CO_2 Emissions from Freight Transport and the Impact of Supply Chain Management

- A case study at Atlas Copco Industrial Technique

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KTH Industrial Engineering and Management

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Abstract

Freight transport is a large contributor to emissions of CO_2 and to mitigate its environmental impact is essential in strive for a sustainable future. Existing reports usually discuss the issues from a national or global perspective, but rarely provide any concrete or practical information on an organizational level. This report aims to describe the key driving factors of CO_2 emissions caused by freight transport and recommend suitable measures for organizations to mitigate their environmental impact. To do this, a case study at Atlas Copco's business area Industrial Technique (ITBA) is performed, four different business scenarios are created and the emissions from the scenarios are simulated. ITBA is a decentralized organization with most of the production sites and sub suppliers in Europe. Over 90% of the finished goods are sent to a distribution center in Belgium and then delivered to the customers.

Today, most customers are located in Europe and this market accounts for nearly 80% of the distributed weight. However, ITBA believe in a strong growth in the North American and Asian markets and that the customer base will look much different in 2020. More customers at longer distances from the distribution center will lead to a heavily increased use of air freight, resulting in higher emission levels. This study shows a clear correlation between the total CO_2 emissions and the share of air freight. In order for ITBA to expand their business and at the same time lower their emissions, actions are required. This report shows that a lower share of air freight and the use of several decentralized distribution centers can reduce the emissions significantly. Other means to lower the emissions include relocation of production sites, education to increase the awareness within the organization and including environmental performance when evaluating third party logistics.

Key-words: CO_2 emissions, freight transport, emission simulation, sustainable supply chain management

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Stockholm, June 2011
Petter Jofred & Peder Öster

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INTRODUCTION

The freight sector is a large contributor to emissions of greenhouse gas (GHG), to mitigate its negative impact on the environment is therefore essential in strives for a sustainable development. Globally the transport-sector currently represents 23% of CO_2 emissions from fossil fuel combustion and approximately 15% of overall GHG emissions (International Transport Forum, 2010). In the discussion of the environmental impact of transports, great attention is given to personal transport, i.e. car traffic and aviation, but freight transport is often neglected. Even if personal transport historically has received greater interest, the freight transport has in recent years more frequently been the focus of research (International Transport Forum, 2009). One reason for this is most certainly the Stern Review; presented in 2006. It states that all types of transportation were responsible for 14 percent of the world's total CO_2 emissions in year 2000, and that the share was increasing. Stern concluded that in order to mitigate the human induced climate change, the transport sector must reduce its emissions drastically (Stern, 2006).

Since then, research and a number of international reports have discussed the issue. International Energy Agency (2009), International Transport Forum (2008; 2010), and the Swedish organization The Network for Transport and Environment (NTM) have all contributed with valuable information and further analysis. However, these reports almost exclusively consider the issue from a macro perspective. This point of view is indeed essential, but for companies and organizations who want to mitigate their environmental footprint, they do not present any substantial guidelines. There are still no international agreements on lowering the emissions from freight transport or any requirements to measure and report emissions. Higher oil prices and fuel taxes, a possible tax on carbon, and international agreements will have economic implications for most companies. Hence, concrete and practical information on an organizational level of how to measure and mitigate emissions from freight transport is becoming critical.

PURPOSE AND RESEARCH QUESTIONS

The purpose of this study is to describe the key driving factors of CO_2 emissions from freight transport within Atlas Copco's business area Industrial Technique (ITBA) and recommend suitable measures to mitigate the emissions. The recommendations will be applicable for ITBA in particular but for similar companies in the industry as well. The aim is to make the emissions from freight transport visible both internally and externally and that it will help ITBA to reach their target to reduce CO_2 emissions from freight transport by 20% in relation to cost of sales (COS) until the year 2020. Questions the study will try to answer are:

- What are the key factors impacting CO_2 emissions from freight transport?
- How does ITBA measure their emissions and how accurate and/or relevant are the measurements?
- What feasible possibilities does ITBA have to reduce the emissions from freight transport?
- What reduction target is suitable?

SCOPE AND DELIMITATIONS OF THE STUDY

This study is performed and completed in five months, to fully investigate and understand this complex subject, much more time would be required. This means that a number of delimitations are necessary to narrow down the scope and to be able to complete the study within the time frame. Only transports within Atlas Copco's business area Industrial Technique are included, hence emissions from other parts of the organization or other parts of the supply chain, such as manufacturing, packaging and warehousing will not be studied.

Atlas Copco's internal policy that the unit paying the freight invoice is responsible for the emissions will be used in the study to determine which transports to include. Since CO_2 accounts for the majority of the total GHG emissions from transport operations, only CO_2 will be included in the study, not other polluting substances like nitrogen oxides (NO_X), or different sulfur compounds. Since ITBA does not own their own transports we will only study what ITBA can do internally to lower their emissions and how they can use their power to influence business partners such as third party logistics, suppliers and customers. Therefore we will not study any technological issues, such as more efficient vehicles, alternative fuels or haul planning.

STRUCTURE OF THE THESIS

Chapter 1 provides the reader with an *Introduction* presenting previous studies, aim and research questions the report will try to answer. The scope and its delimitations are also discussed.

Chapter 2 presents the *Frame of reference* starting with a short presentation of CO_2 emissions on a global level. Thereafter sustainable supply chain management is reviewed including supply chain strategy and a look at how organizations can monitor and evaluate their environmental performance. The most common ways to measure and report CO_2 emissions from freight transport, supply chain stakeholders, green purchasing and third party logistics is then examined. The chapter ends with a review of what the future might look like.

Chapter 3 covers the *Method* applied, including the study's approach, data collection, business scenarios and computer simulation. Finally, the validity, generalizability and reliability of the results are discussed.

Chapter 4 presents the *Case study results*, starting with an overview of the Atlas Copco Group and the business area Industrial Technique. Their supply chain structure, way of measuring CO_2 emissions from freight transport and use of third party logistics is discussed. Lastly follows a review on environmental responsibility within the organization.

Chapter 5 covers the *Analysis*. With the created scenarios as starting point the factors impacting CO_2 emissions from freight transport is discussed. Thereafter, the four different scenarios and the simulation model are analyzed. Finally, the outcome of the scenarios and the uncertainties about the quantitative results is evaluated.

Chapter 6 presents the *Discussion*, starting with Atlas Copco's supply chain structure, their modal split and how to select and evaluate forwarders. Thereafter follows a discussion of measuring and reporting and how to monitor environmental performance. Lastly, the business culture within the organization is discussed.

Chapter 7 includes the *Conclusions* and presents suggestions of further research.

Figure 1: Structure of the thesis

FRAME OF REFERENCE

To be able to understand the issue of emissions from freight transport and how it is interlinked to supply chain management, a frame of reference is needed. This chapter discusses some of the existing research within emission accounting and how to organize the work with emission reduction from a business point of view.

THE GLOBAL LEVEL

During the last decade the discussion of climate change and CO_2 emissions has literarily exploded. One of the first reports discussing the global issue in terms of cost impact was the *Economics of Climate Change* (2006) by the British economist Nicholas Stern. This was in a way the starting point for the political discussion about the impacts of climate change and the corresponding costs of a global temperature rise. Since then the Intergovernmental Panel on Climate Change (IPCC) and the US politician, and former vice president, Al Gore has received the Nobel peace prize for their contribution in highlighting the impacts of climate change. For a truly sustainable development, IPCC recommends stabilization of CO_2 concentrations of 450 ppm in the atmosphere. This would limit the temperature rise to 2°C compared to preindustrial levels and greatly reduce the global impact and damage. The current tendency is way off, and to reach the 450 ppm target IPCC suggests a 50% reduction target from emission levels in 1990 by 2050 (International Transport Forum, 2009).

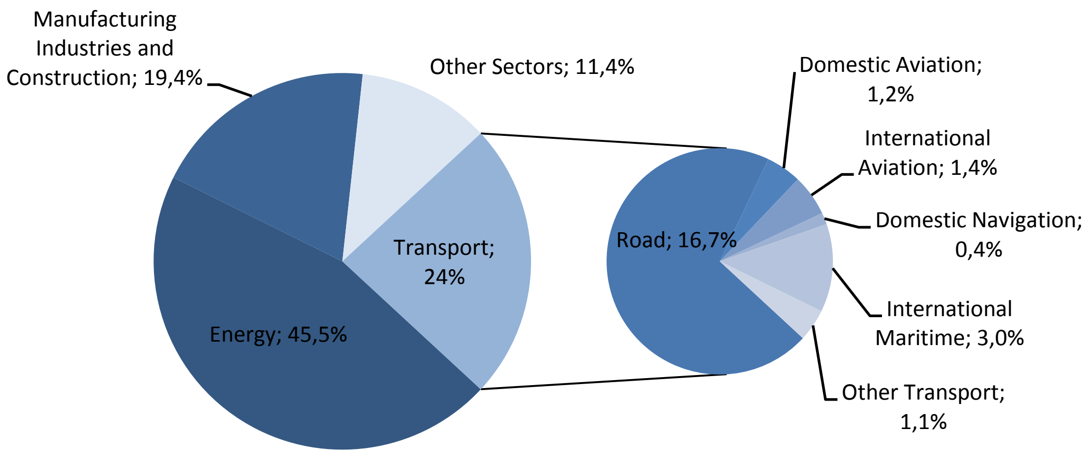


Chart 1: 2006 World CO2 emissions from fossil fuel combustion (International Transport Forum, 2009)

Transport is an important contributor to overall GHG emissions and the second largest sector after electricity production. In 2009 transport represented approximately 24% of the CO_2 emissions from fossil fuel combustion (International Energy Agency, 2010), and the split between transport modes can be seen in *Chart 1*. CO_2 accounts for 93%-95% of the total GHG emissions from transport operations, the remaining 5%-7% consist of other gases such as nitrogen oxides (NO_X), and different sulfur compounds (Cefic-ECTA, 2011). Emissions from transport have grown globally by 45% from 1990 to 2007, and in contrast to other sectors the emissions are still growing. Within EU, emissions of CO_2 from freight transport grew by 24% between 1990 and 2001 (Åkerman & Höjer, 2006). Globally, the yearly growth rate of transport emissions between 1990 and 2000 was 2,11%, but the rate is increasing and from 2000-2006 it was 2,26% annually. This is mainly driven by developing countries, many in Asia, since the annual growth rate in the western world has actually fallen in the last years (International Transport Forum, 2009). With a business as usual approach, the global emissions are projected to grow by 38% from 2006 to 2030 (International Transport Forum, 2010). The challenge is to reduce the dependence on oil without sacrificing the efficiency and mobility of the transport sector (European Commission, 2011). Transportation activity normally increases with economic development and increasing gross domestic product (GDP). This has been seen earlier in the western economics and is now seen in emerging markets, of which many in Asia. A growing transportation activity leads to increasing emissions from transport, hence to reach a sustainable future, the increase must slow down and ultimately be reversed (Asian Development Bank, 2009).

