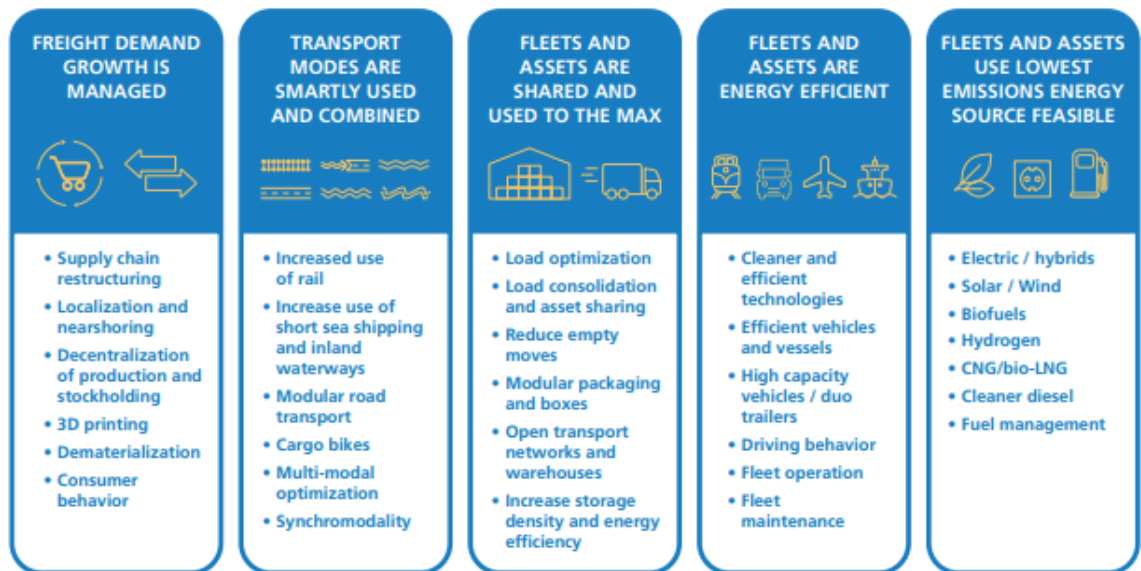


Figure 7-1 Solutions for freight transport and logistics decarbonisation

Source: ALICE-ETP (2019)

These five categories sum up decarbonisation solutions by categories of usage. With this report, authors wanted to point out that there is no single best solution, such as fleet electrification. Every company should approach their business holistically and combine different pathways to decarbonisation. It should do small steps and improvements before focusing on one big project, which is also cost-effective.

Synchromodality appears in EU funded projects to achieve better inland-based alternatives transparency as contrary to road freight transport. In sychromodal chains it should be possible for short-term decision makers to switch between transport modes in real time, so that the best mode option is achieved based on various criteria as costs, timely delivery or loading capacity. The success factor of this concept is high level of collaboration (Pfoser et al., 2016). Possibility to enable switching between modes of transport while a consignment is in transit

could enable reducing risk of lower reliability of rail or river shipping at particular times (Lemmens et al., 2019).

During first empirical research of this thesis, paper-based survey, two main criteria for choosing the most effective solution were questioned – costs and time constraints. During finalisation of the thesis, few other comparison criteria started to be evaluated by other researchers. McKinnon’s book *Decarbonizing Logistics* (2018) focuses among other themes on evaluating the freight transport carbon reduction initiatives by CO₂ abatement potential and ease of implementation combining time and costs (Figure 7-2) to simplify decision making for companies with these two different criteria, showing initiatives of lowest to highest effectiveness.

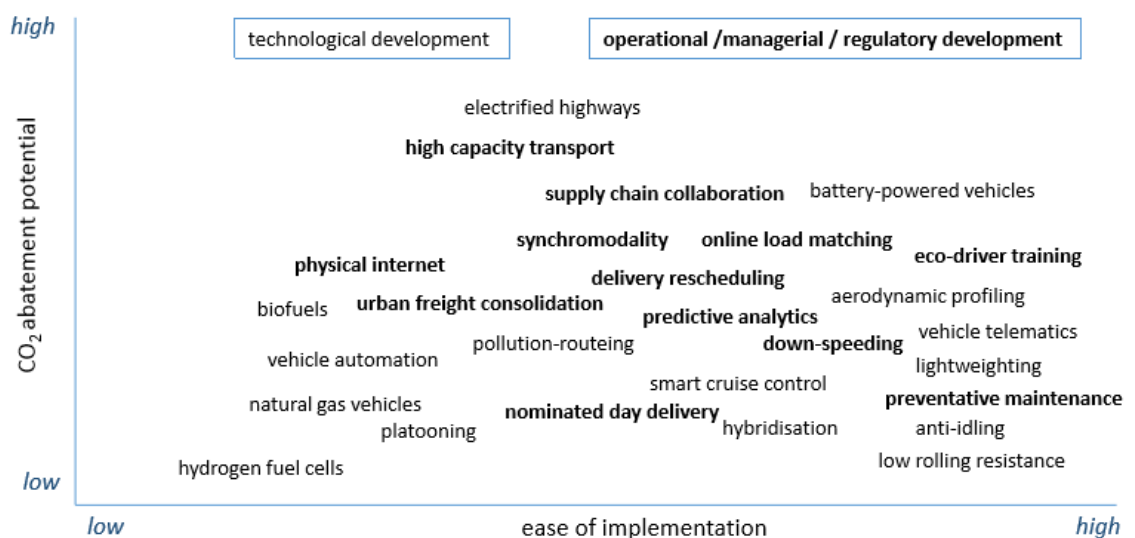


Figure 7-2 Decarbonization of freight transport by CO₂ abatement potential and ease of implementation

Source: McKinnon (2018)

Operational initiatives, regular fleet maintenance and driver training, should be introduced into regular monitoring and have short-time payoff for any fleet owner. Their monitoring can be complemented with technical improvements such as

detailed telematics and driver behaviour monitoring, anti-idling in-cabin systems and enhanced by external retrofitting as aerodynamic equipment and low-rolling resistance tyres, as outlined in Chapter 3. This means, before investing into projects connected with alternative fuels or software for predictive planning, routeing, load-matching or synchronomodality, utilising already existing assets can bring already short-term gains.

Similarly, Cebon (2018) reviewed the initiatives by their reduction potential while keeping barriers low. He considered technical, economic, and political barriers, which reflect the current market readiness of each initiative. In his presentation at OECD freight decarbonisation workshop, he stressed out, that the mainstream initiatives will make a change, rather pioneering one initiative by one company. The initiatives in Figure 7-3 circled in yellow are the current low-barrier ones. According to focus group research, first scenario is to implement the highest effective measures such as driver training, aerodynamics, electrification, backhauls, and synchronised consolidation. For the shippers, high-capacity vehicles reduce total demand on transport. In the second scenario, methane and dual fuel should be developed, or in the third one, electrification of long haul together with biofuels and hydrogen are expected to be mainstreamed around 2040.

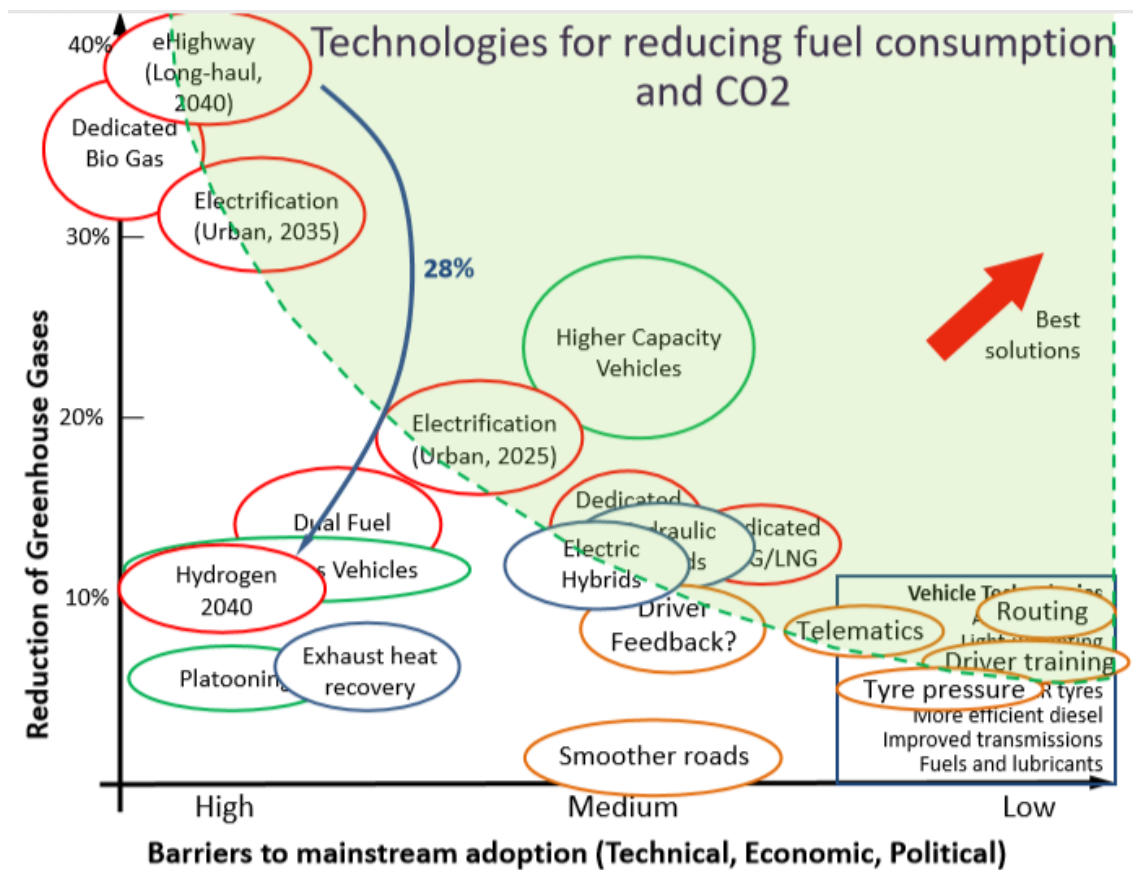


Figure 7-3 Technologies for reducing fuel consumption and CO2

Source: Cebon (2018), <https://www.itf-oecd.org/sites/default/files/docs/technology-roadmap-freight-decarbonising-cebon.pdf>, Accessed on 20.04.2020

The holistic approach supply chain management has not been neglected either, as seen in below Figure 8-4 by Cebon (2018). This figure combines the same criteria but considering increasing efficiency in goods flows. Below initiatives suit retailing and parcel service companies with high number of transport units and are not only considering intralogistics processes but also collaboration with external partners by finding and sharing common capacities. This is very innovative approach and can be used in greening the urban logistics, which has also been a subject of recent research but is not more detailed in this thesis.