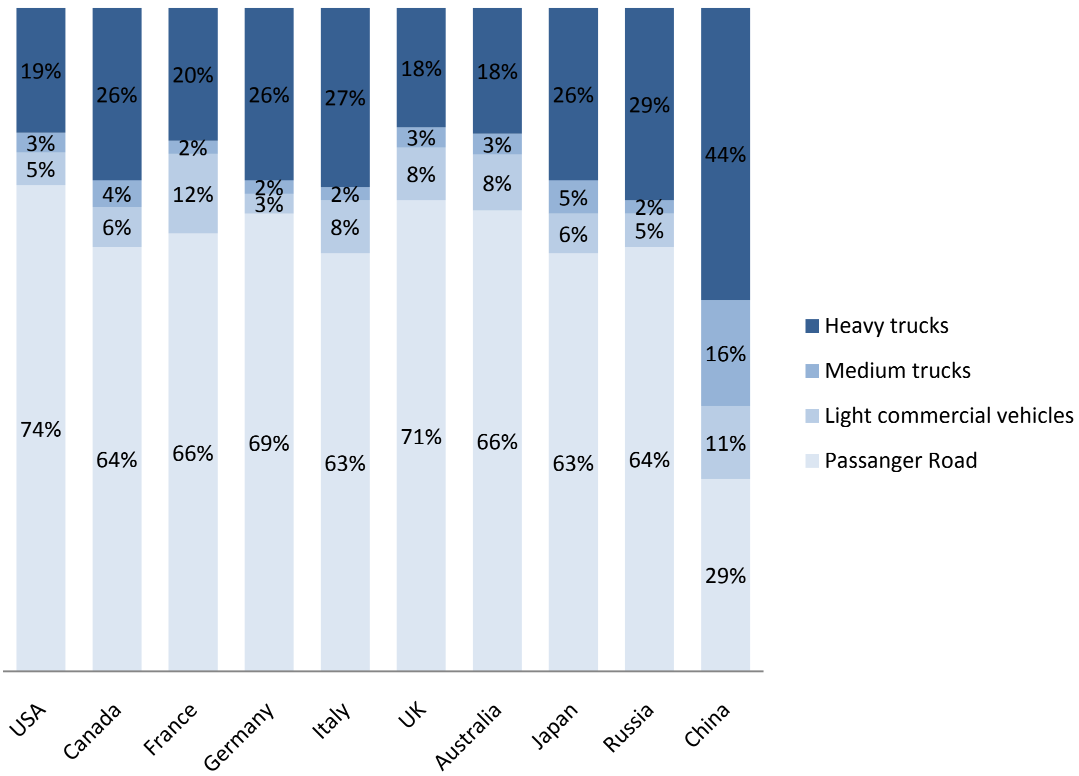


Chart 2: Estimated breakdown of freight versus non-freight road CO_2 emissions in selected countries 2005 (International Transport Forum, 2009)

Of the total transport sector, road transport accounts for more than two thirds of the CO_2 emissions, shipping accounts for 14% and aviation 11%. The difference in emissions passenger transport and freight transport is not always taken into account. This can be estimated for road transport by using fleet composition, fuel consumption and carbon intensity data from different countries. As seen in *Chart 2*, freight transport normally accounts for 30%-40% of the road sector emissions (International Transport Forum, 2010).

SUSTAINABLE SUPPLY CHAIN MANAGEMENT

The concept of sustainability has received great interest in recent years and many companies have adopted the term in their vision and core values. The term sustainability refers to an integration of social, environmental and economic responsibilities (Carter & Rogers, 2008). The most used and quoted definition of sustainability is that of the World Commission on Environment and Development (1987): *"development that meets the needs of the present without compromising the ability of future generations to meet their needs"*. The important thing is integration, a single effort with the goal to improve only the environmental impact is not sustainable. True sustainability occurs when combining all three factors – environmental, social and economic, see *figure 2*. Activities such as reducing packaging, using more fuel efficient transportation or requiring suppliers and forwarders to adopt environmental and social programs can at the same time reduce costs, reduce the environmental impact and improve corporate social reputation (Carter & Rogers, 2008). Globally, about three quarters of the 250 largest firms have a publicly communicated sustainability strategy. Almost 95 percent of these also present an annual corporate sustainability report. In Sweden 54 percent of the 100 largest companies have a public sustainability strategy and about 60% percent also present an annual stand-alone report (KPMG, 2008).

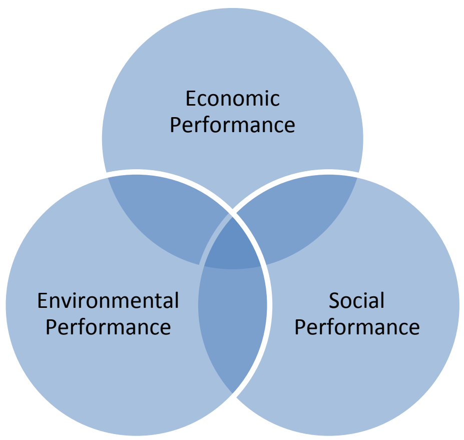


Figure 2: The three building blocks of sustainability (Carter & Rogers, 2008)

The supply chain strategy in most companies today is focused on internal processes such as supply, demand and operations. External factors such as the society, politics and the environment are often ignored and the link to sustainability is therefore lost. This, despite the fact that supply chain significantly determines the social, economic and environmental impact of the company, and clearly affects all stakeholders and shareholders (Cetinkaya et al., 2011). Sustainable supply chain management is defined by Carter and Rogers (2008) as *"the strategic, transparent integration and achievement of an organization´s social, environmental, and economic goal in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chain"*. Cetinkaya et al. (2011) outline four features characterizing a successful sustainable supply chain strategy:

- It is aligned to the underlying corporate and competitive strategy.
- It considers demand, supply, and in particular other, wider general conditions.
- It incorporates environmental, social and economic perspectives in all proposed actions.
- It builds increased shareholder and stakeholder value, especially customer satisfaction.

A sustainable strategy also needs the ability to adapt to future trends and other unexpected events such as increased oil prices, taxes on emissions and new laws and regulations. The company needs to adapt to new trends as early as possible and logistics goals must be maintained and focused towards these trends. The challenge is an early identification of the trends, and to identify which trends are relevant for the own supply chain and what impacts it may have (Cetinkaya et al., 2011). Many companies today adopt environmental programs and invests in new, more environmentally friendly, technology on the basis that it is a possibility to gain or maintain competitive advantage in the future (Sarkis, 2003). Bacallan (2000) describes three reasons behind companies' effort to enhance their competitiveness by improving their environmental performance; to comply with existing or emerging environmental regulations, to address the environmental concerns of their customers, or to mitigate the environmental impact from their products or services. Even if many companies believe that efforts to make the supply chain more environmentally friendly will eventually pay off in an enhanced competitiveness, a clear link between environmental initiatives and profitability is still missing (Bowen et al., 2006).

As seen in *Figure 3*, the supply chain strategy functions as a bridge between competitive strategy and sustainability. The business environment affects which competitive strategy to choose, and this affects which supply chain strategy is suitable. The chosen supply chain strategy has an impact when selecting supply chain partners, structures and processes. And in the end, this affects your supply chains social, economic and environmental performance. Sustainability initiatives and the corporate strategy must be closely interlinked, rather than separate programs that are managed separately of one another (Shrivastava, 1995).

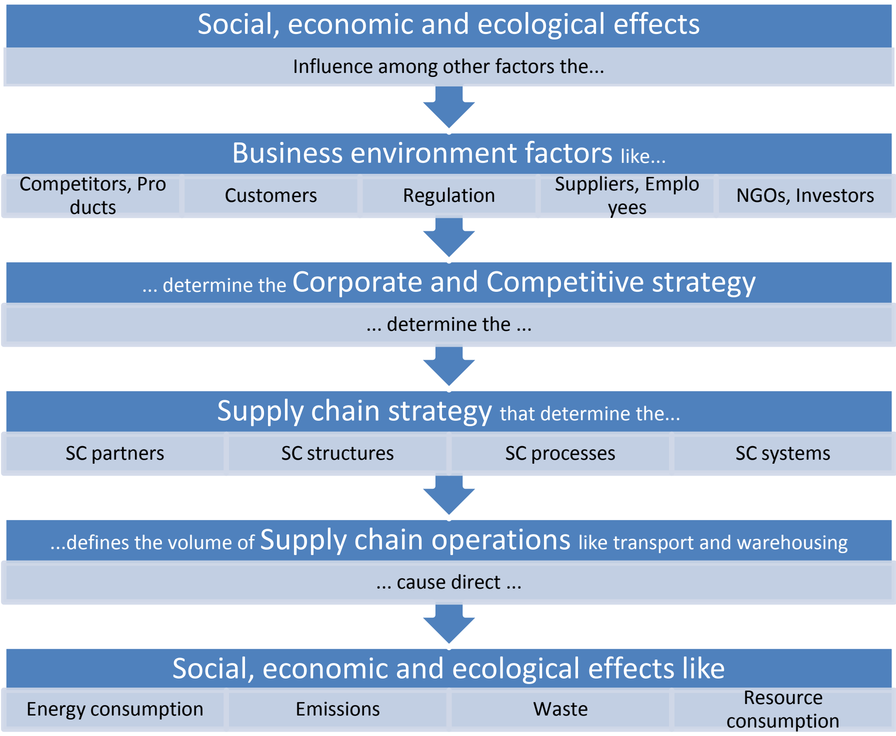


Figure 3: The Supply Chain Strategy Model (Cetinkaya et al., 2011)

Transportation has a major impact on sustainability and the environmental performance. Decisions include; who to partner with, mode of transportation, and just-in-time policies, are a link between business strategy and sustainability. Transportation is also the operation most closely related to customer requirements and customer satisfaction (Sarkis, 2003). Supporting activities in the value chain such as product development, procurement and reverse logistics also relate to sustainable supply chain management. Especially procurement has a great amount of influence when selecting suppliers, asking business partners to adopt environmental programs and ensuring safe and humane working conditions at suppliers and plants. (Carter & Jennings, 2004)

MONITORING AND EVALUATING PERFORMANCE

To implement and evaluate a sustainable supply chain strategy, strategic long term goals needs to be translated into operational short term goals. One way of doing this is to create a number of interrelated key performance indicators (KPI's) and monitor these closely. A KPI system is a practical and straight forward way to implement strategic goals into company operations (Cetinkaya et al., 2011). Specific environmental performance indicators (EPIs) are an important tool in planning, controlling and evaluating environmental performance. A comparison of indicators between previous years, sites or other companies allows for an evaluation of progress and potential improvements within an environmental program (Jasch, 2000).

The international standard ISO 14031: *Guidelines on Environmental Performance Evaluation*, published in 1999, is a model for identifying environmental aspects and a method to choose environmental performance indicators. It is not a standard for certification, as ISO

14001: *Standard for environmental management systems*. Environmental performance evaluation (EPE) is defined as "an internal process and management tool designed to provide management with reliable and verifiable information on an ongoing basis to determine whether an organization's environmental performance meets the criteria set by the management of the organization" (Jasch, 2000). Hrebicek and Ruzicka (2007) describes EPE as a "process to facilitate management decisions regarding an organizations environmental performance by selecting indicators, collecting and analyzing data, assessing information against environmental performance criteria, reporting and communicating, and periodic review and improvement process". The standard distinguishes between two types of EPIs (Wathey & O'Reily, 2000):

- *Management Performance Indicators* (MPIs) describes the measures undertaken by the management to affect the firm's environmental impacts.
- *Operating Performance Indicators* (OPIs) describes the direct strains and impacts on the environment from the firm's operations.

The first objective with an EPI-system is to establish and clarify the current environmental impact of the company. The financial data are probably well known to the business, but the environmental data are often unknown. The current situation must be known before action can be taken to improve it. According to Jasch (2000) environmental performance indicators can be classified as:

- *Absolute indicators*; e.g. tons of raw material, emissions, taken from input-output analysis.
- *Relative indicators*, where input figures are referenced to other variables such as production in tones, revenue, number of employees, office space in m^2; e.g. tones of CO_2 per million of revenue.
- *Indexed indicators*, where figures are expressed as a percentage with respect to a total or as a percentage change to values of previous years etc.
- *Aggregated depictions*, where figures of the same units are summed over more than one production step or product life cycle.
- *Weighted evaluations*, which try to depict figures of varying importance by means of conversion factors.

Long- and short term measures should always be combined but starting with the short term goals might be a good idea; these are probably easier and cheaper to achieve. It is important to set realistic goals and to demonstrate progress in the beginning of the process; otherwise interest and commitment might be lost within the organization. On the other hand, if measures are created and evaluated correctly they can be used to motivate people, teams and business partners. When goals are met the involved people should be acknowledged and rewarded for this. EPIs could also be used as a help in communication, both internally within the organization and externally to business partners and other stakeholders. In this way, the strain to reduce the environmental impact of your business is made visible for managers, investors, customers and NGOs. (Cetinkaya et al., 2011) Principles for the derivation of environmental indicators are presented in the standard (Wathey & O'Reily, 2000):

- *Comparability*: the indicators must be comparable and reflect changes in the environmental performance
- *Target-oriented*: the selected indicators must be aligned with goals which are able to be influenced by the firm.
- *Balanced*: the indicators must reflect environmental performance in a concise manner, and display problem areas as well as benefits in a balanced manner.
- *Continuity*: for sake of comparison, the indicators must be derived by the same criteria and relate to each other through corresponding time series and units.
- *Frequency*: indicators must be derived frequently enough (monthly, quarterly, yearly) so that action can be taken in due time.
- *Comprehensibility*: the indicators must be understandable for the user and correspond to his information needs. The system has to be lucid and concentrate on the most important figures.

MEASURING AND REPORTING CO_2 EMISSIONS FROM FREIGHT TRANSPORT

There are several reasons for calculating and reporting CO_2 emissions in a structured way; to make the emissions visible within the organization, to manage and reduce emissions, to provide figures for the annual report or to adhere to government guidelines (DEFRA, 2010). To be able to reduce the emissions from freight transport, a clear picture of the situation today is required. The calculations must be performed on a regularly basis to be able to track the organization's performance and evaluate the effect of different measures to lower the emissions. Asian Developing Bank (2009) summarizes the activity of measuring and evaluating CO_2 emissions in three steps:

1. Analyzing and monitoring present transport activity and CO_2 emissions.
2. Projecting future transport activity and resulting CO_2 emission levels.
3. Evaluating the impact of policies aimed to reducing both the transport activities and CO_2 emissions.

When calculating the emissions, several methods can be used. The two most widely used calculation methods are the *energy-based approach* and the *activity-based approach*. The aim of these methods is not to calculate the total *carbon footprint* of freight transport operations; they only include the direct emissions from the fuel burned in the engine of the transport vehicle itself (DEFRA, 2010). With an energy-based approach the starting point is the total amount of energy consumed by the transport operations. Based on how much fuel that have been used and the amount of CO_2 created when that particular fuel is burned, the emissions can be calculated. Each fuel type has a specific conversion rate, called emission factor, which shows have much CO_2 is emitted when a unit of that fuel is burned. The factors vary with the carbon content in the fuel; they may therefore be different in different countries (Cefic-ECTA, 2011). The energy-based approach is based on the following formula:

$$CO_2\ emissions = litres\ \cdot kg\ CO_2\ per\ liter\ fuel$$

With an activity-based approach the starting point is instead the actual transport activities. The calculation is often based on the combination of weight of goods transported, length of haul and transport mode. A more accurate approach could also include loading factor, type of traffic (e.g. urban or highway) and type of vehicle (e.g. large or small trucks). For an activity based approach there is distance emission factors developed, that is based on the vehicle type used. They explain how much CO_2 is emitted when transporting one tonne of goods one kilometer with that vehicle type. If there is no data of what vehicles are used, there are general emission factors for a number of different vehicle types, e.g. light lorry, heavy lorry, container ship, bulk ship etc (NTM, 2010). To obtain an accurate estimate of the emissions when using an activity based approach, factors such as loading factor and transport routes must be known. The activity based approach is based on the following formula:

$$CO_2\ emissions = tonnes\ \cdot kilometer\ \cdot g\ CO_2\ per\ tonnekm$$

Some average distance emission factors for road, air and sea are (NTM, 2010):

Road	62g CO_2/tonne-km
Sea	10g CO_2/tonne-km
Air	600g CO_2/tonne-km

When reporting the emissions it is recommended to use both absolute figures and an intensity measurement (DEFRA, 2010). The aim is to lower the absolute figures, in terms of tonnes of CO_2 emitted, which is often the figure presented in the annual report. However, for comparing emissions from different years, or from different business areas within an organization, some sort of relative measurement or intensity ratio is needed. The ratio can be based on units of activity, e.g. emissions per tonne lifted, per pallet or per tonne-kilometer. It can also be based on financial ratios, such as emissions per unit turnover, per unit EBITDA or per employee. These types of measurements should be used carefully, and must be put into perspective of the overall financial performance. A decrease of the turnover will affect the emission ratio in a positive way even if the emissions are the same. Intensity ratios can be constructed in a number of ways, the important thing is that the ratio enables comparison and evaluation of the performance between different reporting periods.

Besides absolute figures supporting information is needed. There must be clear explanation of what is included in the calculation and which calculation method that have been used. Information about reporting period, economic development and major changes in the business puts the emission figures in perspective, and lets you compare different years. When referring to lower emissions, this should always be in comparison of a base year. This could be the first year with all necessary data available or the first year when the new calculation method was used (DEFRA, 2010). Several governments and international organizations have created mandatory reporting schemes, but apart from aviation transport is not included in these. Most reporting schemes and guidelines are based on The Greenhouse Gas Protocol created by a number of independent bodies, World Resource

Institute (WRI) and World Business Council for Sustainable Development (WBCSD) (DEFRA, 2010).

SUPPLY CHAIN STAKEHOLDERS

A sustainable strategy includes corporate social, economic and environmental responsibility. The European Commission (2001) defines this as *"a process by which companies manage their relationships with a variety of stakeholders who can have an important influence on their license to operate"*. But who are these stakeholders? The founder of stakeholder theory, R. Edward Freeman, defines stakeholders as *"groups or individuals of an organization who can affect or are affected by the achievement of the organizations objectives"*. Customers and other stakeholders rarely distinguish between a company, and the rest of the supply chain such as suppliers, sub suppliers outsourced activities. This means that any environmental liabilities will most likely be considered as the company's responsibility and the company will be held solely responsible for the environmental impacts from any organization in the entire supply chain for a product (Rao & Holt, 2005).

The importance and the impact of different stakeholders vary between different corporations and between business units and cannot be generally listed, starting with the most important one. The different stakeholders are instead often grouped into primary and secondary stakeholders. In a supply chain perspective, the primary stakeholders include groups and organizations such as suppliers, customers and service providers. Secondary stakeholders include among others employees, governments, shareholders and consumers (Cetinkaya et al., 2011). The two levels of stakeholders are summarized in *figure 4*.

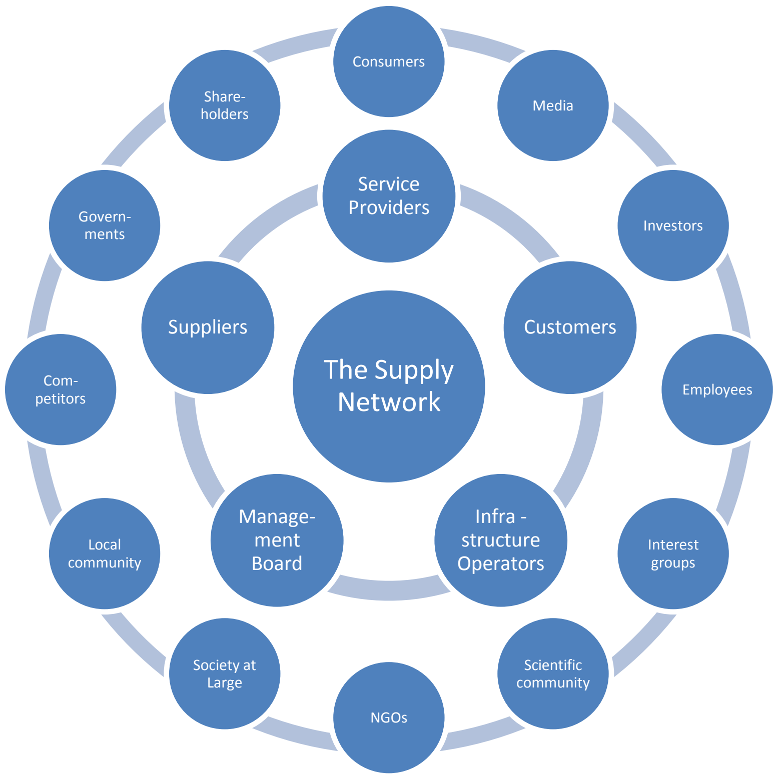


Figure 4: The supply chain stakeholder model (Cetinkaya et al., 2011)

into. Ways to implement and evaluate this can be to use a scoring matrix to rank suppliers on their environmental performance, use of environmental criteria in the selection of suppliers, and requiring suppliers to use an environmental management system (Hamner, 2006). The same strategy used for ordinary suppliers could of course be extended and used when purchasing and negotiating logistics services, such as transport and warehousing contracts. A purchase strategy with the aim to reduce the own corporation's environmental impact is called *Environmentally Conscious Purchasing* by Handfield et al. (2002) or *Green Purchasing* by Hamner (2006), Green et al. (1998) and Handfield and Melnyk (1996). The company must educate and support its own purchase managers. They are the link between the company and its suppliers, and need to be highly skilled in the concepts of environmental management and sustainable supply chain management. Purchase managers must use their power as customers to influence the suppliers and make sure that all necessary actions are taken at the supplier's location. The purchasing department at many companies often lacks the knowledge of environmental management and the staff working with environmental questions often lacks the knowledge about purchasing. Environmental staff should therefore train purchasing staff and vice versa. (Hamner, 2006)

THIRD PARTY LOGISTICS AND THE ENVIRONMENTAL IMPACT AS BUYING CRITERIA

In recent decades there has been a growing trend of outsourcing logistics activities in many industrial sectors. The activities that were previously performed in-house have many times been replaced with third party logistics (3PL). The global industry of third party logistics will grow from $10 billion in 1992 to $56 billion in 2020 (Facanha & Horvath, 2005). The decision to outsource is based on many factors and variables such as risk and control, cost, service and information technology (Rao & Young, 1994). 3PL have the specialized knowledge and technology and owns control of the whole transportation chain. Hence they can optimize load building to improve vehicle utilization and reducing the number of loads and transport routing to minimize the total distance traveled (Facanha & Horvath, 2005). The growing demand for outsourcing has resulted in the emergence of large companies that offer a wide range of logistics solutions on an international and even intercontinental scale. Such logistics service providers (LSPs) offer a total solution for their customer's logistics network and not only transport or warehousing functions (Selviaridis & Spring, 2007). In this category companies like DHL, Schenker, TNT, UPS, DSV and Kuehne+Nagel are found.

Logistics outsourcing has received much interest in recent years from companies trying to reduce costs, lead times and improve service reliability, although the environmental effects have not been studied in the same extent (Facanha & Horvath, 2005). The environmental impact of logistics activities has received a greater interest but is still considered as a minor criterion. When selecting 3PL partners, decisions are still made on the traditional performance objectives, such as cost, service quality and reliability, flexibility, responsiveness to requests and financial stability (Selviaridis & Spring, 2007; Lieb & Lieb, 2010). The environmental concerns have at best been included as a minimum requirement or into non-financial measures (Wolf & Seuring, 2010). 3PL offers a wide range of services but transportation has by far the largest environmental impact. Even if many of the transport buyers and 3PL have started to measure and evaluate the emissions from freight transport, there is only limited knowledge on how the results impact the company's economy today or in the future. It is not expected that 3PL companies will change their logistics operations to become more environmentally friendly. Although environmental concerns from customers, demand of greener alternatives from business partners and stronger regulations will probably result in more efficient and more sustainable operations (Facanha & Horvath, 2005). "*Logistics can be regarded as the missing link for the provision of greener products and services to customers, allowing companies to produce even greener products if the corresponding logistics also become green"* (Wolf & Seuring, 2010). Lieb and Lieb (2010) report on a number of analytical initiatives for calculation of carbon footprint started by firms in the 3PL industry upon requests from customers. Customers often request a carbon footprint metrics tool to measure and report CO_2 emissions based on tonne-km, which shows an increasing interest to be able to evaluate both the economical and environmental costs of a particular logistics solution. However, the translation of environmental performance into financial terms or the integration of environmental key figures into financial planning is not the reality today, environmental aspects and economic aspects are still managed separately. In order to achieve synergies between economy and ecology, the company needs to find staff that is competent in both logistical and environmental issues at the same time (Wolf & Seuring, 2010).

FUTURE TRENDS

To reach the IPCC target of 450 ppm CO_2 concentration in the atmosphere, a wide range of actions to lower the emissions from freight transport is required until 2020. Although, levels of traffic intensity, especially freight transport are still increasing and further increase of current emission levels will make it impossible to reach the target. Freight transport by lorry and air is growing fast, as a result of improved infrastructure, lowered trade barriers between countries and continents and lowered transport costs (Åkerman & Höjer, 2006). Action must be taken and several governments and the European Union have set targets for reduction of CO_2 emissions from freight transport, but a global agreement on emission reduction are not yet to be seen.