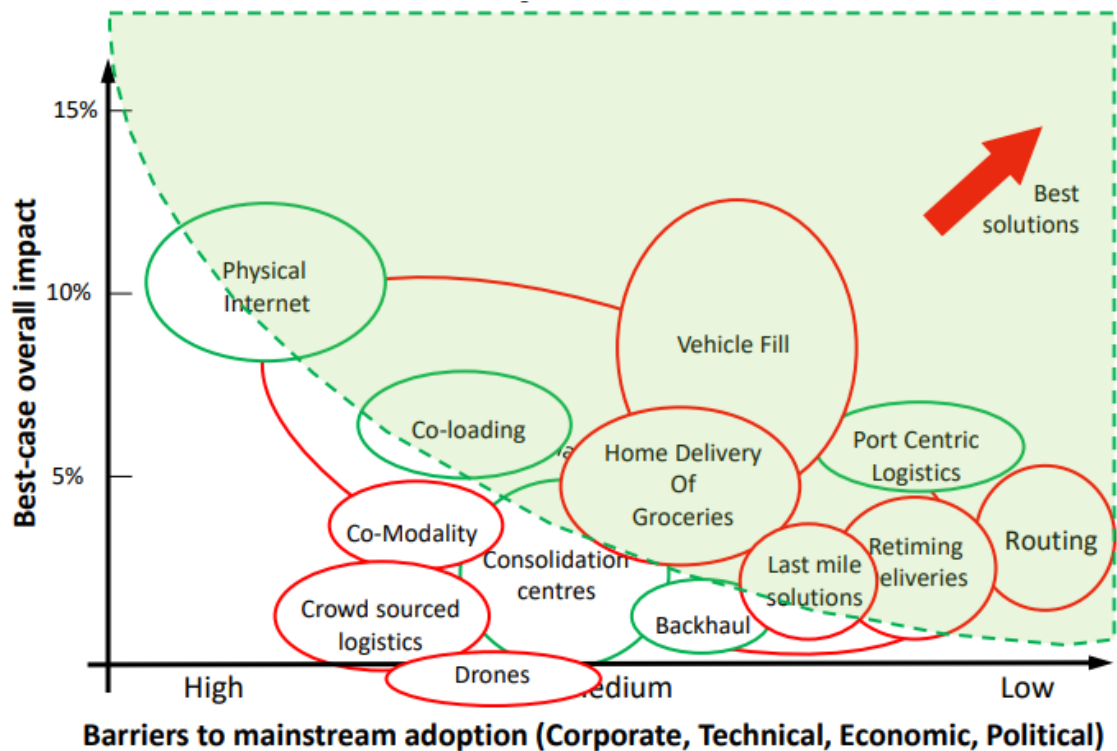


Figure 7-4 Logistics measures for reducing fuel consumption and CO2

Source: Cebon (2018), <https://www.itf-oecd.org/sites/default/files/docs/technology-roadmap-freight-decarbonising-cebon.pdf>, Accessed on 20.04.2020

At the same time, publication was issued by OECD/ITF (2018): “Towards Road Freight Decarbonisation: Trends, Measures and Policies” which also suggests that for the future, the most effective measure remains driver eco-training and vehicle capacity utilisation while keeping the fleet as it is. Collaboration among companies will also contribute to vehicle utilisation. When renewing the fleet, they suggested known measures that were mentioned in Chapter 3 of this thesis. This study also lists future challenges for decarbonisation, the main one will be growing e-commerce presence with tighter delivery windows and telematics technology to control driver’s performance. However, it also discusses driver’s readiness for this technology. This can be confirmed by author’s daily practice which shows that drivers must be constantly monitored and motivated to be able to cooperate. As the decarbonisation measures are not compulsory for most of

the sectors yet, those who decide to contribute voluntarily, should choose to start with “*measures with low barriers that have some effectiveness in reducing emissions – these are low tech solutions and those with mature technology*” OECD/ITF (2018), p. 85.

7.3 Multicriteria Decision Making Process Using AHP Method

Latest research in Chapter 7.1 shows solution driven decarbonisation strategies based on comparing different couples of criteria but it is not considering multiple criteria choices. Recently, multicriteria research has been used in green logistics and green supply chain management too. Evaluating and measuring the performance of GSCM in terms of implemented practices has attracted little attention (Boutkhoul et al., 2016). Companies of various sizes and business models may have different decision-making strategies based on stakeholder’s interests, their available resources, respectively their implementation barriers. Very often, managers must decide depending on the barriers that company currently faces, if they decide to start quickly. Therefore, further research in this thesis answers current need of decision making upon multiple criteria. An AHP method based on known criteria was chosen.

7.3.1 AHP method, definition, and application

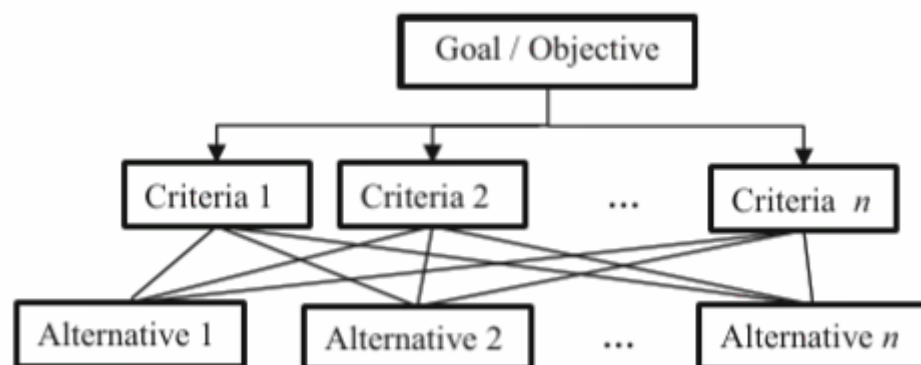
The analytical hierarchical process method (AHP) was developed by Saaty and has since been used in multiple studies on multicriteria decision making in politics, business studies and other social sciences. In business field, it was used for choice of suppliers (Rajesh and Malliga, 2013), process simulation software

(Guimarães et al., 2018), manufacturing software (Manoj et al., 2020), logistics locations (Wang and Liu, 2007), reverse logistics (Bouzon et al., 2016).

AHP is one of the multiple-criteria decision analysis methods. It helps to resolve subjective decision-making problems based on pairwise comparison of two criteria with help of mathematical process and in the end find the best options under current circumstances.

There are four steps to conclude the best alternatives (Qu et al., 2017):

Step 1 Establish the hierarchy of criteria (C) and alternatives (a)



Step 2 Make a pairwise comparison decision matrix (M), see formula (1), where for instance a_{21} represents the importance of C2 over C1 on scale 1 to 9 (original from (Saaty, 1980) respectively 3,5,7,9 (Kwong and Bai, 2002)).

On this scale, 1 always lies in the middle as equal importance of both criteria. Slightly more favourable, or moderate importance is 3, and further 5 is of strong importance, 7 very strong importance and 9 is extreme importance of one criterion above the other (Saaty, 1980). Table 7-1 describes the scale used in this thesis:

Table 7-1 Intensity scales of importance

Source: Adapted from Goepel (2018), p 3

Intensity	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong Importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another, its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
2,4,6,8 can be used to express intermediate values		

Step 3 Calculate the priorities to obtain the weights of criteria $w_1, w_2 \dots w_n$, by normalizing matrix. This is done by summing of each column and then dividing each value by summed value,

$$w_k = \frac{1}{n} \sum_{j=1}^n \frac{a_{kj}}{\sum_{i=1}^n a_{ij}}, \quad k = (1, 2, \dots, n) \quad (2)$$

where relative weight of k^{th} criteria (w_k) is obtained by averaging the values of the k^{th} row in the matrix

Step 4 Check consistency of judgements by testing minimal Consistency ratio (CR).

$$CR = \frac{CI}{RI}, \quad (3)$$

where CI is the consistency index and RI is random index.

Consistency index is

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

where maximal eigenvalue is calculated from weights of criteria obtained in

$$\lambda_{max} = \frac{\sum_{j=1}^n \frac{\sum_{k=1}^n w_k a_{jk}}{w_j}}{n} \quad j = (1, 2, \dots, n), k = (1, 2, \dots, n) \quad (5)$$

CR should not be higher than 10% (Saaty, 1995). If it is, the respondent's judgements are less consistent. In this case, judgements should be re-visited and adjusted so that consistency ratio is below 0.1 (Saaty, 1980).

To perform the overall evaluation of weights of criteria from more respondents, the relative weights of aggregated decisions are added. If the respondent's single results have inconsistency above 0.1, a row geometric mean method is recommended to verify the requirement of consistency recommended by this method (Escobar et al., 2004). Geometric mean (formula 6) helps to avoid error and find consensus by group decision making (Saaty, 1980). Geometric mean thus ensures homogeneity, as measurements are on ratio scale and represent how many more times the alternative dominates (Bernasconi et al., 2014).

$$\left(\prod_{i=1}^n x_i \right)^{\frac{1}{n}} = \sqrt[n]{x_1 x_2 \dots x_n} \quad (6)$$

The same process can be repeated for evaluation of alternatives. Then each alternative is rated based on one criterion. Then, alternatives are rated and assigned to best fitting criteria.

As the method is sometimes criticized for dealing with subjective views, and unbalanced judgement thus inconsistent managerial priorities, authors often combine it with other selection criteria methods like TOPSYS (Manoj et al., 2020), BSC (balanced scorecard) (Bentes et al., 2012), fuzzy multiple-attribute decision-making (FMADM) (Yang and Chen, 2004), fuzzy AHP-TOPSIS (Boutkhoum et al., 2016) and analytical network process (ANP) (Aragóns-Beltrán et al., 2014). For the purpose of the thesis and limitations in data collection, the dataset was only evaluated based on AHP method and thus limitations are mentioned in discussion chapter.

7.3.2 Choosing criteria based on literature and own empirical research

Various sized companies and different types of industries may have different decision-making criteria based on their resources, respectively their barriers in the implementation. Thus, a further literature review was combined with first paper-based questionnaire's results and its interpretation in Resource-Based Theory. According to Grant (1991), there are six major categories of resources in a firm:

- Financial resources
- Physical resources
- Human resources

- Technological resources

A firm appraises strengths and weaknesses of these resources relative to competitors and identifies opportunities for better utilisation. In the next steps, it identifies their capabilities and their potential for sustainable competitive advantage and appropriability of their returns (Grant, 1991). Researching the most suitable criteria for logistics decarbonisation measures in literature review was based on identifying the barriers and drivers connected to this kind of decision making. When a manager knows his firm's drivers and barriers to decarbonisation, he can deduct the criteria as well. As there is vast research in drivers and barriers to green logistics or SCM, they needed to be summarized to main categories. Additionally, own empirical results from first practitioner's survey, were considered, as it had the focus on the intended result.

Sources in Table 7-2 already contributed with extensive research of drivers, barriers, and criteria of implementation of green logistics, green supply chain management in literature and practice.

Table 7-2 Existing research on drivers and barriers of GSCM

Source: Author

Jayant and Azhar (2014)	[1]
Kaur et al. (2018)	[2]
Elbarky and Elzarka (2018)	[3]
Boutkhoul et al. (2016)	[4]
McKinnon (2018)	[5]
Cebon (2018)	[6]
Author, Chapter 5	[7]
Author, Chapter 6	[8]
Somsuk and Laosirihongthong (2017)	[9]
Mala and Musova (2015)	[10]

A deep case study of decarbonisation drivers on a Swedish ferry line identified cost savings, risk of implementation costs, meeting regulatory framework, energy consumption, strengthening customer relationships and diversifying sustainable service portfolio (Christodoulou and Cullinane, 2020). In Indian car manufacturing sector, the most common barriers were connected to lack of top management commitment, lack of environmental and technical knowledge (Jayant and Azhar, 2014). This may suggest that developing countries are one step behind GSCM development. However, there has been a review on green supply chain management barriers in Canadian manufacturing sector showed most common barriers: lack of awareness and trainings, difficulty identifying opportunities, lack of technical expertise and lack of corporate social responsibility (Kaur et al., 2018). Thus, it was confirmed that automotive sector in developing and developed countries face the same challenges.

A comprehensive literature review and survey of over 100 Egyptian companies was provided by Elbarky and Elzarka (2018). Table 20 summarizes external and internal barriers to implementation of decarbonisation measures of SMEs.

Table 7-3 The common and highly frequent barrier in each category based on the interview's findings.

Source: Elbarky and Elzakra (2018), p. 8.

Category		Barriers
Internal	Cost / Financial constraints	High capital investment
	Human Resources	Lack of trained personnel
		Resistance to change
	Commitment of interested parties	Poor supplier commitment
	Awareness	Lack of awareness of potential advantages of GSC
	Management System	Lack of adequate knowledge about implementation
Lack of management skills and environmental knowledge		
Lack of inter-departments cooperation in communication		
External	Commitment of interested parties	Cultural diversity
	Resources	Unavailability of clean fuel
		Lack of direct incentives

These findings can be confirmed by research on Slovakian small firms from various industries. They have selected most common barriers of green logistics implementation high upfront investment cost, uncertain return on investment, lack of support from the state (Mala and Musova, 2015). Choice of greener suppliers, environmentally friendlier transportation alternatives or low energy consumption were not implemented yet. The authors found that 70% of respondents are not training their employees in green logistics initiatives and half of respondents are not planning to do so. Authors suggest that educating employees could result in interest, responsibility, and open new options of collaboration with suppliers.