The growth in transport intensity has historically been closely tied to the economic growth, i.e. GDP. However, this relationship has been debated and some researchers suggest that there is no need at all for transport growth to follow the economic growth (Banister & Stead, 2002). The growth of transport intensity in the latest 30 years is mainly explained by increased transport distances due to globalization. So even if the total transport volumes carried have decreased slightly in industrialized countries, but the reduction does not compensate for the heavily increased transport distances (Åkerman & Höjer, 2006). The relocation of warehousing to other countries or even continents is expected to grow until 2020 and manufacturing capacity and inventory are expected to be more centralized which means that the average length of haul and total tonne-km's will probably increase (Piecyk &

McKinnon, 2010). It is assumed that products with a low cost/weight ratio are produced more locally in 2050 than today but products with a high cost/weight ratio are probably still sold in a global market with long distance transport as a consequence. However, the trends of miniaturization and dematerialization, with lighter and more durable products are expected to continue, which means a possible reduction of transport intensity (Banister & Stead, 2002; Åkerman & Höjer, 2006).

Åkerman and Höjer (2006) also refer to the use of IT as a possible key to lowering emissions from freight transport. The idea is *glocal production*, where international corporations centralizes company management and product development, while the physical production may be decentralized, located closer to end customers. This will lower the need for the so called "cross-freight transport", where materials and products are transported back and forth between continents. Global sourcing will continue to grow and this means an increase of the intercontinental freight but might reduce the national or local inbound freight (Banister & Stead, 2002). The ongoing trend with outsourcing of non-core activities is expected to grow and extra transport links being added to the supply chain (Hickman & Banister, 2007). The trend to relocate production to "right cost countries" will also continue, even if the countries are not the same as in the beginning of the 21th century. Piecyk and McKinnon (2010) summarize six key factors affecting the emissions from road freight transport in 2020:

- *Structural factors* - number, location and capacity of manufacturing units, warehouses and other supply chain facilities
- *Commercial factors* - related to companies supply chain strategies
- *Operational factors* - affecting the scheduling of product flow
- *Functional factors* - choice of vehicle and route planning
- *Product-related factors* - affecting transport demand and transport activities
- *External factors* - government regulations taxes and advances in technology

Despite a continuing globalization and a higher demand for transportation activities, several authors predict a possible reduction in transport emissions of about 60 % until 2030 (Hickman & Banister, 2007). IPCC (1996) estimates a possible reduction of emissions from road freight of 20% - 60% between 1996 and 2025, some even says a reduction of 60% is manageable until 2020 (Swahn, 2011). This by developing more efficient engines, higher lorries with the ability to triple stack pallets, and implementing alternative fuels. For air transport, a 44% reduction of fuel intensity per tonne-km is possible until the year 2050 by refining the conventional turbofan aircraft (Åkerman & Höjer, 2006). The introduction of new aircraft models, such as the flying wing, new engines or alternative fuels may of course have an even greater impact, but the development of new technologies is uncertain (Åkerman, 2005). Sea freight is in general very heterogenic, where each ship has its own characteristics and environmental performance. This makes it difficult to draw a general picture of the possible environmental improvements of sea freight, although one clear factor of impact is speed. High speed means high water resistance and hence high emissions. On the contrary, a reduction in speed from 20 knots to 16 knots means a 40% reduction of the emissions (Swahn, 2011). Steen et al. (1997) means that a 30% reduction of the overall emissions from sea freight is possible with existing technology. In total, a current projection involving low and high estimates predict that the emission reductions from freight transport will fall 62% to 25% short of reaching the 450 ppm trajectory by 2020 (International Transport Forum, 2009).

Transport mode	Potential change by 2050 (%)
Lorry (<100 km)	-40
Lorry (>100km)	-30
Light Lorry (<3,5 tonnes)	-45
Rail	-30
Ferry (20 knots)	-30
Cargo Ship	-30
Air	-44

Table 1: The possible percental reduction in emissions for different transport modes by 2050 (Åkerman, 2005)

METHOD

The chapter discusses research strategy and the approach used to answer the research questions. The different steps in the study such as data collection, creation of scenarios and simulation are all presented. Finally the reliability, validity and generalizability of the results are discussed.

APPROACH

In order to satisfy the purpose of the study and to answer the research questions a case study is performed at ITBA. We focus on understanding the current situation and dynamics at the company in general and how they work with environmental questions in particular. The data collection includes semi structured interviews and studies of internal freight data. In order to investigate possible futures, scenario planning is used to construct four different scenarios for the year 2020. Scenario planning is a well known method for analyzing and evaluating possible futures and is particularly suitable for situations where much is still unknown and where e.g. new legislation will totally change the market (Lindgren & Bandhold, 2008). The four scenarios are all *possible* futures and represent four divergent set of events. The scenarios are evaluated and quantified with the simulation software STELLA™. A model is built of the current supply chain setup and distribution network and a number of variables are then changed in a methodically way to create the four scenarios. This will help us to answer how the total emissions from freight transport vary with e.g. economic growth, distribution strategy, supplier base, customer location or amount of airfreight used. It also provides information about how fragile ITBA's reduction target is. The outcome is a number of recommendations for how ITBA can influence the environmental impact of their freight transport. The study can be summarized in four major steps:

1. Collect data using interviews and freight records
2. Create scenarios for 2020 using scenario planning
3. Simulate the scenarios and present the results
4. Compare results and recommend suitable measures to lower the emissions

COLLECTING DATA

Case studies is a research strategy that involves using one or more cases to create theoretical constructs, propositions and theory from case-based, empirical evidence. It usually includes a combination of methods for data collection such as archival records and interviews (Yin, 2009). The evidence may be qualitative, quantitative, or both (Eisenhardt, 1989). Our data collection includes both qualitative data (interviews and documents) and quantitative data (freight statistics). Strength in case studies is the combination of the two types of data and used correctly they corroborate each other and synergies arise. Qualitative data are useful for understanding the current situation and underlying relationships, and these conclusions can be strengthened by quantitative support. By using quantitative data as a supplement, the researcher may also avoid being affected by false or divergent perceptions among respondents in the interviews (Eisenhardt, 1989).

To understand the data within a context of the company and other factors, background information is collected, including general information about Atlas Copco in terms of history, business culture and the way they work with sustainability. Interviews are performed with key respondents at different departments of the organization, such as logistics, purchasing, sales, distribution centers, factories, and safety-health-environment (SHE). Interviews are also conducted with researchers and representatives of other organizations and NGOs. The interviews are performed in a semi structured way, meaning that we will have questions prepared but they are used more as a guide through the interview. The questions are also different from one interview to another, depending on the respondent. As a complement to the interviews, a handful of key informants provide valuable information about the company, the operations and personal contact with respondents. During the study a close contact is kept with the respondents and the informants. To understand the distribution network, freight data from the internal enterprise resource planning system for factories and distribution centers is collected. The external and internal communication, such as annual reports and policies about sustainability and environmental accounting is also studied. In contrast to the interviews, this gives a different view of how the company is working with these types of questions. With a research strategy consisting of several data sources, including interviews, and archival record, a so called data triangulation is achieved. In this way facts and results of the case study are supported by more than a single source of evidence (Yin, 2009). The information obtained from interviews is especially important, hence this is primary data.

CREATING BUSINESS SCENARIOS

To evaluate possible futures in the year 2020 scenario planning is used to create four different scenarios. Each scenario represent a possible future in 2020 in which ITBA have to operate. Factors of impact are identified and then combined in order to obtain four scenarios, as different as possible. Scenario planning is a strategic tool for visualizing possible images of the future. The different futures are then used as groundwork for organizational decisions (Shoemaker, 1995). Scenario planning is useful in situations of paradigm shift or non-linear development and for businesses or areas with a high degree of uncertainty, where new technology or new legislation is likely to totally change the market (Lindgren & Bandhold, 2008). In situations of rapid development and a high degree of uncertainty it is impossible to know exactly what the future will look like. A successful strategy is one that plays out well across several possible futures. To find that robust strategy, several scenarios are created, such that each scenario diverges markedly from the others. The different scenarios are all stories about the future, each one describing *"a possible world in which we might someday have to live and work"* (Wilkinson, 1995). The purpose of scenario planning is not to pinpoint future events, it is rather a way of highlighting large scale factors that influence or push the future in different directions. The future will more likely consist of factors from all scenarios. The aim is to make these factors visible, so if they happen the planners will at least recognize them. The aim is to make better decisions today about a future we don't know much about (Wilkinson, 1995). Scenario planning is a way of combining discussions about futures in a long perspective and strategic planning in a short or medium term perspective. If we know the factors influencing the future development, we can prepare ourselves, work proactively and take advantage of the changes (Lindgren & Bandhold, 2008). Scenarios allow managers to gain a better understanding of the possible business environments they will need to tackle in the future (Cetinkaya et al., 2011). A scenario is not a static final state; it is a descriptive and living picture of a possible way to a future, a convincing story that includes the basic questions; who does what with whom, when, where and why? (Lindgren & Bandhold, 2008). The different business scenarios for 2020 are only assumptions, and should not be considered as predictions of the future. Most likely none of the scenarios will come true. They should instead be used as a strategic method to visualize possible futures, and to identify the main factors affecting the process.

When a number of factors or uncertainties have been selected it is time to combine these and create scenarios. Qualitative analysis is needed when dealing with questions like; what happens if A or B occur? What will this mean and what are the impacts on our business? A simple way is to combine two factors at a time and then adding other plausible combinations. The aim is to use both hemispheres of the brain, both the ability to analyze and the imagination. Scenario planning is not only a tool for planning; it is also a valuable way of learning. To think of possible scenarios helps to understand the logic in processes and to clarify key factors, important stake holders, and the possibility to influence (Lindgren & Bandhold, 2008). Balfe and Tretheway (2010) summarize the process of scenario planning into four building blocks, where the study is based on the two initial blocks:

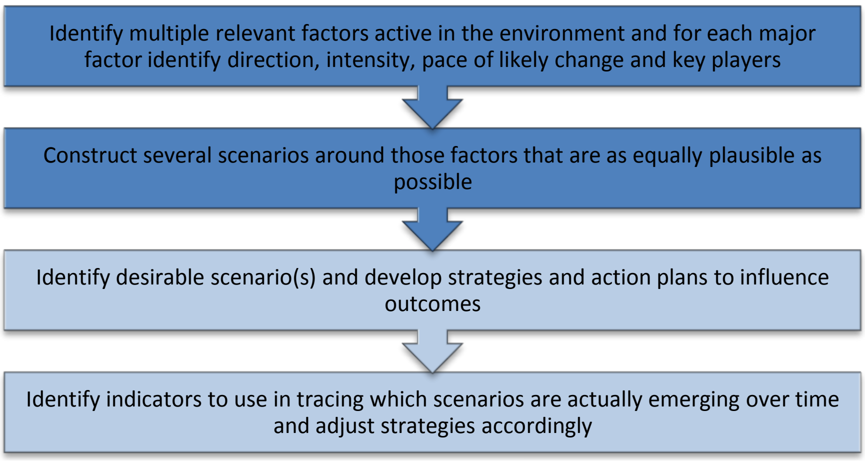


Figure 5: The four building blocks of scenario planning (Balfe & Tretheway, 2010)

SIMULATION

To simulate the CO_2 emissions in the four scenarios we use a systems dynamics approach and the simulation software STELLA™. Systems dynamics is a well known and much used methodology that is capable of studying and modeling complex systems such as supply chain networks. It is a good way to understand the whole system as well as the interactions between various components of the integrated system (Özbayrak et al., 2007). System dynamics is a way of problem solving in living systems and links together hard control theory with soft system theory (Fiala, 2005), and one of the best methods for analyzing complex systems (Higuchi & Troutt, 2004). A system dynamics approach is appropriate when analyzing a system that includes core variables that are known to adjust over time (van Ackere et al., 1997) and function very well when analyzing strategic scenarios and for simulating policies and operations (Helo, 2000). The STELLA software is one of many applications for implementing, visualizing, and evaluating concepts of system dynamics; hence it is very useful when modeling a complex supply chain network (Fiala, 2005).