Somsuk and Laosirihongthong (2017) conducted a literature review and applied Delphi method to see trend in drivers of GSCM in Thailand. They found 12 applicable drivers deriving from multiple theories (resource-based values,

relational-based and institutional theory) found in Figure 7-6. Four most important drivers in electronics industry Thailand are ‘government pressures,’ ‘top management support,’ ‘customer pressures,’ and ‘cost reduction,’ while ‘employee involvement/motivation’ is the least influential/significant driver.

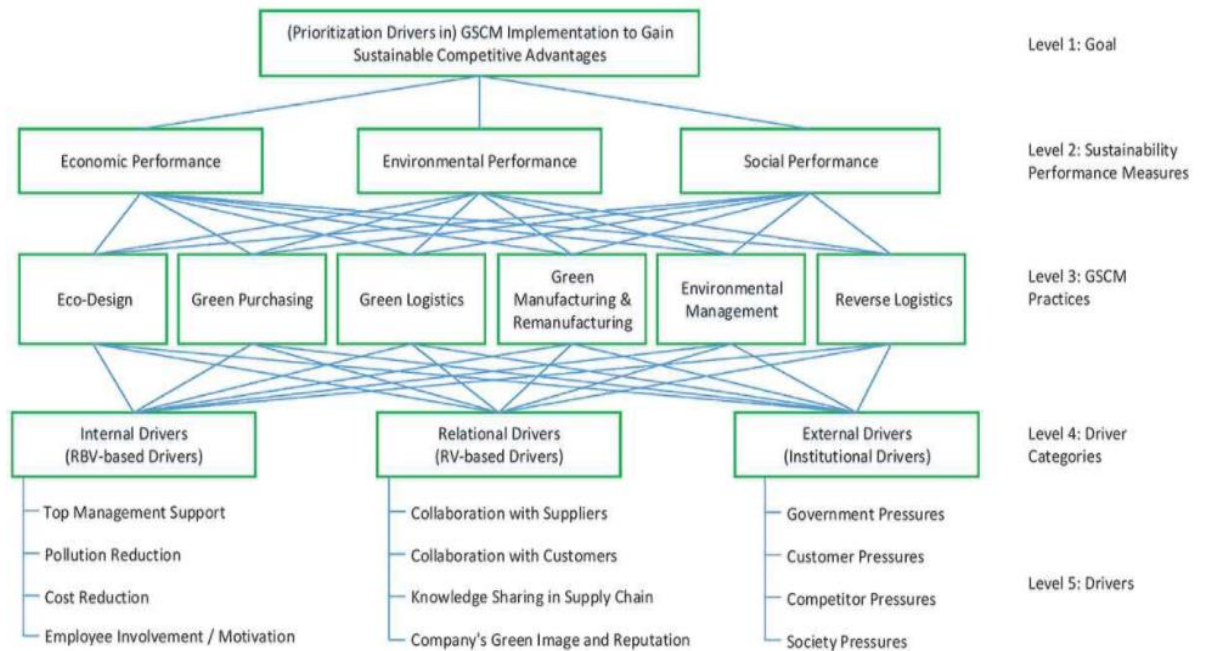


Figure 7-5 Hierarchical model of drivers to implement GSCM toward sustainability in Thai experts' perspectives

Source: Somsuk and Laosirihongthong (2017), p. 184.

Application of AHP method on identifying hierarchy of criteria for application of GSCM measures was used by Boutkhoum et al. (2016), who applied fuzzy AHP and TOPIS and chose following criteria based on below stated papers (p.12):

1) Economic criteria (EC):

- EC1: Increase in productivity (Green Kenneth et al., 2012)
- EC2: Decrease costs of material purchasing and energy consumption (De Giovanni and Esposito Vinzi, 2012)

- EC3: Increased firm's competitiveness (Lee et al. 2013).
 - EC4: Increase in profitability (De Giovanni and Esposito Vinzi, 2012)
- 2) Organizational criteria (OC):
- OC1: Lack of Human resources (Perron 2005).
 - OC2: Lack of technological infrastructure and technical expertise (Perron 2005; Revell and Rutherford 2003).
 - OC3: Lack of proper organizational structure to create and share knowledge (Ahmad and Daghfous 2010).
- 3) Environment criteria (EnC):
- EnC1: Improvement in environmental quality of products/processes (Zailani et al. 2012).
 - EnC2: Reduction in air emissions, liquid and solid wastes (De Giovanni and Vinzi 2012).
 - EnC3: Decrease in use of harmful/hazardous materials/components (De Giovanni and Vinzi 2012).

They found that most important criteria were increase of profitability improvement on environmental performance and reduction in air emissions and waste.

Although, drivers, barriers and selection criteria can be found in various studies, they should be reviewed through researcher's own findings. Thanks to survey and interview research from Chapters 5 and 6, these criteria were found also in respondent's answers. The analysis of question 7 in Chapter 5 on implementation barriers showed that respondents chose mostly option d, "partners not easy to persuade", and a "low budget or high up-front costs". Cooperation and openness of partners was the biggest burden, and in the interview analysis in Chapter 6.5, one respondent confirmed the "lack of willingness of customers to support the co-financing of the projects" with their service suppliers. Second ranked barrier in the survey was "high upfront investment" that supports this interviewees

statement by more survey respondents. Therefore, it was also necessary to consider both criteria.

Although companies face various challenges, eight most significant criteria were chosen for application of the chosen method based on sources in Table 7-2 and are their significance is presented in Table 7-4.

Table 7-4 Criteria for implementation of decarbonisation measures.

Source: Author

CO2 abatement potential	[4], [5], [9]
Low personnel requirements	[1], [3], [4], [10]
Low expertise requirements	[1], [2], [3], [9], [10]
Upfront cost	[3], [7], [9], [10]
Total cost of implementation	[4], [6], [7], [8], [9]
Ease of collaboration with partners	[3], [7], [8], [9]
Available infrastructure / technology	[2], [4], [6], [10]
Wide geographical application	[3], [5]

Even after the initial choice of methods, further research by Toelke and McKinnon (2021) in Figure 7-6 confirmed motivational factors of European SME carriers show, that most important internal drivers were cost saving potential, culture and company values and return on investment. The external drivers were customers' requirements, suppliers (original equipment manufacturer's technology) and EU law.

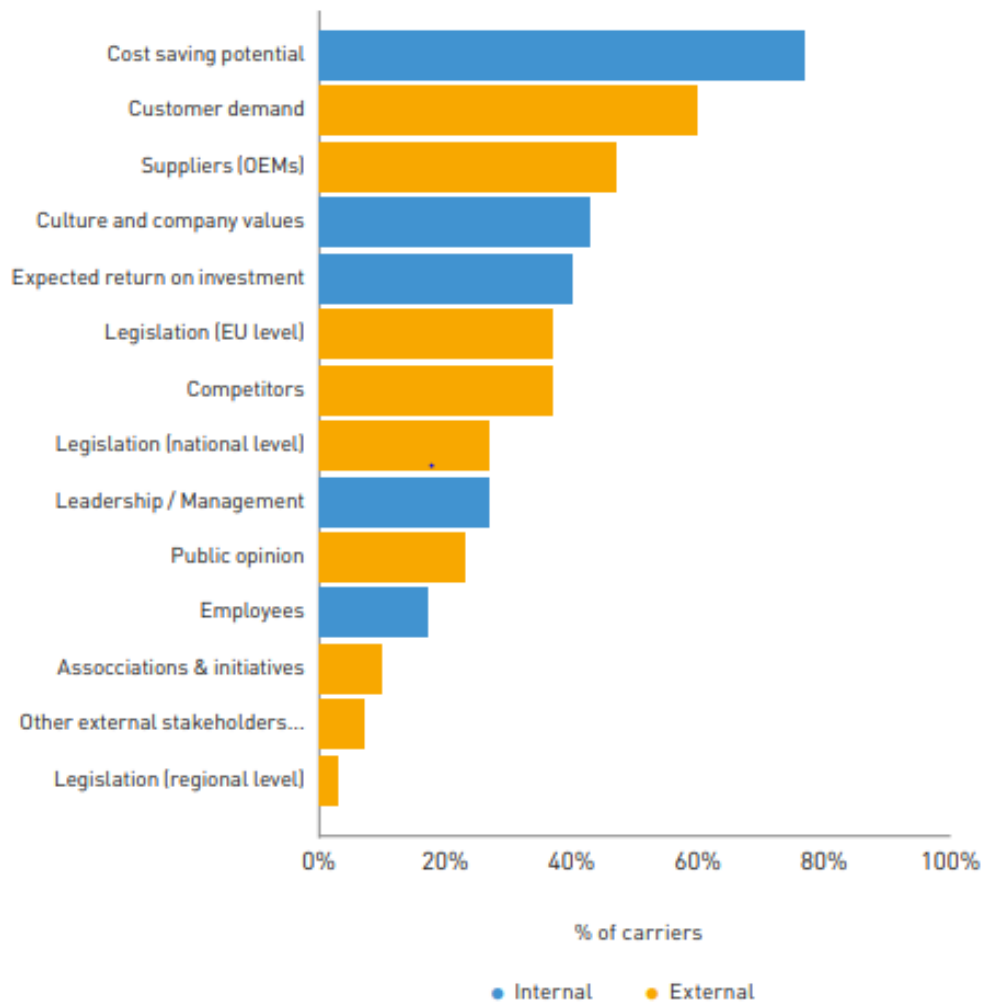


Figure 7-6 Internal and external driving factors on decarbonisation of SMEs in transport.

Source: Toelke and McKinnon (2021)

7.3.3 Sample and data analysis

The given sample was chosen to find group decision from experts from different fields and company sizes. The data was obtained from an online questionnaire, English version from [surveymonkey.com](https://www.surveymonkey.com) and Slovak version from [survio.com](https://www.survio.com). Originally, it was planned to apply AHP research on focus groups in April-June 2020 with small-medium enterprise group compared to experienced large firm group. Initial planning started in February 2020, but unfortunately, entirely unexpected pandemic COVID-19 caused uncertainty of travel, furloughs,

enforced part-time jobs. Focus groups are recommended because it is also possible to continuously adjust decision-making process of participants and rethink the grade of importance if the consistency ratio is too high. However, when applying group decision making when all participants are present, several issues arise as relationship of members, level of aggregation and averaging methods (Bernasconi et al., 2014).

Second alternative was to collect surveys. Online tool SurveyMonkey was used. The accompanying e-mail and criteria in questions are shown in Appendix D. First part of the survey was general information on the company, as used in previous survey, and second part consisted of 28 combinations of 8 criteria. Prior to the first round of sharing, survey was proofed by Dr Tuck and Dr Roh and recommendations were considered (specifying the choice scale, better explanation at the beginning).

First survey round was sent on 1st November 2020 to 70 corporate firms, experts on logistics and sustainability. This list consisted mainly of previous contacts, and some contacts needed to be updated, therefore phone calls followed a week after. Second reminders were sent on 23rd December 2020. During this period 2 incomplete surveys arrived, although some respondents promised filling in the survey. Further phone calls followed to arrange phone-guided survey, but no participant had time. Two complete responses were collected. Further reminders followed on 19th February per individual E-Mails and phone calls. One respondent was willing to answer mid of April due to ongoing projects. From January until March, further 5 responses came incomplete. As the survey was anonymous, researcher could not call respondents to ask why they did not fill in the entire

survey. One respondent gave feedback that the survey is too theoretical, vague, and intangible, as his main criteria are productive mileage, average fuel consumption, loading degree, modal options, and duo trailers. Further 2 respondents promised to participate but they never came back to the survey.

Due to constant unreachability of managers and very low response rate, researcher decided to phone associations gathering freight-forwarding and SMEs. Slovak association of freight forwarders promised to send it out to 100 members and SME association in Slovakia sent it out to 30 members last week of March and reminders were sent beginning of April 2021. Therefore, survey was translated to Slovak language. Two further full responses were gathered. Due to lack of time, researcher decided to analyse these four full responses and make further suggestions for research. Due to expert opinions from logistics, the validity and reliability were strong for these participants. However, final result cannot be generalised as more groups should be compared.

Using and AHP / ANP well-known software, Super Decisions, Version 3.2 was used to systematically record data collection. Free Excel sheet designed by Goepel (2018) helped to calculate the result and reduce possibility of mistakes in manual calculations.

First respondent (R1) was senior logistics manager of a freight forwarding enterprise, present in packed transport (road, rail, barge, short sea), warehousing and offering other value-added services. Second respondent (R2) was a junior sustainability manager also from large global enterprise offering logistics of equipment pooling – reusable pallets & crates for the world's largest manufacturers. Third respondent (R3) was a general manager of mid-sized

company operating on one continent, providing services in freight forwarding, warehousing, and customs declaration. Fourth respondent (R4) was a junior manager of a large company operating on one continent, working in educational sphere of sustainable transport.

Figure 7-7 shows overview of results were obtained based on software calculations:

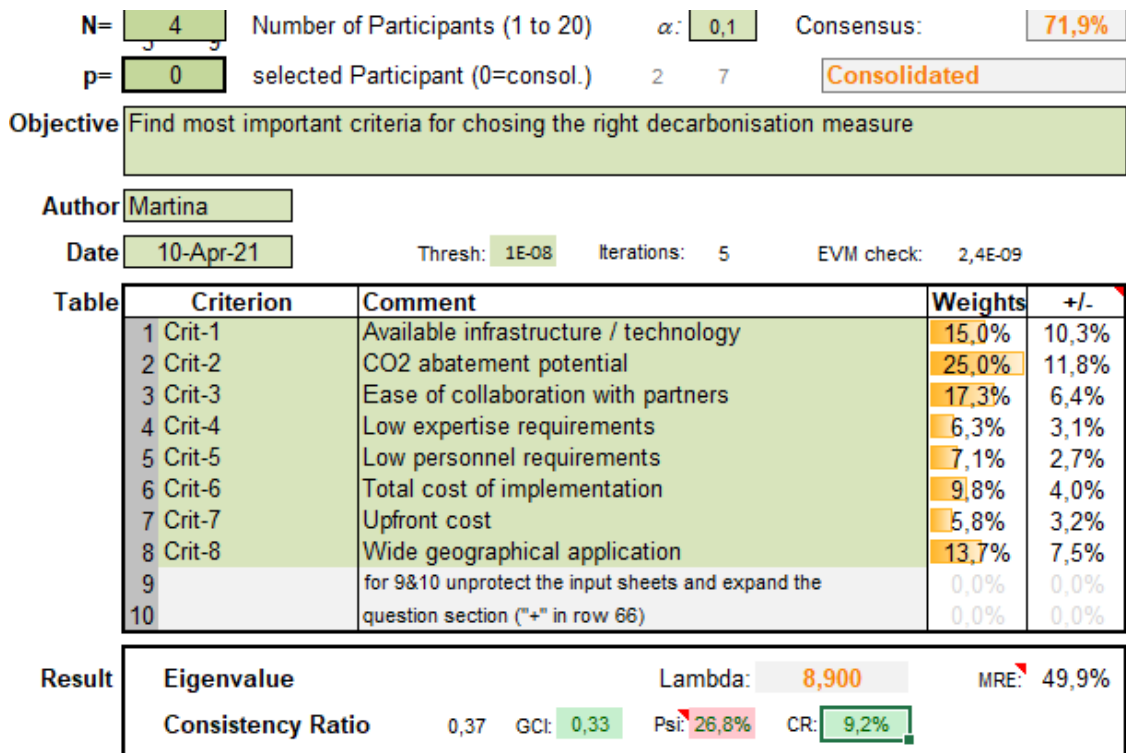


Figure 7-7 Final group result criteria rating

Source: Author

Group consistency ratio was 0,092 which is below 0,1 and thus group response consistency was ensured.

Figures 7-7 and 7-8 also show weights and thus importance of selected top three criteria as follows: 1. CO2 abatement potential, 2. Ease of collaboration with partners, 3. available infrastructure / technology.

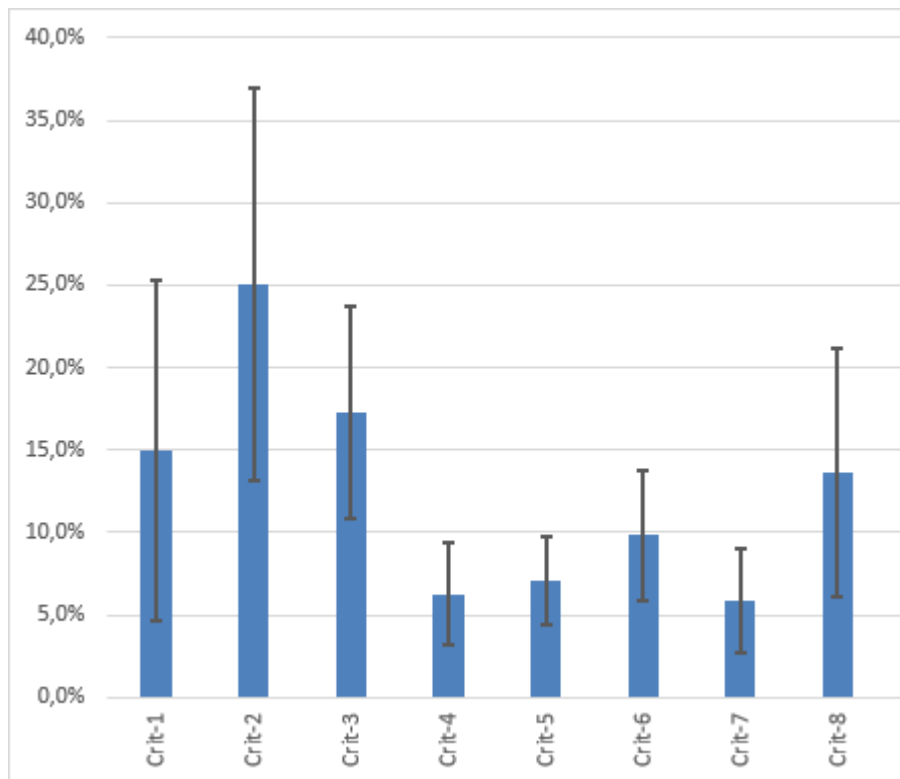


Figure 7-8 Graph of criteria rating

Source: Author

Although there are not many generalizable papers on criteria in decision-making in green logistics, some papers and their top criteria can be compared to these findings. CO2 abatement potential as the most important preference was similar to preferences around reduction of environmental impact by Boutkhoum et al. (2016). Ease of collaboration is mentioned as one of top three criteria in Thailand (Somsuk and Laosirihongthong, 2017) and other authors could agree on need of technical knowledge and ripeness of technology (Jayant and Azhar, 2014).

7.4 Summary

Recent research focuses on bringing more practical framework for wider audience and these frameworks have different structure and possibilities of application than the original model of this thesis. Chapter 7 summarises the last findings from literature and finds repeating initiatives from previous research, finds new initiatives as synchromodality or possibilities for the future such as electric roadways, platooning and finds new measures that are spanning towards more use of IT systems. Researchers also identified that there are many options, some of them less and others more feasible. There were models built to compare them based on two criteria. Researcher identifies that nobody applied a multi-criteria decision-making process. Therefore, a comprehensive literature review is undertaken to find the most important criteria and AHP method is used to find hierarchy from the most important to the least important one. The results of survey can be used in further research as preliminary or exploratory study for further findings.

Chapter 8 Discussion

The last chapter summarises and compares findings from literature and from surveys and interview. It also completes the initiatives by refining the conceptual framework. Contributions to the theory and practical implications of the findings conclude the applicability of the research. Research limitations and further suggestions for research are concluding this chapter.

8.5 Key Findings

The first aim of the thesis was initially to describe logistics externalities on the environment. Focusing on CO₂ reduction and exploring ways, how to achieve it, brought researcher to the second aim of identifying all initiatives, that companies can apply to reduce their carbon footprint. Academic literature, articles and websites of international organisations provided background to the topic of climate change and impact of logistics for content of Chapter 2. This chapter brought closer look at negative externalities from freight transport and warehousing. The environmental problems associated with freight transport are well portrayed in the literature (Piecyk and McKinnon, 2010). The most urgent one is global warming, as the growth of carbon emissions tend to exceed the allowed limit of 2 degrees Celsius. Different impacts on the planet are being portrayed. Nevertheless, it is not only governmental issue. It is up to businesses to act responsible. In Chapter 3, the context of logistics emissions in the overall supply chain operations is explained. Sometimes, it is necessary to do the whole life-cycle assessment of the product, to identify footprint of logistics operations and set priorities for CO₂ emissions reduction. There are several ways, how to

achieve it. Majority of academics agree that CO₂ emissions in atmosphere cause severe damage to the planet. To address these issues, companies need to take responsibility for their negative environmental impact. Chapter 3 pointed out that logistics sector is predicted to grow in next 30 years as the international trade will grow. The focus needs to be shifted more on developing countries and regions with higher growth rate. Here the growth might outnumber their CO₂ abatement potential. Therefore, with available knowledge on logistics decarbonisation, the measures can be taken quickly. This thesis at the beginning outlines definitions of logistics and supply chain and their interconnectedness. This scope will be as wide as possible so that many industries or freight forwarders get a general key for their decarbonisation. It further compiles measures that companies can introduce for decarbonizing each part of their logistics and/or supply chain. Depending on their operations, practitioners can choose from wide number of initiatives in transportation, warehousing and combining both. After application of these measures, reduction of CO₂ emissions can be expected. The practical part also compares the significance of some measures in current practice and foresees the near-term future by experienced practitioners. The same methods that are used with engaged companies are then used for comparison with small or medium enterprises. The comparison and barriers to taking measures bring a light to areas that need to be worked on in the future. At the end of this chapter, a conceptual model for guiding CO₂ emissions reduction in logistics operation was developed.

Chapter 4 outlined philosophy of the research, main paradigms and helped researcher to guide their stance and methods used. This not only complements

previous models which did not include overall logistics measures, but also prepares a framework for empirical research.

Chapter 5 and 6 found also other aspects of decarbonisation. By implementing decarbonisation measures company not only can reduce its emissions, but it can also save costs and attract partnering companies. Sustainability is a sign of financial health of a company. Customers already award points to green practices, when tendering for new transport service providers. However, in some cases, freight forwarders wait for input and co-financing from their clients. Empirical research influenced final decarbonisation framework (Figure 8-1). Supply-Chain Management view was added to the model.

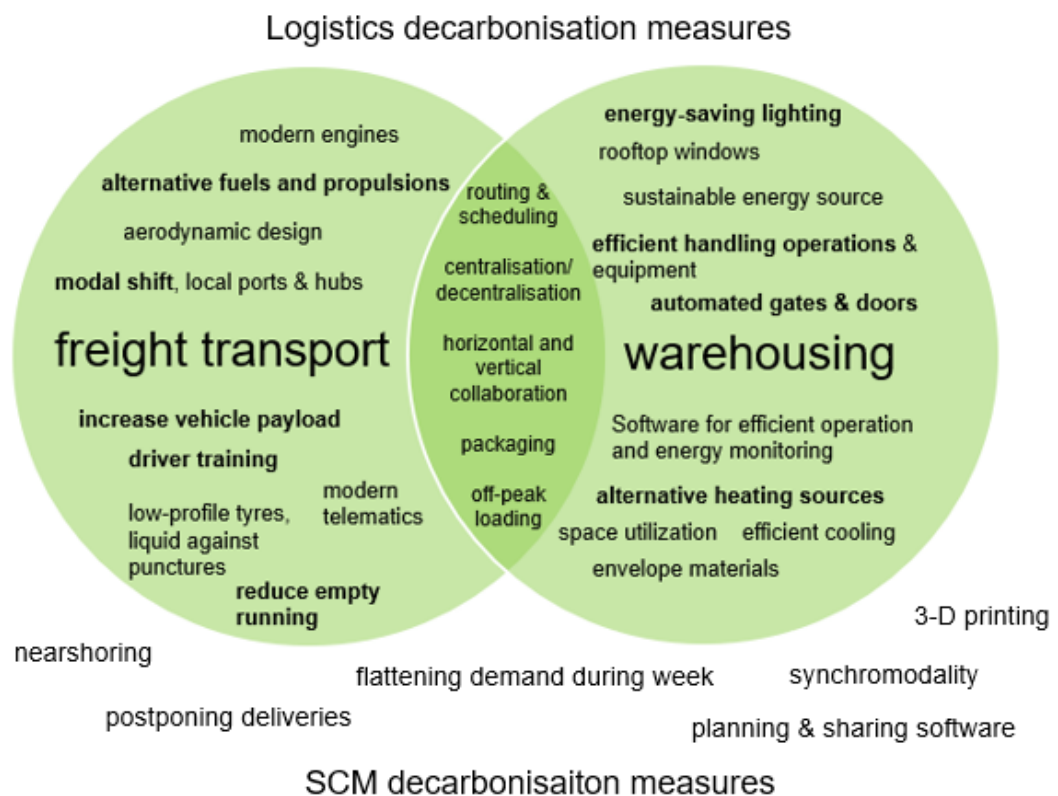


Figure 8-1 Logistics decarbonisation framework
Source: Author

Logistics decarbonisation framework unites theoretical and practical knowledge on decarbonisation initiatives in logistics in previous chapters, The framework stems from basic conceptual model from Chapter 3, which bases on main body of research work in transportation and warehousing research and is being completed by contributions summarized in Chapter 7. This Chapter also opens problematics of multi-criteria decision making for practitioners. The criteria are found in literature and confirmed by previous results from first paper-based survey and interviews. Consequently, analysis of a group consisting of 4 expert provides three most important criteria: 1. CO2 abatement potential, 2. Ease of collaboration with partners, 3. available infrastructure / technology. Previous research confirms that these criteria were confirmed by other studies.