Initially the supply chain structure and distribution network as today is simulated. Necessary variables, such as economic growth, modal split, and location of distribution centers, factories, suppliers and customers are included. The result obtained from this initial run, i.e. tonnes of CO_2 per year, is then used as a benchmark for comparing results from the future scenarios. The variables are then changed to reflect each of the four scenarios and the simulation is run in STELLA. The results are obtained as data tables and graphs and compared with the benchmark result of today's set up.

To be able to quantify the emissions in the different scenarios from 2010 to 2020, the computer software STELLA is used to simulate the total emissions. In the model, every distance used is defined, e.g. distances between sub suppliers and production units, production units and distribution centers and between distribution centers and customers. The distance between two locations naturally varies depending on transport mode and for these figures we use a web-based distance calculator recommended by NTM. The weight delivered to each location is then defined in a similar way. The weights are ITBA's internally reported weights for 2010. Finally the emission factors are defined for each transport mode, based on figures from NTM. In the end, it all comes down to the formula:

$$Total\ CO_2\ emissions = \sum weight \cdot distance \cdot emission\ factor$$

The data file consists of hundreds of cells but the general flows can be described in a simple way, seen in *Figure 6*.

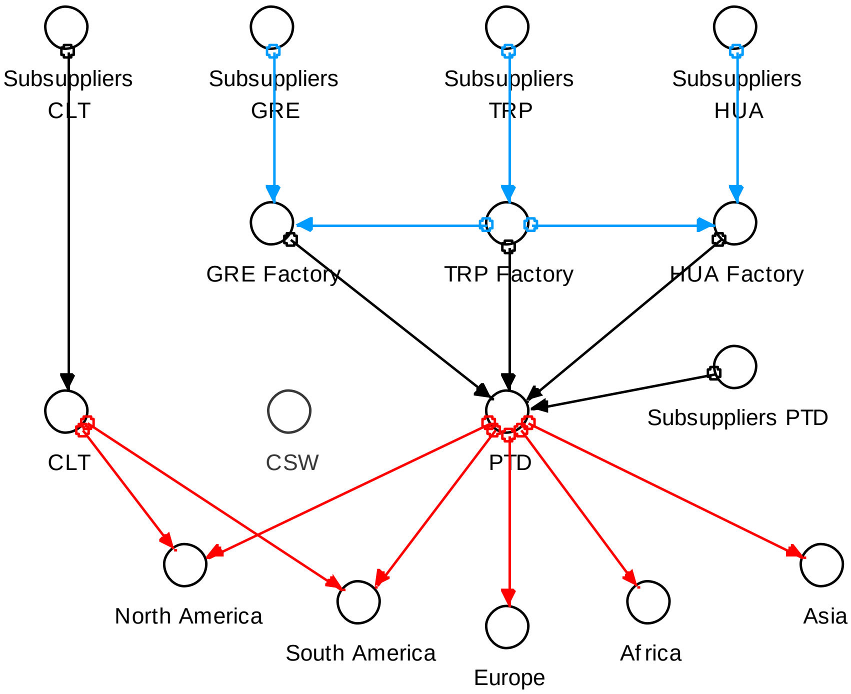


Figure 6: Simplified STELLA model of the transport flows

The model takes into account the weight- and technology development until 2020. The strength of the model is that it is relatively easy to see what happens if for instance the technology development is larger than anticipated, the market has a global dip or if one specific market grows more/less than expected. It is also possible to extract a number of different KPI's, e.g. CO_2/tonne-km, shipped weight per transport mode, weight per continent etc. The weakness of the model is that it is entirely built on second hand information, data not controlled by the authors. If this data is not correct, one might very well get miss led by the results. However, it is important to remember that the model's purpose is not to provide the user with exact figures for amounts of emitted CO_2 but to give the user an idea of what affects the emissions.

VALIDITY, RELIABILITY AND GENERALIZABILITY OF THE RESULTS

The study is partly based on interviews with chosen respondents. In terms of validity this means that valuable respondents might be missed. There is also a risk that important questions are missed or answers misinterpreted. In order to avoid this, information from interviews have been confirmed with the respondents again when possible. Since internal interviews are used to understand the company, the data is based on the current situation and organizational culture within the company. This means that the result might not be representative but based on existing trajectories originating from previous history of the organization. The difficulties with biased data can be mitigated by using numerous and highly knowledgeable informants from different parts of the organization and with different perspective (Eisenhardt & Grabner, 2007). To complement the internal interviews, respondents from external organizations and NGOs are used. With this approach, a relevant picture of the current structures and difficulties within ITBA, as well as an external view on the complex problems is obtained.

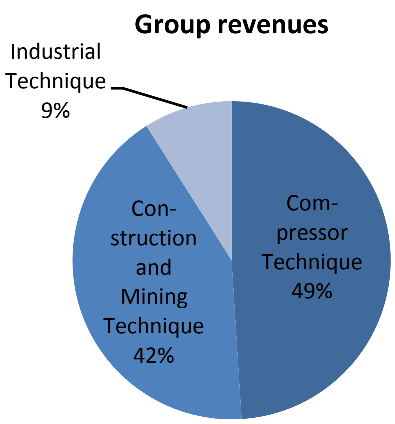
The reliability of the study, i.e. the possibility to replicate the study with the same results, is dependent on a number of factors. The situation is only studied at a specific point of time, which means that also the results are specific for this time and with similar external circumstances. The current situation, where environmental issues in general and CO_2 emissions in particular, are discussed frequently determines the interest from companies for these issues. A lower interest or a different public opinion might also affect the result of this study. If generalizing the results of the study, care must be taken in terms of the company size, industry, type of products, type of customers and supply chain structure. Also the economic and political situation in affected countries must be taken into account. Eisenhardt (1989) also argues that case studies describes a very specific phenomenon and may result in narrow and idiosyncratic theory. Some of the findings could probably be summarized and applied for the other business areas within Atlas Copco. However, the differences in terms of products and customers between the business areas make it more suitable to apply the results on other companies or organizations with similar business structure or products.

CASE STUDY RESULTS

The case study is the ground work in this study and forms the base for the analysis. In this chapter, data from the internal interviews is summarized and the situation within the company today is described.

ATLAS COPCO GROUP

Atlas Copco is an industrial group offering a wide range of products from compressors, construction and mining equipment to power tools and assembly systems. The business was founded in Stockholm in 1873 as AB Atlas and is still based there. The group is organized in three business areas, Compressor Technique (CT), Construction and Mining Technique (CMT) and Industrial Technique (IT). The business areas operate through divisions which functions as separate operational units, each responsible to deliver growth and profit. The divisions conduct business through customer centers, product companies and distribution centers. Totally the group has customers in 178 countries worldwide. Atlas Copco has traditionally grown by acquisitions and works with a multi-brand strategy where more than 30 brands are used worldwide. For 2010 the total revenues was BSEK 70 and the group had in total 33 000 employees, see *Chart 3*. (Atlas Copco, 2011)



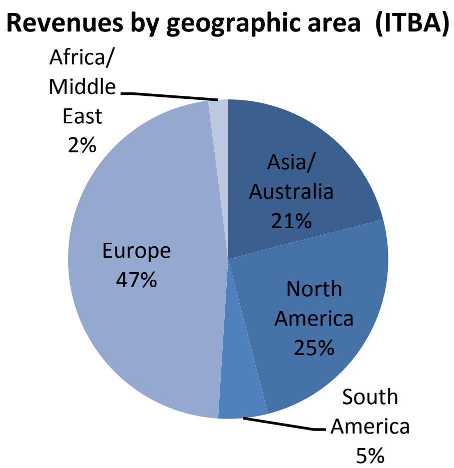


Chart 3: Atlas Copco group revenues 2010 by business area and ITBA revenues 2010 by geographical region (Atlas Copco, 2011)

BUSINESS AREA INDUSTRIAL TECHNIQUE

ITBA develops, manufactures and markets industrial power tools, assembly systems, software, after-market products and service. The products range from screwdrivers, nut runners and drills to air motors and complete assembly systems. Brands used for industrial power tools and assembly systems are Atlas Copco, Chicago Pneumatic, Rodcraft, Fuji and Desoutter. Product development and main manufacturing units are located in Sweden and France, with smaller units also in Hungary, Italy, China and Japan. The business area is divided consists of four divisions and all manufacturing and distribution is concentrated to the divisions Tooltec. Important customer segments are the motor vehicle industry, shipyards, electrical appliances and aerospace. The motor vehicle industry is the dominant one and account for about half of the annual revenues. For 2010 the total revenues was MSEK 6 472 (Atlas Copco, 2011). As seen in *Figure 8*, about two thirds of the customers are located in Europe, with Germany as the biggest market. Asia and North America each accounts for about one sixth of the sales. However the internal estimate for the sales distribution in 2020 is that it will be roughly divided in three – 30% of the sales in North America, 30% in Europe and 30% in Asia.

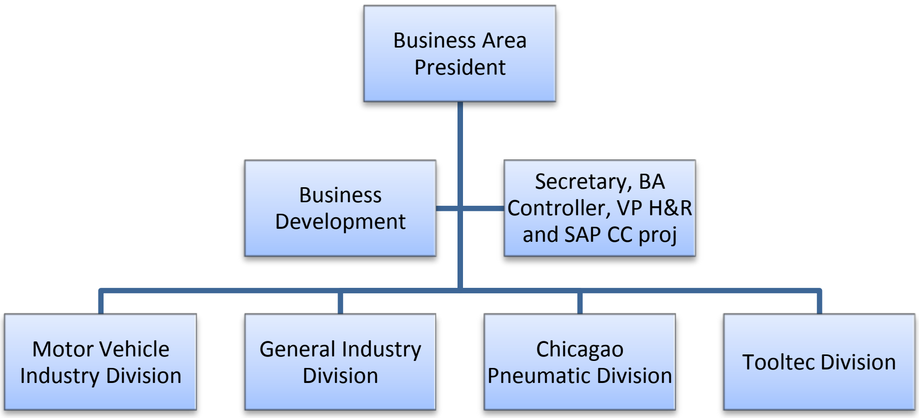


Figure 7: Organizational chart of business area Industrial Technique (Atlas Copco, 2011)

SUPPLY CHAIN STRUCTURE

The current supply chain structure is based on manufacturing and assembly units, mainly in Europe, and a distribution center (DC) in Belgium, called *Power Tools Distribution* (PTD). Another distribution center located in US is used to a smaller extent for goods for the US market. The production sites are located in Sweden (Tierp, Nacka) France (Nantes) Hungary (Szigetszentmiklós), Italy, China (Qingdao) and Japan (Osaka). The facilities in Italy, China and Japan are minor compared to the others, and therefore excluded in this study. ITBA also have a centralized service unit in Poland, called *Central Service Workshop* (CSW).

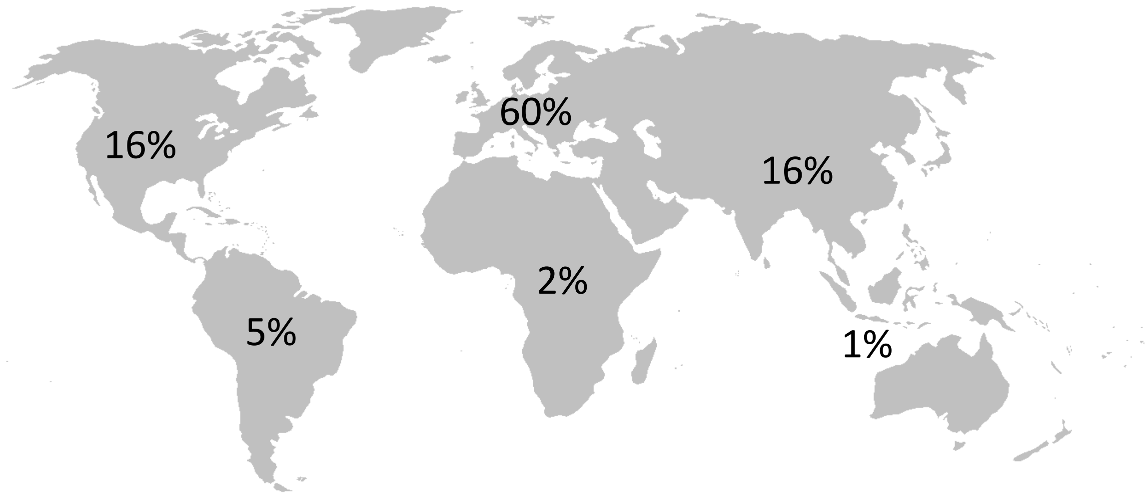


Figure 8: Sales distribution per geographical area, ITBA 2010

Manufacturing and assembly units

All production units handle their own inbound process and the necessary transport arrangements. In general for the three main units, most of the suppliers are located on a moderate distance; hence road transport by truck is used for most of the inbound transport. For some goods from suppliers located in Asia, sea- and air freight is used. The total inbound weight for these units is presented in *Table 2*. There is an internal policy for stock keeping units (SKU's) that are used in manufacturing and assembling. The policy states that the facility with the highest consumption of the specific SKU is also responsible for the supplier agreement and purchasing. If the SKU is needed at another facility it is ordered internally and shipped from the responsible facility. All finished products and parts are shipped from the manufacturing units to PTD where it is kept on stock. However, this is not the case for drop-shipments where products are sent directly from factory to customer due to back orders and the need to reduce lead-times. Most of the finished products are sent by truck to PTD, but air freight is much more frequently used for drop-shipments (Lindström, 2011). The facility in Tierp in Sweden is the biggest manufacturing and assembly unit within ITBA and forwarders used include DHL, TNT, UPS, Schenker, Swedish Postal Service, and a few other small companies.