Chapter 8 summarizes findings that were outlined in aims and objectives of this research. In this chapter, the research gap is filled in by complementing literature review and summarizing all initiatives found by surveys and interviews.

8.6 Contributions to The Theory

Firstly, summarization of initiatives found in the comprehensive literature review helped to formulate a conceptual model for logistics decarbonisation measures. Such model has not been published by academia so far, therefore it is unique in its content and can be further developed and progress when innovations occur. Model was based on transportation and warehousing models by (McKinnon et al., 2015) and (Marchant and Baker, 2015). Secondly, this model is being refined by findings from practice and initiatives are being commented on by real practitioners, mostly senior managers in sustainability or logistics.

According to practitioners, initiatives in Table 8-1 have gained less of their attention and therefore should further be examined why. This table lists initiatives that were suggested by practitioners to add them to listed initiatives in the survey and interview.

Table 8-1 Gaps in literature found by surveys and interviews

Source: Author

Gaps in literature	Transport	Warehousing	Combined
Surveys - exploratory	postponing deliveries, flattening demand, , de-speeding, weight optimization by combining light and heavy cargo, aerodynamics on truck-trailer combination	paper pallets, packaging size	reverse logistics, use of IT system for network optimisation
Interviews - explanatory	scheduling for higher payload, packaging	roof top windows, alternative heating resources (pallets, heat from forklift charging), software for smart goods movement	sharing planning platforms

Research in these areas has progressed since then but has no sufficient depth yet. Reverse logistics was already researched since around 2010's but has not been considered as combination of transportation and warehousing efforts by author.

Other objective was to find initiatives with low or no use by practitioners. In survey, it was also considered, whether some initiatives were going to be used within 5 years and these were then excluded from this list, as practitioners already had awareness and projects planned. Findings from Table 8-2 can be used by academia to focus on examining more initiatives, are not that known to practice.

Table 8-2 Initiatives with low or no use in practice

Source: Author

Low or no use in practice	Transport	Warehousing	Combined
Surveys - exploratory	low rolling-resistance tyres, alternative propulsion telematics	sustainable envelope, automatic gates and doors	off-peak loading hours
Interviews - explanatory	aerodynamics, low-rolling resistance tyres	motivating workers to commute by bike	collaboration of manufacturers, off-peak loading hours

After finalising this thesis conceptual model, Smart Freight Centre also issued a decarbonisation framework for freight transport (SFC, 2016). This model takes perspective on sorting initiatives in terms of changes on vehicle, possibilities on optimisation in freight movement and restructuring entire transport system, modes, and routes. It brings different view on how to approach the initiatives. It suggests starting either by optimising current logistics processes or investing in new technologies. In this case, manufacturers who do not own fleet, as suggested by one interviewee, only partly influence technical side of fleet purchasing and maintenance and thus can focus their attention rather on vehicle optimisation, asset sharing with partners, backloading trucks on roundtrips and choosing their modal split.

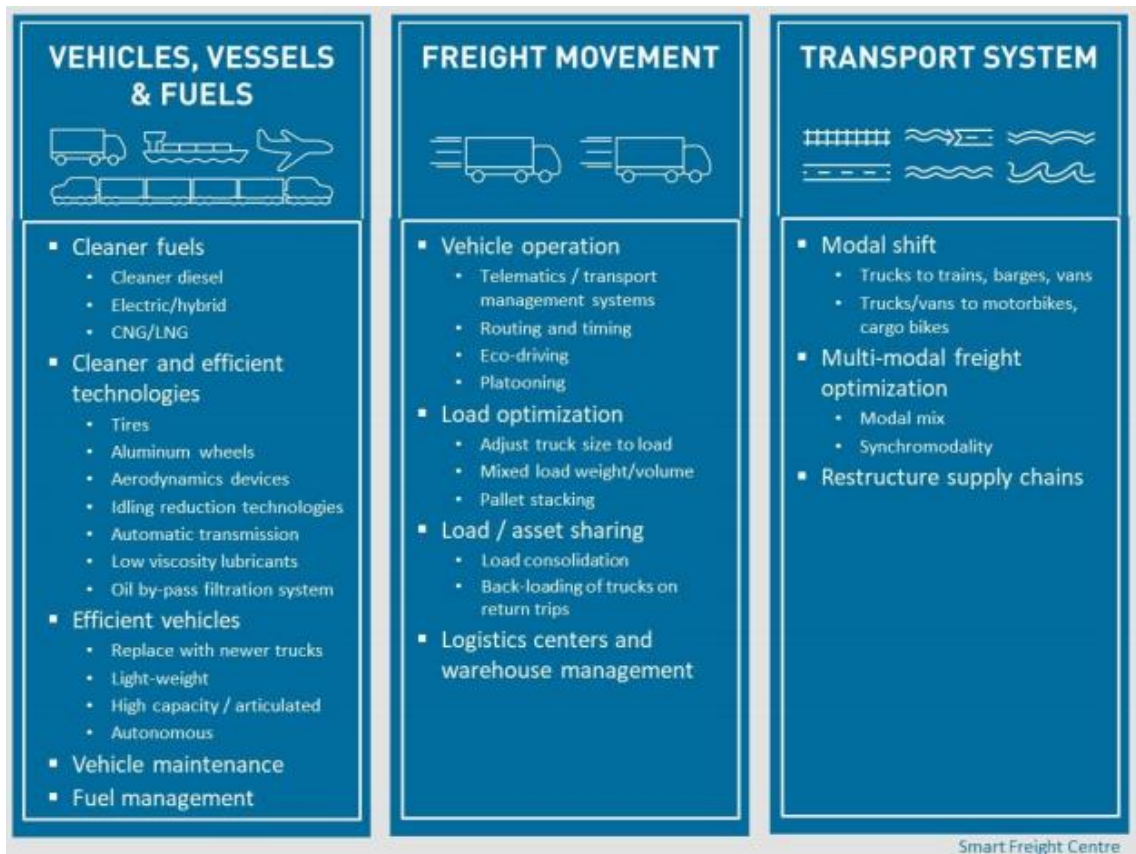


Figure 8-2 Technologies and measures relevant to road freight carriers

Source: SFC (2016), p.7

The final framework displays all current or near-future initiatives that can be further researched. From methodological viewpoint a deductive approach was applied. By mixing qualitative data from paper-based surveys and evaluating quantitative data from web-based questionnaires the bias of both types of data were evaluated. Research cycles were applied by complementing the literature after each round of survey or interview data analysis. Also, not many researchers verify findings from interviews by comparing them to printed data of a company, such as annual report, in this case corporate social responsibility report. This research also suggests that focusing on practitioners dealing with the topic and collecting data at conferences by personal interaction improves responsiveness.

Further contribution to theory is applying Resource-Based Theory and Resource Orchestration Theory on decarbonisation of SMEs is a new approach as by now, only application of this theory on general sustainability or environmental performance of complete firm were researched. Thus, deeper understanding of implications on SMEs connected with relevant literature has been developed. Findings in drivers and barriers in surveys and further literature confirm that SMEs and other firms have many reasons why to choose a specific decarbonisation measure. This thesis lists the reasons and converts them to criteria for taking their initiatives. Application of AHP method on sorting criteria by priority can guide researcher when finding new criteria or conducting further data gathering.

8.7 Practical Implications

The logistics sector is lacking a comprehensive guide of to provide information to practice on CO₂ emissions reduction measures (Tacken et al., 2014). 99% of European carriers are small and medium companies, with under 50 employees and they often do not have resources to progress in this topic. According to survey conducted in 2020, still 43% of these carriers are not able to calculate and report their GHG emissions, a third are calculating them on the company level, and a quarter does it for the customer (Toelke and McKinnon, 2021).

Logistics decarbonisation is just one and small part of company's overall decarbonisation and even smaller section of overall sustainability. Despite of this fact, when a firm embarks on logistics decarbonisation, it often unveils a complex field of approaches and offered measures. This thesis aimed to help this decision

making and execution easier and simplify the thought process for practitioners with limited resources by providing knowledge for wide audience.

Chapter 2 and Chapter 3 provide a background for newcomers to the sustainability side of logistics operations. Second chapter bring extensive information how logistics contributes to climate change. In third chapter the reader can find various ways of measuring emissions from logistics, the scopes which are used for carbon reporting and fundamentals of life cycle analysis. After preparation and own process analysis, company can get into detailed projects of logistics decarbonisation. Further questionnaires and interviews summarize current practice's viewpoints and actions on logistics decarbonisation. The most used measures are mentioned in concluding words of Chapter 5 and 6. Practitioners can therefore start with most wide-spread measures as they have been already tested and implemented by their predecessors. This research can also provide a guidance for experienced companies with established sustainability department. Sometimes, companies tend to focus on specific measures and forget about some other options, that are there and can be deployed in the future. This thesis helps also to find importance in setting priorities and criteria in Chapter 7, when getting lost in too many options.

Practitioners with low awareness and few reasons to start their logistics decarbonisation can also read about the competitive advantage of finding their existing resources and using their skills and knowledge for optimisation of their operations. This not only consequently lowers their costs, but they also gain competitive and innovative advantage and thus can stand out in the large logistics market.

8.8 Limitations of The Research

Although the researcher's intention was to conduct the literature review and analyse the empirical findings in the most rigorous manner, there is a need to raise awareness on some limitations. Awareness that no research is perfect is important and needs criteria to be assessed against and judged by its own merits.

8.8.1 Literature review

Due to large number and scope of the researched initiatives, the time spent on reading articles on each initiative had to be limited not to get lost in details of well-researched areas as number of research papers very depending on the measure. At the beginning, researcher focused on identifying various externalities from logistics that were rather not summarised by one article, therefore different resources had to be considered and combined. When reviewing the externalities of freight transport, much focus was brought to HGVs and less on technological improvements in other transport modes. Also, when researching CO₂ reduction measures, some technical aspects such as vehicle aerodynamics or motor technologies were hard to understand, as researcher did not have background in technical sciences. Therefore, focus was brought on introduction of each initiative's practical usage, benefits, shortages, and if possible, cost and reduction potential. This research provides guidance to current practice and lists initiatives that will be used more within 5 years. However, it does not forecast any initiatives for the far future from the empirical view, it rather relies on predictions of experts in research (professors of mechanical engineering or original equipment manufacturers). Hence, this model will need a refining at a 5-year basis.

8.8.2 Geographical limitations

Initial chapters on literature review compare statistics from international organisations and bring up narrower view of European statistics, best practice, and technology as researcher expects to have respondents of multinational companies, with higher number of headquarters in the EU and thus following EU programs and government regulations. To some extent, however, it can be applied to other regions such as USA and China as the CO₂ emissions have global effect. The methods of calculating vehicle or building emissions for statistic and thus emission reduction potential are different from continent to continent, but listed initiatives are applicable also outside of Europe. Therefore, generalizing very specific research from one country or industry should be considered carefully. As the most papers in early 2010's are stemming from Europe, conceptual model was also based on European findings, however after later verification with practitioners, and further papers stemming from Asia or US, the conceptual framework can be tested and applied outside of Europe.

8.8.3 Application on company age, size, and industry

Companies need to adjust CO₂ reduction measures to their specifics. The applicability of the whole range of initiatives at once is limited by operational or financial resources of the company. SMEs often find it difficult to plan and long-term, so they carefully chose initiatives that do not bring many financial risks. For SMEs it is also difficult to dedicate one well-paid expert's position to the projects, as the finance is often imbalanced and scarce. In case of fast growth, small firm rather prioritises managing basic operations and urgent customer care rather

than enhancement of logistics processes or comprehensive sustainability strategy.

From the operational viewpoint, some measures might have higher effect on some industries, than the other, depending on types of vehicles, delivery flexibility and switching to modal shift or different warehousing operations. For example, when warehouse operations are only eight hours, hydrogen forklift may not be economical or if company is having predominantly long-haul shipments, electric trucks lay further in the future, than smaller vehicles for local deliveries which are already now in use.

8.8.4 Respondents and data gathering

The number of respondents in interviews was relatively small, but their good expertise could confirm the validity of their responses. For the surveys, it would be interesting to keep the continuity and apply refined paper-based questionnaires by participation on more conferences, collecting yearly data on current situation and seeing interviewee's development and progress on initiatives over years. Sadly, the Green Freight Europe initiative ended couple of years after conducting the research. However, new organisation, Smart Freight Centre was established in 2013 and started attracting new corporate members with goal to find unified freight carbon calculator (managed in 2016) as well as continuing sharing expertise by working with universities. Some respondent's firms joined this NGO, whereas other respondents changed career path. With this career change, the expertise in some companies disappeared and firm lost focus on decarbonisation of their logistics, thus the data from same responding

companies would have a lower validity, which was avoided when phoning few previous contact persons to join the AHP focus group.

Medium and small sized companies were not considered for surveys and interviews due to their limited resources and knowledge; therefore, the benchmark was set by large practitioners. However, there can be innovative small firms with good quality client portfolio, that can outperform their big competitors at some decarbonising measures. This became visible also to researchers after 2018, when many journal articles and even books started studies on small manufacturer's sustainable branding and marketing (Rudawska, 2018).

Reflecting on periods when the data was collected, surveys and interviews were conducted in a period within first 5 years after 2010, when green logistics literature strengthened, and large body of enterprises started being involved in their logistics decarbonisation. Therefore, it was a right starting point for exploratory study of real world and later continuing explaining the phenomenon with interview with experts. On the other hand, when SMEs were still slacking behind large enterprises in period of 2015-2020 and were starting to understand the problematics and build their competitive advantage, COVID-19 crosses their effort in new processes. The pandemic has had a profound impact on organisations all around the world as they had to address new range of procedures to minimise risk and focus on safe working practices (Bailey and Breslin, 2021). Practitioners were too busy with restructuring their logistics, adapting on new schedules, uncertainty, and furloughs. It was very difficult to gather new data and after multiple reminders and calls companies did not respond on the survey.

8.9 Suggestions for Future Research

Realizing the limitations and finding new open topics during the research journey led to conclusions for further research, and to help fill in the gap by new findings.

8.9.1 Gaps in research on decarbonisation measures

Further research should focus on specific initiatives that are not so popular in business studies on improving performance efficiency. In transport, it was low-rolling resistance tyres, aerodynamics of chassis and trailer. Most of the research focuses on HGV, therefore other modes of transport as well as smaller vans need to be considered. Small vans are rather researched in specific papers focusing on city logistics or last-mile deliveries. However, there are large numbers of vans delivering express cargo or urgent shipments across the continents.

In warehousing, there is limited number of articles, how to reduce energy consumption by a warehouse building. Efficient heating and cooling systems for warehousing have not been much described. Technological refurbishing of warehouses for electric forklifts could be also explained better. There were also no articles found on warehouse management systems that also measure CO₂ emissions from energy consumption. Freis et al. (2016) suggest applying their warehouse decarbonisation calculation and framework to apply on different types or warehouse usage and stages of automation. Suggestions of energy saving and comparison of automatic high-bay warehouse versus classical warehousing hall with manual equipment would be beneficial. Focus remains on dry-cargo warehouses, lacking considerations of envelope, insulation and technologies for refrigerated warehouses.

Avoiding congestion by loading and off-loading in early morning or evening hours was also not much known to practitioners. There is a new decarbonisation potential of horizontal and vertical collaboration. It seems to be gaining on awareness among research and practitioners however the practical examples are too few as there is still limitation of trustworthiness and fear of breaking fair competition law.

Assessing the financial implications of the initiatives in terms of payback as cost was identified as most important criterion and benchmarking of the initiatives among practitioners need to be further researched (Tacken et al., 2014). However, as this research suggests, other criteria can be also more important than costs, such as overall CO₂ abatement potential, available infrastructure/technology and geographical application.

Impact of ICT usage in decarbonisation of logistics is very little explored (Sanchez Rodrigues et al., 2015) which was also confirmed by interviewees. This area deserves a larger body of research as in 2020's there are many start-ups as well as large players offering products on predictive analysis and traffic optimisation, synchronomodality, real-time tracking and carbon calculation from primary data from vehicles, trains or vessels. The same applies on smart warehousing systems and warehouse automation.

8.9.2 Alternative research methods

Although this research focused on surveys and interviews due to time and geographical limitations, many other methods or combinations of methods are

used by pragmatists. Examples from business applications, such as case studies are a good guidance for practitioners.

There are also other methods that could conclude similar findings, such as focus groups and case studies. Foremost more case studies using information obtained from the interview and complemented by CSR reports could gather vast amount of data on current state of the industry.

Reflecting on findings in Chapter 7, further research could consider other methods than solely AHP for decision making process in green supply chain management. Some researchers suggest, that it is too numerical for expressing respondent's values and suggest fuzzy AHP method ((Kilincci and Onal, 2011).

8.9.3 Increase engagement of practice with academia

In Study on logistics service provider's CSR, only 20% of companies indicated having links with higher education and authors suggest that strengthening this collaboration could help firms have better contact to highly skilled graduates, as well as universities have a very updated view on their research's practical applicability (Piecyk and Björklund, 2015). Concluding the implication of COVID-19 on the organisation processes, it would be interesting to see how the crisis leadership strengthened preparedness for 'tomorrow's crisis' and helped to strengthen links between research and practice (Bailey and Breslin, 2021). This pandemic also brought a significant positive impact of organising online conferences, key panels, and webinars, where best practitioners and academics share their knowledge and experience with wider audiences, are discussing questions placed by attendees. These questions are primary source for

foundations of further research. Hopefully, this trend will continue after coming back to 'new normal' world and these events stay as accessible for large number of participants and affordable for firms with limited financial resources.

8.10 Summary

This chapter concluded the outcomes of the research. Key findings from both academic literature and practitioner's responses were summarized. Conceptual model was redefined and can be used by current researchers and practice as an overall guidance to the CO₂ reduction measures. The limitations of scale and scope of the research were discussed and considered later in further suggestions for research. The main contributions for academia as well as for practitioners showed the originality of the research. The model can help further research on finding new as well as exploring existing CO₂ initiatives and guide companies how to reduce their environmental impact therefore it is undoubtedly a very practical contribution to the knowledge.

Appendix A. Paper-based questionnaire

Part 1 General Information about the respondent

1. Your position in the company
 - 1.1. Higher management
 - 1.2. Middle management
 - 1.3. Assistant
 - 1.4. External consultant

2. Size of the company by employees
 - 2.1. Small sized company (>50 employees)
 - 2.2. Mid-sized company (50-250 employees)
 - 2.3. Large size company (250-1000 employees)
 - 2.4. Enterprise (1000< employees)

3. Size of the company by turnover (Mil. EURO per year)
 - 3.1. >1
 - 3.2. 1-5
 - 3.3. 5-10
 - 3.4. 10-20
 - 3.5. 20-40
 - 3.6. 40-100
 - 3.7. > 100

4. Presence of the company (please name the country / continent)
 - 4.1. National
 - 4.2. One continent
 - 4.3. Multi-continent

5. Type of company
 - 5.1. Shipper
 - 5.2. Carrier
 - 5.3. Warehousing company
 - 5.4. Consultancy
 - 5.5. ICT provider
 - 5.6. NGO
 - 5.7. Government body

6. Industry your company is present in – please name. If only transportation and warehousing company, please state if forwarder or haulier or only warehousing.

Part 2 CO2 reduction initiatives in logistics, general questions

1. Have you already implemented any CO2 reduction initiatives in your strategic management?
2. When did your company start to introduce CO2 reduction initiatives in strategic management?
3. What was the budget for CO2 reduction initiatives at the beginning and for which time range?
4. What is the current budget for CO2 reduction in your company per year?
5. How many employees are involved in coordinating CO2 reduction initiatives and projects?
6. What are the drivers which attract your company to adopt green logistics in their strategy?
 - a. Reputation and marketing strategy
 - b. Cost saving
 - c. Customers
 - d. Social responsibility
 - e. Governmental regulation
 - f. Local conditions and requirements
 - g. NGO's pressure
 - h. Other (please name)
7. What are the burdens?
 - a. Low budget / high at-front investment cost
 - b. Higher management cost
 - c. Not enough information
 - d. Partners are not easy to persuade
 - e. Bad infrastructure
 - f. Competitors adopting a green washing approach
8. Did you encounter positive feedback from senior management?
9. Did you encounter positive feedback from your partner companies?
10. Do you already include CO2 reduction initiatives in long-term contracts with your LSPs?
Please name.
11. Do you plan to include more? Please name.
12. Do you share the costs for implementation of these strategies with your partners? How?
13. Do you share the costs for implementation with your competitors? How?
14. How did the initiatives affect your everyday operational business?
 - a. Slowed-down processes, made them more complicated
 - b. Drove them to simplification, improved processes
 - c. No effect / No change
15. Are you willing to share the information of your improvements with other companies for free?
16. Do you see any difference in Western and Eastern European companies in terms of CO2 reduction initiatives? Explain.
17. Do you see your Eastern European partners lag in willingness to reduce their carbon emissions? Explain.

Part 3 CO2 reduction initiatives in land-based freight transport

1. Which modes do you use in transporting your goods and what mode is dominating?
 - a. Rail
 - b. Road
 - c. Short sea
 - d. Intermodal
 - e. Multimodal
2. The following initiatives have been found by literature review. Which of them have you applied?

Initiatives	Operational	Strategic
Transport	handling	modal shift
	Short-term technological improvements	Long-term technological improvements ²
	routing and scheduling	fleet renovation
	loading (payload and backhauls)	alternative fuels
	energy efficiency in driving	

3. What were the drivers to use them?
4. Which initiatives are you planning to use in the future?
5. Which initiatives are missing in this model?
6. Please sort first operational and then strategic initiatives according to their time of implementation.
7. Please mark the most and the least cost requiring initiatives.
8. Can you suggest some technological improvements that are not very usual and that are feasible for you in short time period?
9. Have you tried to pioneer any initiative?
 - a. Yes - Please state the examples
 - b. No
10. Have you risked implementing any initiative and failed?
 - a. Yes - Please state the examples
 - b. No

Part 4 CO2 reduction initiatives in warehousing

1. If warehousing company - how many warehouses does your company operate?
2. If customer – how many warehouses do you use approximately to store the goods?
3. What kind of warehouses are they?
 - a. Refrigerated
 - b. Standard warehouse
 - c. Automatized warehouse
 - d. Semi-automatized warehouse
 - e. Non-automatized warehouse
4. The following initiatives have been found by literature review. Which of them have you applied?

Initiatives	Operational	Strategic
Warehousing	improving operations	sustainable building envelope
	material use (forklifts etc.)	sustainable equipment purchasing
	waste management and recycling	alternative energy sources
	space utilization	generating own energy
	operational energy use	energy efficient heating and cooling

5. What were the drivers to use them?
6. Which initiatives are you planning to use in the future?
7. Which initiatives are missing in this model?
8. Please sort first operational and then strategic initiatives according to their time of implementation.
9. Please mark the most and the least cost requiring initiatives.
10. Can you suggest some technological improvements that are not very usual and that are feasible for you in short time period?
11. Have you tried to pioneer any initiative?
 - a. Yes - Please state the examples
 - b. No
12. Have you risked implementing any initiative and failed?
 - a. Yes - Please state the examples
 - b. No

Appendix B. Web-based survey



CO2 reduction initiatives in logistics operations

Thank you for taking time to respond.