Manufacturing Unit	Inbound, total shipped tonnes 2010
Tierpsverken (Sweden)	770
Industrial Technique Hungary (Hungary)	260
CP Technocenter (France)	50

Table 2: Inbound volumes per production unit, ITBA 2010

Power Tools Distribution

In 1991 ITBA decided to centralize the warehousing to one location and PTD was opened in Belgium. Earlier many of the customer centers (CC's) had kept local stock on products for respective market. The different local warehouses were now consolidated and centralized to PTD along with customer services and distribution logistics management. Today PTD handles the warehousing for all tools, accessories and spares, in total more than 75 000 SKU's. PTD also handles all customer orders within ITBA, and in a regular day PTD receives about 6 000 order lines and ship out about 2 000 packages with a net weight of 120 tonnes. Of the road transport within Europe UPS is used for 60%-70% of the total weight. The total outbound weight is presented in *Table 3*. When customers order products they place the order to their closest CC. The CC then forwards the order to PTD via electronic data interchange (EDI). PTD receive, pick, pack and ship the order within the same day. The target is that European customers should have their goods delivered the day after ordering - a policy that internally is called *Daily Direct Delivery* or *DDD*. PTD invoices the CC for the goods and the CC invoices in turn the customer.

Continent	Outbound, total shipped tonnes 2010
Europe	4 500
Asia	330
North America	300
South America	170
Africa	100
Oceania	3

Table 3: Outbound volumes from PTD per geographical region, ITBA 2010

Central Service Workshop

ITBA has a centralized service facility called CSW located in Gromadka in Poland. Customer owned products which needs to be repaired is sent via the local CC to CSW. The tool is repaired and sent back directly from CSW to the customer. If service is needed, the customer organizes and pays for the transport from his premises to the local CC. Each CC then uses UPS (i.e. their own UPS-account) to ship the tool to the UPS hub in Bautzen, Germany. Each morning all tools sitting in Bautzen are picked up and transported 109 kilometers over the German-Polish border, to Gromadka by a local transport firm. This part is paid by CSW and hence included in their emission reporting. The local forwarder only uses small vans, i.e. max 3,5 tonnes. When the service is completed and the tool is to be sent back to the customer, it is first sent to Bautzen and then shipped by UPS to customers address. This transport is organized and paid directly by CSW, and also included in the reporting. When spare parts are needed, these are ordered from PTD and shipped via Bautzen to CSW. For this transport PTD is responsible and pays the invoice. The same setup is applied for consignment stock operations.

MEASURING AND REPORTING CO_2 EMISSIONS FROM TRANSPORT

The policy today within ITBA is that each business unit, including manufacturing and assembly units, distribution centers, and customer centers, should report their emissions each quarter. For every unit there is one person responsible for reporting the emissions and the data is submitted in a data warehouse tool called *Sustainability Village* where reports can be generated with any unit, timeline or output. Head of all the responsible persons is the SHE manager, which extracts data from Sustainability Village and creates consolidated reports for business area- and group management. According to the internal policy, each unit should preferably use CO_2 data provided by the forwarders. If this is not available, an activity-based approach where the emissions are calculated according to an internal model is used. However, the actual method to calculate the emissions varies between the units.

PTD is responsible for the biggest share of emissions since they are handling all the inbound transports from production units, external suppliers and the outbound transport to customers. They are also the unit with the most sophisticated calculation model for estimating the emissions. They use an activity based method where internal freight data (i.e. shipped weight and supplier/customer location) and distance emission factors are used. For the inbound process data is missing of what transport mode is used. An estimate is done; shipments within Europe is considered as road transport, intercontinental shipments are considered as air freight if the total weight is less than 300 kg, otherwise as sea freight. This is also the part with the greatest uncertainty in the calculation model. However the emissions from the inbound process are minor compared to the outbound transport. When reporting, PTD uses internal freight data by creating reports from the ERP system where weight and customer location is summarized by country and continent. For transports within Europe the weight per country is multiplied by the linear distance from PTD to the capital of that country. The tonne-kms is then multiplied by the distance emission factor for the transport mode used. Countries outside Europe are consolidated into continents and a distance to a likely "commercial center" of each continent is used for calculating the total tonne-kms. The commercial center of Africa is for instance Johannesburg in South Africa. Today the major forwarders can provide quite detailed CO_2 statistics about the transports performed for a specific customer. However, this data is not used; the reason is that it would be too difficult to compare the total emissions from one year to another if new data were introduced.

At the assembly and manufacturing unit in Tierp some provides CO_2 data directly, and this is then used in the reporting. Other forwarders do not provide this type of information, and the emissions have to be estimated manually by the environmental manager who does the reporting. Internal freight data of weights and supplier location is used and the emissions are estimated. At the site in France, internal freight data from the ERP system is used when calculating emissions. The number of parcels and total weight is collected but categorized only as national or international. The national shipments are all transported by road but for international shipments assumptions are done regarding transport mode and distances. At the site in Hungary, forwarders provide transport of weights distances and transport routes every quarter. These figures are then used for calculating the total emissions from the inbound transport. Another uncertainty is that some of the inbound transports to manufacturing units may be missed. This as suppliers might have manufacturing in Asia but a local warehouse near the ITBA site. ITBA only sees and pay for the transport between the supplier's local warehouse and their own location. Until now CSW have been using the old method for calculating CO_2 emissions form transport, i.e. an energy-based approach, where the local forwarder and UPS provided fuel consumption statistics each quarter. UPS also provides statistics of how many tonnes of good that are shipped out from Bautzen each quarter, but these figures are not used for calculating and reporting the emissions. It is difficult to obtain the correct CO_2 emissions based on the shipped weight since the shipments are sent to different parts in Europe, always with a combination of different destinations in one van or truck. They have not asked UPS if it is possible to get the CO_2 data from transport operations directly each quarter.

THE USE OF THIRD PARTY LOGISTICS

Today all freight transport within the business area is outsourced to forwarding companies. All transport is handled locally, meaning that all production units, PTD and CSW negotiate their own contracts with forwarders. All the big forwarders operate on an international level and in almost all European countries, however, ITBA have several local contracts with the companies. All units, including PTD, are required to lower their emissions from transport by 20% until 2020. But in reality PTD don't have much possibility to influence what transport modes used for the outbound freight. This is instead a consequence of what delivery time the customer center has promised the customer. The internal emission reduction target is therefore basically pushed down to the forwarders. Many of the forwarders have the same or a similar reduction target as ITBA and some respondents would like to see an internal policy which states that ITBA only uses forwarders with an equivalent or more ambitious reduction target.

Even if the forwarding companies operate on a global basis, there are vast differences between countries and local affiliates of the companies. Some track all data in a central system, and offer customers to get a complete environmental report each month or each quarter. Some forwarders do this for free, others charge the customer for it, and others don't track these things at all. Schenker offer their customers a web-based portal, where customers can log in and see the total emissions originating from their transports. Today DHL, TNT, UPS and Kuehne+Nagel can provide PTD with absolute CO_2 emissions. Although this opportunity have not been implemented due to difficulties when comparing the statistics for different years. The aim from SHE management is to use the absolute CO_2 data provided by the forwarders, since they have the most accurate information regarding the whole transport chain, including environmental performance of vehicles, transport routes and total distances. PTD is evaluating the forwarders annually in terms of quality and environmental performance, but this is not used to exclude any forwarder. It is still the traditional criteria such as cost, service quality and reliability that determine the overall performance. During the first half of 2011 a series of business reviews were held with the big forwarders used in Sweden. This was a good opportunity to talk about environmental issues and possible improvements in the cooperation between the companies. The aim is to have these meetings twice a year and continually discuss environmental issues and track the environmental performance for each forwarder.

ENVIRONMENTAL RESPONSIBILITY

Within the business area there is a shared responsibility for environmental issues related to transports. It is always the specific business unit paying for the transport that is responsible for the emissions, but not always the one making the decisions on delivery times and transport mode. The customer centers have all the contact with customers and in order to keep the customers satisfied they try to minimize lead times. Since the lead time determines the available choices of transport modes, PTD have limited influence to affect the emissions caused by these transports even though they are responsible for them. There are also contradicting targets within the organization; for example the target of emissions reduction, versus the target for cost savings and target for delivery times. One example is shipments to Norway where it, for parcels with a weight below 5 kg, is the equal transport cost for air- and road freight. Today the goods are shipped by truck, but it was discussed to use air freight to improve customer satisfaction. Today, it is difficult to combine these types of targets and in the end it is always the cost reduction that is the most important.

ITBA faces several difficulties in the work with improving the environmental performance of freight transport. First and foremost; the products have a high value but a low weight which means that the transport cost is negligible compared to the product value. This means that even if air freight is much more expensive than road- or sea freight, it has no actual impact on the decision regarding transport mode. Second; the cost for air freight from Europe to Asia is relatively cheap, due to the much higher volumes transported in the opposite direction further reducing the cost impact for ITBA. Third; for urgent shipments, air freight is often the only alternative. In the year 2010 the business really picked up again after the economic downturn in 2008-2009. This meant higher pressure on the supply chain to meet the increased demand. The result was more urgent backorders and more air freight was used, especially when shipping products directly from the production site to customers, so called drop-shipments.

ANALYSIS

To analyze what will happen with the emissions from freight transport until 2020 and what ITBA must do to reach their reduction target; four different scenarios are created. The CO_2 emissions from each of the four scenarios are then simulated and the result is used when discussing suitable measures to lower the emissions.

THE SCENARIOS

When creating scenarios it is important to first outline the studied time frame. Since ITBA's internal reduction target is a 20% reduction compared to COS until 2020 with 2010 as a base year, this is the time frame used. The scenarios take place in 2020 and reflect possible futures with different characteristics that ITBA might have to adapt to.

Factors of impact

The results from the interviews are used to identify a number of factors that have a direct impact on the CO_2 emissions from freight transport. Modal split, supply chain structure, sales distribution and technological development are taken into account when creating the scenarios. The first factor studied is *modal split,* i.e. which transport modes that are used and to what extent. This is one of the factors with greatest impact, this because of the significant difference between the emission factors for air-, sea- and road freight. Air freight is almost ten times more polluting than road freight and even small volumes that are transported long distances with air freight makes a huge impact on the total emissions. *Supply chain structure* has a great impact on the distances in the supply chain. Both a centralized and a decentralized supply chain structure may reduce distances in one end but increase them in the other. Should the production be located near the suppliers or near the customers? Or is there a way of having it all? Supplier locations, production locations and customer locations all determine the locations of warehouses and DC's. The location and number of warehouses and DC's affect in turn the distances and lead times between the different links in the supply chain. The estimate of a sales distribution according to 30-30-30 in 2020 makes it interesting to look at the current supply chain structure and see how the new sales distribution affects the emissions. *Technology development* has an impact on vehicle efficiency and hence on how much lower the emissions from different transport modes will be. Since the study do not include how or when any technological changes or improvements take place an estimate of how much the emission factors will decrease to 2020 is used. The average reduction is set to 20% and is based on data from NTM (2010) and Åkerman and Höjer (2006). When creating the scenarios the factors of impact are changed in different ways and by doing this; four different pictures of the future are obtained. Each scenario represents a possible future with unique characteristics and could be seen as a story about the period from now until 2020 that resulted in the specific situation.

Scenario 1 – *Happy where we are*

The business has developed quite well for ITBA and the weight/COS ratio has increased by 5% since 2010. The growth in the Asian market has not been as high as expected and customer location looks largely the same as it did in 2010. Europe is still the dominant market with almost 80% of the weight of sold goods. Severe cooperation difficulties have characterized the environmental work initiated by the United Nations and the European Union. Due to this, there has been no agreement upon new international legislation for CO_2 emissions and no environmental taxes have been implemented. Although, most major transport companies have partly renewed their fleets of vehicles and vessels which has contributed to slightly decrease the emissions from transport operations with an average of 20%. ITBA has had the same supply chain setup the last ten years, with major plants in Europe and a central distribution center in Belgium. The split between the modes of transport is still the same as it was in 2010.

Scenario 2 – *Environ… -what?*

During the last ten years the Asian market has grown rapidly and sales now represent one third of the weight delivered by ITBA. North- and South America is also going strong and is combined at an equivalent level. Despite this growth around the world, Europe has been a disappointment and is now equal to North America and Asia in terms of sales. In total, the global weight/COS ratio has increased by 5% since 2010. Even though these changes have led to a massive increase in intercontinental freight transport, almost exclusively by air, ITBA has taken a defensive position and the supply chain structure is the same as earlier. The main reason for this is that the fuel prices remains on a relatively low level and no environmental taxes have yet been implemented. The only positive environmental development during the time period has been a small technical development which has contributed to slightly lower emissions from vehicles and vessels.

Scenario 3 – *Two new and one grew*

Just like in scenario 2, the geographic change during the last ten years has been extreme. Europe and Africa, North- and South America, and Asia all represent one third of the total market. The total global weight/COS ratio has increased by 5% since 2010. Due to significantly higher fuel prices, carbon taxes, and legislation, ITBA decided in 2012 to implement two new distribution centers, one in China and one in India, fully operating from 2015. Even the use of the already existing distribution centre in Charlotte, North Carolina is expanded. All four DC's supply their own continent, except for PTD (Belgium) which also supply Africa. ITBA has accepted longer lead times and the outgoing freight from the factories that was earlier transported by lorries is now transported by boat. The outgoing air freight from the distribution centers has due to this decision decreased from the earlier 100% (for intercontinental outbound freight) to 70%; the other 30% is transported by road freight. For the Asian market, DC China supplies 70% of the market and DC India 30%.

Scenario 4 – *Environmental frenzy*

Just like scenario 3, economic development and geographical changes has characterized the last ten years for ITBA. Although, to mitigate the company's environmental impact has been a main focus. Therefore, ITBA started to use three new distribution centers, DC China, DC India and DC Charlotte as early as in 2013. The positive effect this change had for the CO_2 emissions inspired ITBA to go even further, and in 2017 even the production units where moved into new locations; each site located as close to the distribution center it supplies as possible. At the same time and for the same reason, ITBA changed their supplier base. This change, combined contributed to decrease the distance to the distribution centers to an average of 150 km. Even though the main reason to move the production units and change sub suppliers was to further reduce the CO_2 emissions, it also contributed to reduce the lead times. The technical improvements have reduced the CO_2 emissions per tonne-km with approximately 20%. A summary of the four scenarios is presented in *table 4*.

Factor of impact	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Customer Location	As Today	30-30-30	30-30-30	30-30-30
New DC's	No	No	Yes	Yes
Relocation of Prod. Sites	No	No	No	Yes
Average Tech. Development	-20%	-20%	-20%	-20%
Economic Development/COS	+5%	+5%	+5%	+5%

Table 4: Summary of the characteristics of the scenarios

OUTCOME OF THE SCENARIOS

In the first scenario there has been a steady positive development of the overall business but the markets in North America and Asia has been a disappointment. The same sales distribution and same supply chain setup leads to a development of the emissions that are only dependent on the total amount of shipped goods (i.e. total sales) and the technology development. As seen in *Chart 4*, the total emissions in relation to COS decrease somewhat until 2020 but ITBA does not reach their target of a reduction with 20% of the levels 2010.

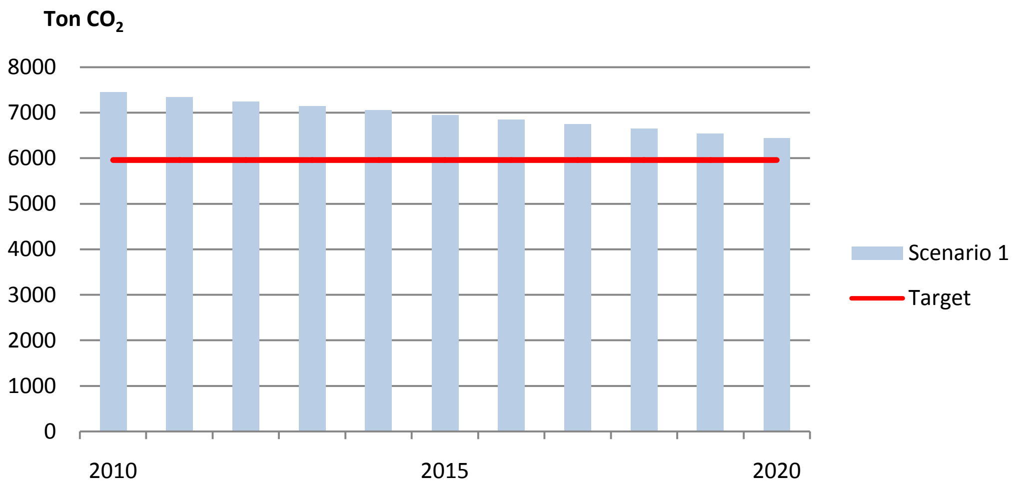


Chart 4: Total CO_2 emissions 2010-2020, scenario 1

In the second scenario we use the same set up as in the first scenario but change the customer base according to the internal estimate of 30-30-30 in 2020. The result is more customers on longer distances and with the same supply chain setup, where everything is shipped by air freight outside of Europe, this means a heavily increase of the emissions. Since the new customer base is based on ITBA's internal projection for 2020, this is a good picture of the development of the emissions if nothing is done about the supply chain structure.

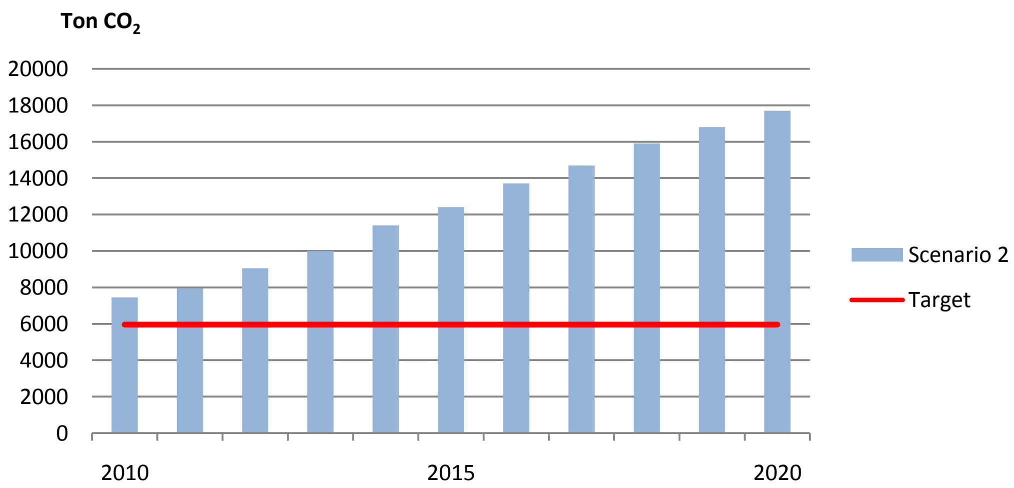


Chart 5: Total CO_2 emissions 2010-2020, scenario 2

In the third scenario the supply chain structure is changed and the implementation of four DC's from 2015 is included. Sea freight is used for all transports between production sites and DC's, this makes a major impact on the total emissions. The drop of emissions is a clear signal of how significant the share of air freight is in the system today; even a small reduction of air freight would give a major reduction of the emissions.

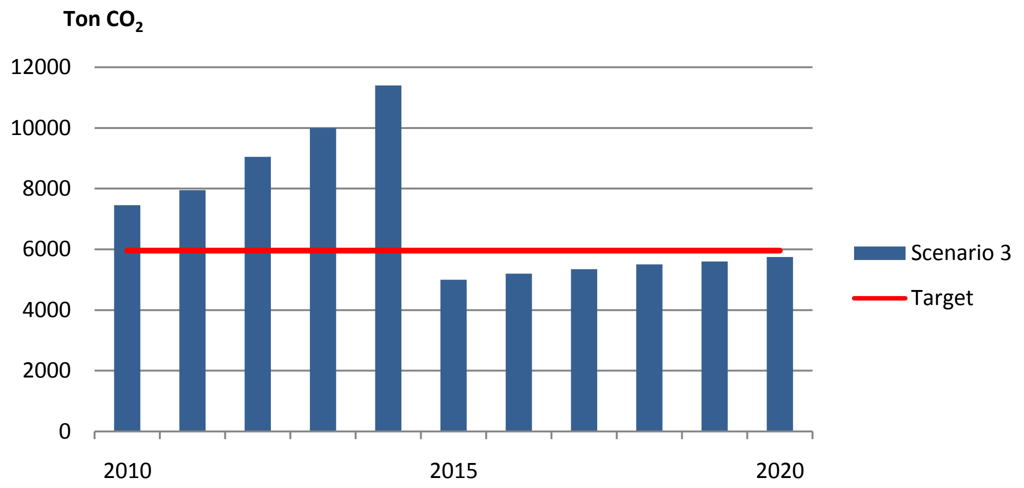


Chart 6: Total CO_2 emissions 2010-2020, scenario 3

The forth scenario is an extension of the third – The offensive way. The weight distribution is one third in South- and North America, one third in Europe and one third in Asia. The implementation of four DC's takes place as early as in 2013. In 2017 all production sites and sub suppliers are relocated to areas closer to the distribution center they supply with an average distance of 150 km. As seen in the figure the implementation of new DC's has the largest impact. However, the lower level of emitted CO_2 for the outbound flow results in greater importance for the inbound flow and the relocation of the factories and sub suppliers do indeed contribute to lower the emissions to quite some extent. In this scenario, ITBA manages to lower their emissions with over 30% and reach their reduction target with margin.

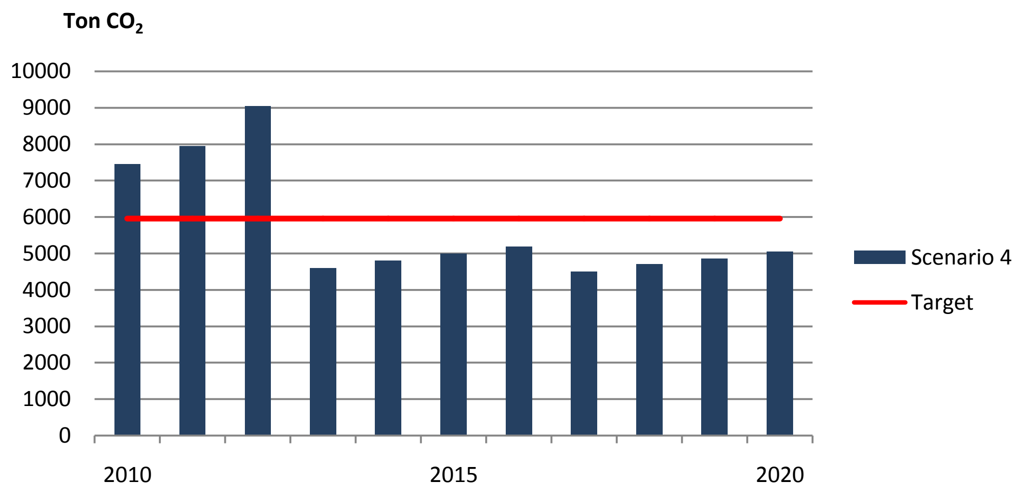


Chart 7: Total CO_2 emissions 2010-2020, scenario 4

The simulation clearly shows that ITBA must act in order to reach their reduction target of 20% by 2020 in relation to COS compared to the level of 2010. Without any action ITBA misses their target even if they do not expand.