This survey aims to explore initiatives that companies nowadays undertake to decarbonise their logistics operations.

First section aims to find out the size of the company, industry and managers involved in execution of green logistics initiatives. Second part focuses on transport measures, third part on warehousing and last one includes initiatives that connect both transport and warehousing.

Please fill in only one of given options. If you are involved only in transport or only in warehousing, you can skip the site by clicking "next". If you find that any initiatives are missing in the list, or you have any other comments, please use comment section below. At the end, please press "done".

OK



CO2 reduction initiatives in logistics operations

General information

* 1. Your position in the company

- Senior manager
- Junior manager
- Other (please specify)

* 2. Type of your position


- Logistics manager
- Sustainability manager
- Green logistics manager
- Other (please specify)

* 3. Size of the company by employees 


- Mid-size company (50 - 250 employees)
- Large company (250 - 1000 employees)
- Enterprise (1000< employees)
- Other (please specify)

* 4. Size of the company by turnover 

- 10 - 50 mil. € / year
- 50 - 100 mil. € / year
- > 100 mil. € / year
- Other (please specify)

* 5. Presence of the company 

- National
- One continent
- Global
- Other (please specify)

* 6. Type of company 

- Freight forwarder
- Transportation only
- Warehousing only
- Other (please specify)
- Manufacturer
- Wholesaler

7. Field of presence (optional) 

PREV

NEXT

8. Which CO2 reduction initiatives do you use in transportation?

	Currently using	Planning to implement within 5 years	Not planning yet
Modal shift	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technical improvements (aerodynamics, light weighting...)	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Low rolling-resistance tyres	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
Driver eco-training	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Alternative fuels (biofuels, biogas, LNG...)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Alternative propulsion (electric, hybrid...)	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Increasing vehicle payload	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reducing empty running	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
Modern telematics	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

9. Which CO2 reduction initiatives do you use in warehousing?

	Currently using	Planning to implement within 5 years	Not planning yet
Sustainable envelope materials and design	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Energy efficient lighting	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Energy efficient heating and cooling	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Sustainable energy source	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
Automated gates and doors	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
Energy efficient handling equipment	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Efficient layout of the warehouse	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Optimised handling operations	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

10. Which CO2 reduction initiatives do you use in logistics system?

	Currently using	Planning to implement within 5 years	Not planning yet
Collaboration (horizontal / vertical)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Consolidation	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Centralisation	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Off-peak loading hours (early morning, late evening)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

OK

PREV

NEXT

Your response is highly valued and appreciated.

If you wish to receive results of this survey, or have any questions or feedback, please use this email:

martina.hanuskova@plymouth.ac.uk

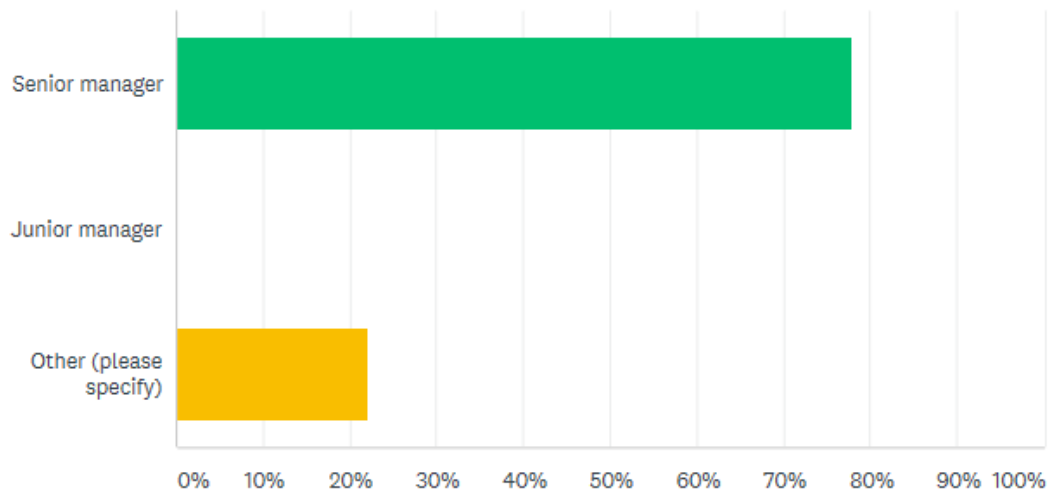
OK

PREV

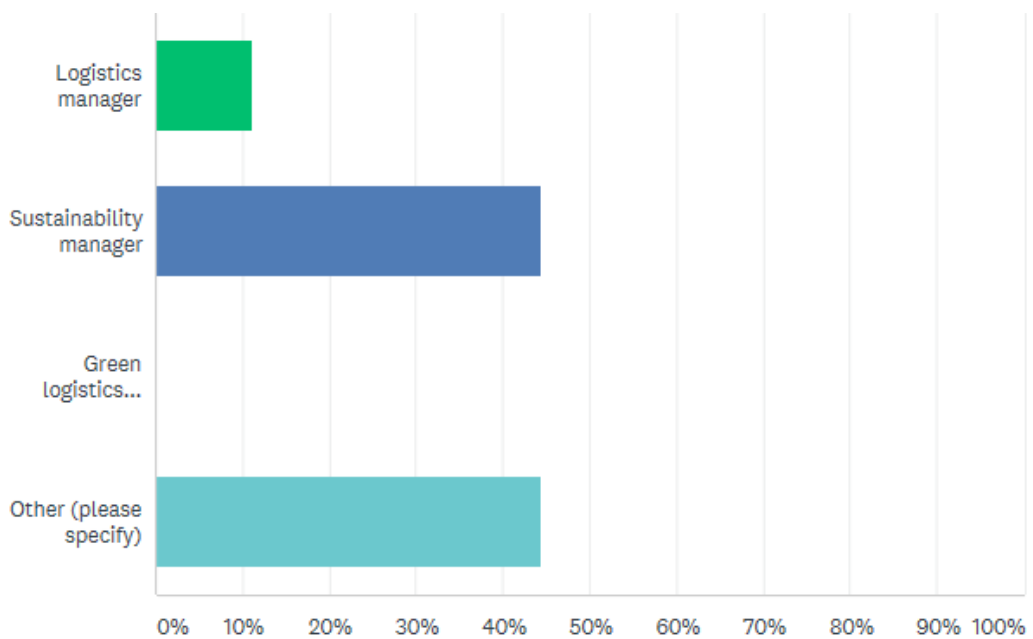
DONE

Appendix C. Sample from web-based survey

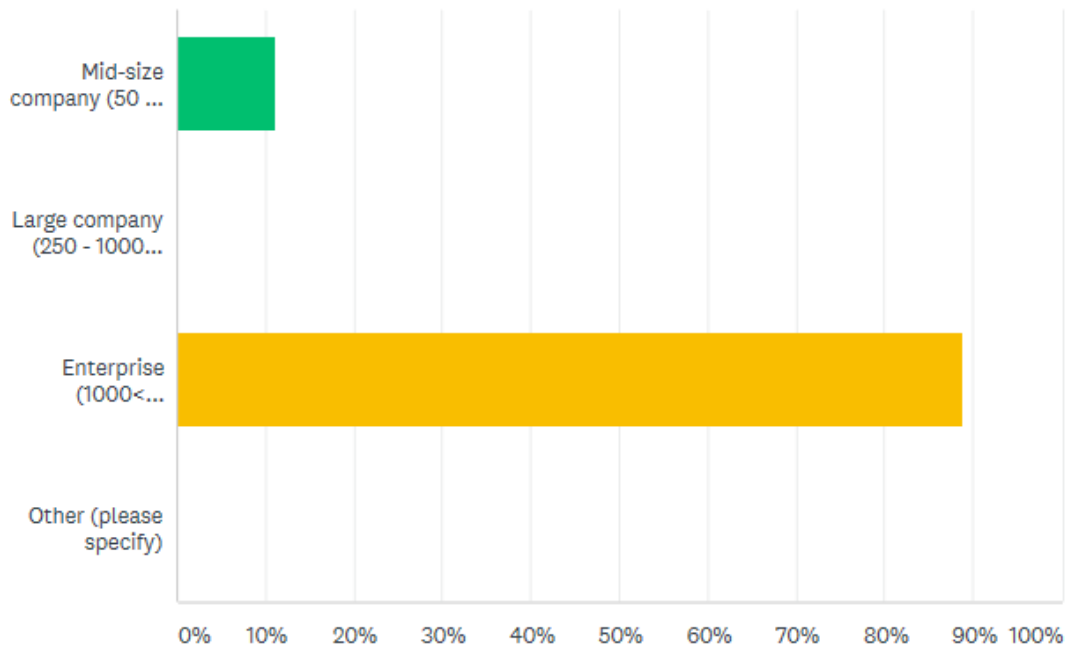
Q1: Your position in the company.



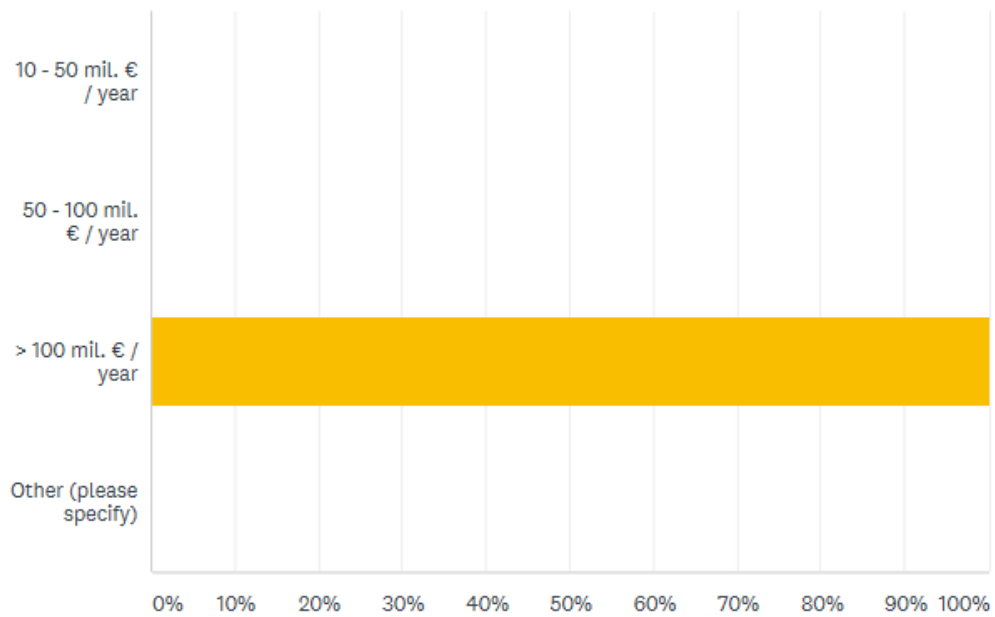
Q2: Type of your position.



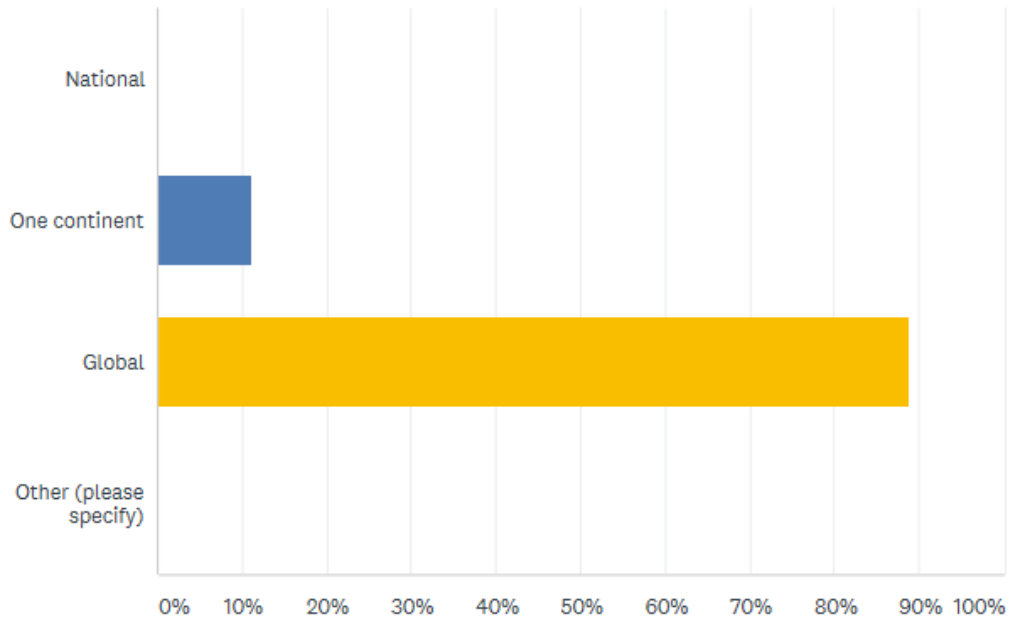
Q3: Size of the company by employees



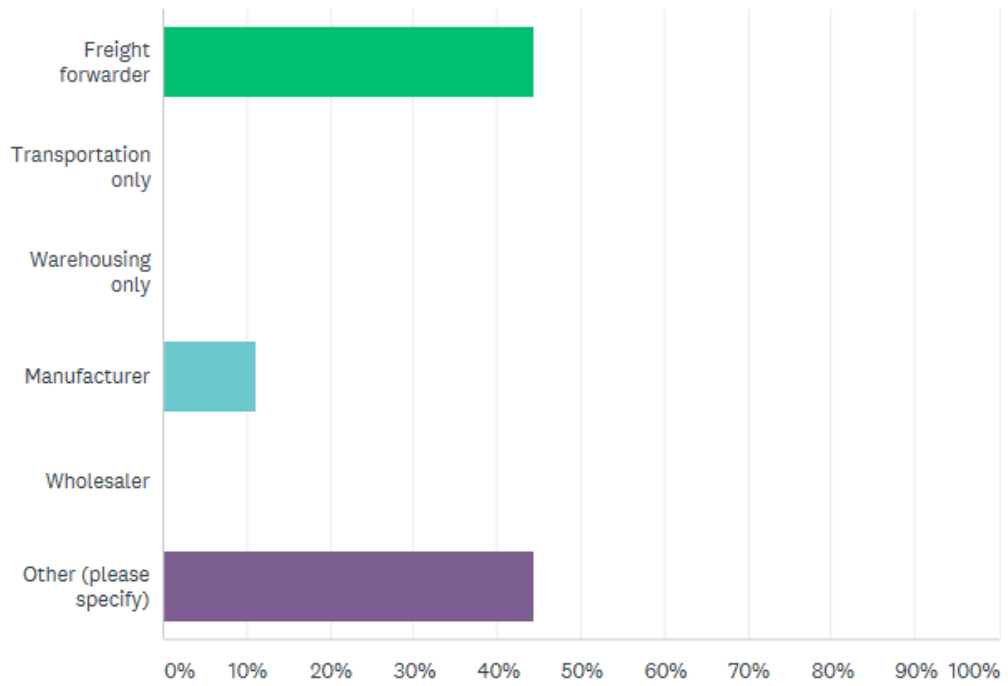
Q4: Size of the company by turnover.



Q5: Presence of the company.



Q6: Type of company.



Appendix D. Questionnaire on criteria

EN:

Dear manager,

We are conducting a research on multiple criteria for selecting best logistics decarbonisation measures.

We value your expertise, and it is possible that you have responded on previous survey, therefore you have been contacted again.

Please help us realize our research objective and fill in this 5-minute anonymous survey:

<https://de.surveymonkey.com/r/LMYXS95>

Your response is highly appreciated. If you wish to receive results of this survey, or have any questions or feedback, please contact me.

Kind regards,

SK:

Vážený pán, vážená pani,

Vykonávame výskum na základe viacerých kritérií pre výber najlepších opatrení na dekarbonizáciu logistiky.

Radi by sme zlepšili udržateľnosť prepravy a skladovania, predovšetkým malých a stredných podnikov.

Pomôžte nám realizovať náš výskumný cieľ a vyplňte tento 10-minútový anonymný prieskum:

<https://www.surveymonkey.com/survey/d/A9S1B6X0J4H7A1N0K>

Ak si želáte dostať bezplatné výsledky tejto štúdie, kontaktujte ma prosím na e-mail.

S priateľským pozdravom,

Martina Hanusková

Postgraduate researcher

University of Plymouth | Drake Circus | Plymouth | Devon PL4 8AA

Email: martina.hanuskova@plymouth.ac.uk

EN;

There are many measures how you can reduce your carbon footprint of your supply chain. If you have no capacity to measure your company's logistics footprint or have other constraints, where do you start?

This survey aims to identify most important criteria for choice of CO2 reduction measures. It will guide you to compare the criteria based on their pairwise importance and the result will show, what are the current practitioner's most important requirements to achieve quick wins. It hopes to help managers to find the most suitable CO2 reduction initiatives in logistics.

SK:

Existuje mnoho opatrení, ako môžete znížiť uhlíkovú stopu svojej logistiky. Ak nemáte kapacitu na meranie emisií svojej spoločnosti alebo máte iné obmedzenia, kde teda začať?

Cieľom tohto prieskumu je určiť najdôležitejšie kritériá pre výber opatrení na zníženie CO2.

Prevedieme Vás porovnaním kritérií na základe ich dôležitosti a výsledok ukáže, aké sú najdôležitejšie požiadavky súčasného manažéra na dosiahnutie rýchleho pokroku. Dúfame, že na konci pomôžeme praxi nájsť najvhodnejšie opatrenia na zníženie CO2 v logistike.

Začiarknite najvhodnejšie políčko podľa vášho názoru na to, aké dôležité je jedno kritérium oproti druhému, tzn. ak je pravá strana viac dôležitá, vyberte bod viac vpravo od stredu, a ak je váha rovnaká alebo ste nerozhodní, vyberte nulu.

SurveyMonkey / Survio text of criteria comparison:

CO2 abatement potential vs. low personnel requirements
Potenciál zníženia CO2 oproti nízkym personálnym požiadavkám

low personnel requirements vs. low expertise requirements
nízke personálne požiadavky oproti nízkym odborným požiadavkám

low expertise requirements vs. low upfront cost
nízke požiadavky na odbornosť oproti nízkym počiatovým nákladom

low upfront cost vs. total cost of implementation
nízke počiatkové náklady oproti celkovým nákladom na implementáciu

total cost of implementation vs. ease of collaboration with partners
celkové náklady na implementáciu oproti ľahkej spolupráci s partnermi

ease of collaboration with partners vs. available infrastructure / technology
ľahká spolupráca s partnermi oproti dostupnej infraštruktúre / technológiám

available infrastructure / technology vs. wide geographical application
dostupná infraštruktúra / technológie oproti širokému geografickému použitiu

wide geographical application vs. CO2 abatement potential
široké geografické využitie oproti potenciálu znižovania CO2

CO2 abatement potential vs. low expertise requirements
potenciál zníženia CO2 oproti nízkym požiadavkám na odborné znalosti

low personnel requirements vs. total cost of implementation
nízke personálne požiadavky oproti celkovým nákladom na implementáciu

low expertise requirements vs. ease of collaboration with partners
nízke požiadavky na odbornosť oproti ľahkej spolupráci s partnermi

total cost of implementation vs. low expertise requirements
celkové náklady na implementáciu oproti nízkym požiadavkám na odborné znalosti

low upfront cost vs. available infrastructure / technology
nízke počiatkové náklady oproti dostupnej infraštruktúre / technológiám

total cost of implementation vs. wide geographical application
celkové náklady na implementáciu oproti širokému geografickému použitiu

ease of collaboration with partners vs. wide geographical application
ľahká spolupráca s partnermi oproti širokému geografickému použitiu

low personnel requirements vs. available infrastructure / technology
nízke personálne požiadavky oproti dostupnej infraštruktúre / technológiám

CO2 abatement potential vs. low upfront cost
Potenciál zníženia CO2 oproti nízkym počiatovým nákladom

total cost of implementation vs. available infrastructure / technology
celkové náklady na implementáciu oproti dostupnej infraštruktúre / technológiám

low upfront cost vs. wide geographical application
nízke počiatkové náklady oproti širokému geografickému použitiu

low personnel requirements vs. low upfront cost
nízke personálne požiadavky oproti nízkym počiatkovým nákladom

CO2 abatement potential vs. total cost of implementation
Potenciál zníženia CO2 oproti celkovým nákladom na implementáciu

low expertise requirements vs. available infrastructure / technology
nízke požiadavky na odbornosť oproti dostupnej infraštruktúre / technológiám

ease of collaboration with partners vs. CO2 abatement potential
ľahká spolupráca s partnermi oproti potenciálu znižovania CO2

low personnel requirements vs. ease of collaboration with partners
nízke personálne požiadavky oproti ľahkej spolupráci s partnermi

CO2 abatement potential vs. available infrastructure / technology
Potenciál zníženia CO2 oproti dostupnej infraštruktúre / technológiám

wide geographical application vs. low expertise requirements
široké geografické uplatnenie oproti nízkym požiadavkám na odborné znalosti

wide geographical application vs. low personnel requirements
široké geografické uplatnenie oproti nízkym nízkym personálnym požiadavkám

low upfront cost vs. ease of collaboration with partners
nízke počiatkové náklady oproti ľahkej spolupráci s partnermi

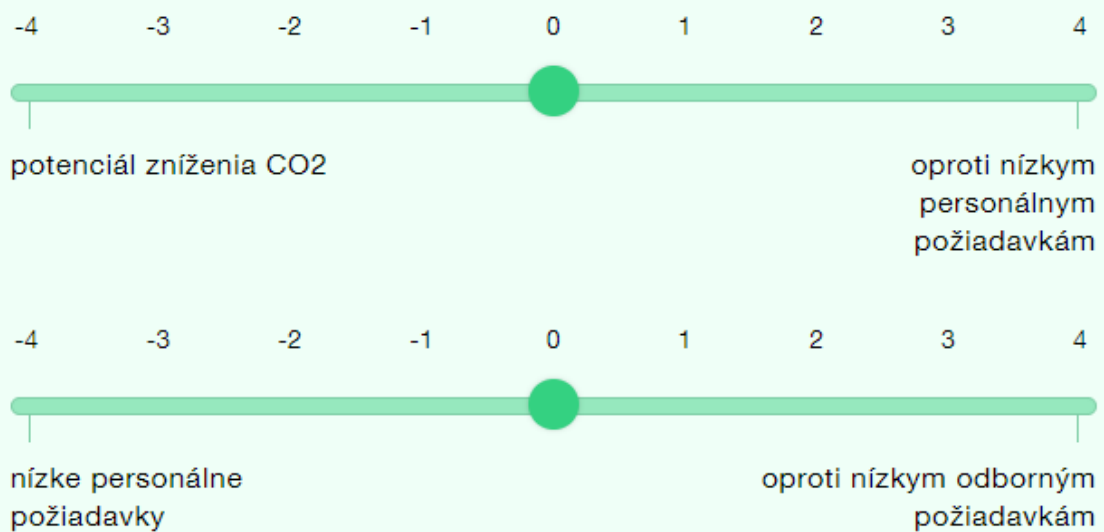
Preview SurveyMonkey:

* 8. In this pairwise comparison, please put more points on the side - left(L) or right (R), which criterion you find more important (left or right one). 9 is the strongest preference, if you are indifferent, chose the middle (1)

	9-L	7-L	5-L	3-L	1	3-R	5-R	7-R	9-R
CO2 abatement potential vs. low personnel requirements	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
low personnel requirements vs. low expertise requirements	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Preview survio:

1. Začiarknite najvhodnejšie políčko podľa vášho názoru na to, aké dôležité je jedno kritérium oproti druhému, tzn. ak je pravá strana viac dôležitá, vyberte bod viac vpravo od stredu, a ak je váha rovnaká alebo ste nerozhodní, vyberte nulu.*



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