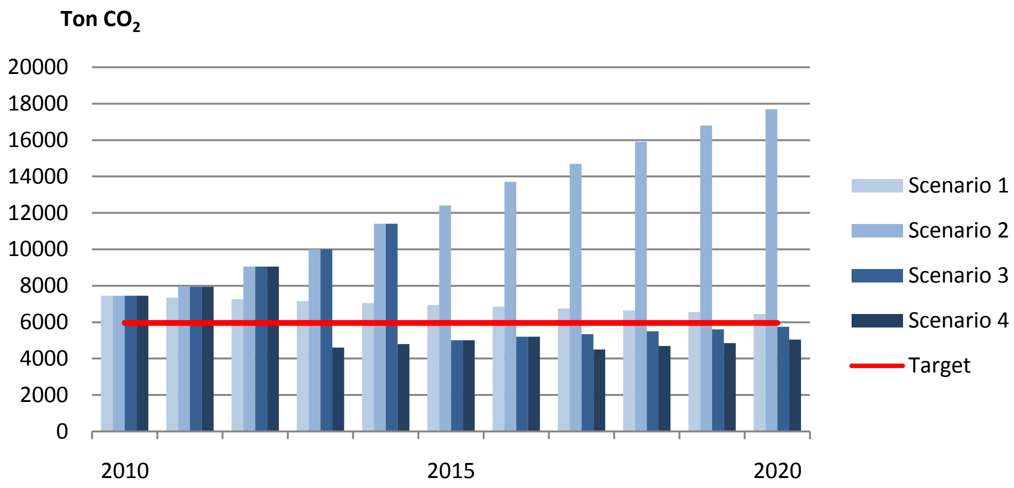


Chart 8: Total CO_2 emissions 2010-2020, summary

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Ton CO_2 in 2010	7450	7450	7450	7450
Target for Ton CO_2 in 2020	5950	5950	5950	5950
Ton CO_2 in 2020	6450	17700	5750	5050
CO_2 in 2020 compared to 2010	**87%**	**238%**	**77%**	**68%**

Table 5: Quantitative outcome of the scenarios

UNCERTAINTIES ABOUT THE QUANTITATIVE RESULTS

It is important to know that these scenarios do not present any valid figures or accurate predictions; the purpose is rather to show the driving factors behind the emissions. All weight data comes from ITBA and has not been critically reviewed by the authors to any extent. If these figures prove to be much too high in some regions or too low in others, the result might very well differ considerably. The distances used to calculate the emissions in the model are in most cases the shortest route, this is not realistic. Large forwarders normally send the goods via different transport hubs in order to get higher load factors; this might be advantageous from an environmental perspective but makes the calculations wrong none the less. To obtain a general, correct emission factor is impossible. A half full vehicle does not consume half the fuel compared to a full, the consumption depends on speed, landscape, fuel quality etc. The emission factors used in the model are taken from NTM – an organization known for their knowledge in this area and with international reputation, but the figures can still never be seen as anything but rough estimation.

DISCUSSION

With a starting point in the results from the case study and the outcome of the analysis, possible measures to lower the emissions are discussed in this chapter. On the basis of the scenarios, a number of factors impacting the emissions from freight transport where identified. The factors where then analyzed and the simulation model clearly showed the factors with greatest impact on the emissions. These are now combined and form the ground work for our conclusions.

SUPPLY CHAIN STRUCTURE

As seen when simulating the scenarios, the number and the location of distribution centers in relation to the customer base play a significant role for the total emissions in the end. Today, with almost 80% of the total outbound volume shipped to customers in Europe, a single distribution center in the middle of Europe is probably the best option. But if the customer base changes it is obviously not the best setup, as seen when simulating the second scenario. More customers at longer distances from the DC supplied with air freight means a heavily increase of the emissions. With a more decentralized customer base, a decentralized supply chain structure is the best option to reduce the emissions. To decentralize, and implement regional DC's with regional inventory is one way of shortening the distances to customers. The benefit of this setup is of course dependant on the use of more environmentally friendly transport modes for the inbound process and once again it is the share of air freight in the transport system that determines the overall environmental performance.

To decentralize even the production sites is the next step in the work towards lower emissions. This step is more sensitive since it might affect product quality, intellectual property rights and the direct control of the production. As seen in the simulation, decentralized production facilities has a positive effect on the emissions but not as much as decentralized DC's. Implementation of new DC's and opening of new production facilities are long term investments and need to be a deeply rooted business decision. It is associated with big investments and a risk of higher costs in the transition period. All timings and parameters in the supply chain needs to be changed and adjusted to fit the new setup and this might take some time to get in place. It has a financial impact on the business as well, since longer lead times and higher inventory means more capital employed.

MODAL SPLIT

When studying the emission factors it is clear that different transport modes are more or less polluting. This makes the decision of transport mode one of the most important when trying to reduce the emissions from freight transport. In terms of CO_2 emissions, air freight is about 30 times more polluting than sea freight and 10 times more polluting than road freight. This means that even a small amount of air freight will heavily affect the total emissions in a negative way. Today most of the inbound volume is transported within or between different European countries, hence road freight is used. The goods from other parts of the world are mainly transported on sea and to a lesser extent air. Environmentally wise, the inbound process is minor compared to outbound and accounts for only 30% of the total emissions, despite the fact that inbound and outbound volumes are almost equal, see *appendix 2*. The outbound flow from PTD to customers represents over 70% of the total emissions, even though almost 80% of the weight is delivered to customers within Europe, see *appendix 3*. The goods delivered to customers within Europe are mainly transported by road freight; only 5% of the goods are delivered by air freight. The reason for the high share for the outbound flow is the 20% sent to customers outside Europe; these goods are exclusively flown and represent over 90% of the emissions from the outbound flow. This shows that the total emissions from ITBA's freight transports are almost exclusively driven by the share of air freight. The reasons for using solely air freight for intercontinental transports are clear; air freight is much faster for long distance transportation and the cost is almost negligible since the goods consist of expensive, relatively light products. However, air freight is used even for transports within Europe for backorders and the modal split is therefore dependent not only on customer location, but also on the work load at the production sites.

SELECTING AND EVALUATING FORWARDERS

One important factor in the work towards lower emissions is the selection and evaluation of the used forwarders. Since ITBA only uses external forwarders for transports, it is vital that also these companies work with similar reduction targets and the same strive to make the transport chain greener as the buying company. The forwarding companies have control of the whole transportation chain and they are responsible of renewing fleets, improving load factor, haul planning and driving techniques. ITBA can use their customer power when negotiating with forwarders and clearly state that a number of basic environmental measures are required. ITBA can also implement an internal policy that states which forwarders that have an acceptable environmental policy and ITBA could cooperate with. Today the forwarders are evaluated in terms of environmental performance, but it has a minor impact compared to traditional factors such as cost and service quality. To pressure the forwarders to become more environmentally friendly, the environmental performance must be used as a more important evaluation parameter and even buying criteria.

MEASURE AND REPORT THE EMISSIONS IN A UNIFORM WAY

The first step towards lower emissions from freight transport is to measure and report the emissions in an accurate and standardized way. When today's emissions are known, a reduction target can be set and the work towards that initiated. The aim must be to get the CO_2 data directly from the forwarders since they have all the necessary information about vehicles used, distances and load factor. When it comes to providing data, it is in most cases a question of what is included in the contract. It is essential for ITBA to be clear and unanimous when negotiating these issues with the forwarders. Regardless of if the negotiation takes place in Sweden, Belgium or France, a requirement or claim to get the CO_2 data directly from the forwarder should be included in the transport contracts.

Since 2010 is set to be the base year used for accounting emissions, the methods used in 2010 is in most cases still used. Some units within ITBA experience problems in the way of measuring the emissions, since it causes difficulties to compare different years. This is a problem when updating and improving the methods used for calculating the emissions. A central system that is easy to update with new information and that recalculates previous years would mean that improvements more easily could be implemented.

MONITORING PERFORMANCE

Today ITBA reports emissions from freight transports in absolute figures and in relation to COS. This is also the only figures used to evaluate the environmental performance from year to year. This is a problem when the results of improvements and environmental initiatives disappear in this consolidated top level data. One way of evaluating environmental performance over time is to create a scorecard with a number of different KPI's and monitor these closely. One of the most frequently used KPI's for tracking emissions from freight transport is CO_2 per tonne-km, which more correctly describes the environmental performance of the complete supply chain. Other possible KPI's could be CO_2 per tonne shipped goods, total share of air freight or number of forwarders with an acceptable environmental policy. The KPI's should be interlinked to yearly targets for employees working with decisions regarding freight transport and good results should be rewarded. The reason for measuring and reporting emissions is to be able to see trends and to find ways of reducing the emissions. The organization must therefore be able to see that operational changes get reflected in the CO_2 statistics from one year to another. Otherwise environmental initiatives and successful improvements may remain invisible in the consolidated statistics. This could lead to a drastic reduction of motivation, especially within top management, and counteract any environmental actions initiated by SHE management.

BUSINESS CULTURE

No one fully owns the question of environmental issues. In a sense it is everyone's responsibility, but this often result in that it becomes no one's responsibility. When shipping goods to customers it is the CC in the particular country that has the direct contact and makes the agreements on the delivery terms. This affects the delivery time and in the end determines the transport mode used for the transport. Today the current policy is that customers should have the products the day after placing the order so on longer distances, i.e. outside Europe, this means air freight. This policy has been used as a selling argument in the external communication, which means that customers expect to have the products shortly after ordering. Today the customer has no possibility to influence or choose delivery time, so this becomes a question of how ITBA wants to promote themselves. Should the focus be on speed or on environmentally friendly options? One possibility to communicate both could be to give the customer an option to choose between different delivery times and at the same time state the emissions originating from that particular transport on the invoice. This could be a nice way of communicating that ITBA is taking the environmental issues seriously, but at the same time understands the customers need for speed.

CONCLUSIONS AND FURTHER RESEARCH

This report is a contribution to previous research by explaining how organizations better can understand the driving factors behind their CO_2 emissions. By simulating the transport flows, much information can be obtained which can help organizations significantly to understand how they can lower their environmental impact as well as anticipate how effective different measures might be. In this chapter the conclusions are summarized and suggestions for further research presented.

CONCLUSIONS

The strongest driving factor impacting the CO_2 emissions is the modal split. Air freight emissions per kilometer are almost ten times as high as the emissions from road freight and over thirty times as high as the emissions from sea freight. This means that if 10% of the total weight goes from air freight to sea freight, the emissions may decrease with 9.7% or even more depending on how much longer the sea distance is. ITBA today exclusively use air freight for intercontinental outbound transports. If all this goods was sent by sea- and road freight instead, the emitted CO_2 would decrease with over 70%. ITBA is a much decentralized organization and the method for measuring the CO_2 emissions looks different at different sites. PTD, who are responsible for the largest share of emissions, measures the emissions in absolute numbers, per tonne-km and in relation to COS which is the KPI used in the emission reports. At smaller sites the emissions are only reported in absolute numbers and in relation to COS. To have the emissions in relation to COS as the standard KPI is not optimal. COS is a confidential financial post which makes it hard to predict and evaluate the performance both for internal and external stakeholders. Since COS does not have anything to do with the transports, it is also hard to track or interpret changes in the KPI; an decrease in emissions compared to COS could very well be a result of more environmental transportation, but it could at the same time just be a result of higher costs. A better KPI would be to look at CO_2/tonne-km, a standard KPI in many organizations. This would make tracking improvements or deteriorations significantly easier as well as benchmarking with other organizations.

At PTD, the reported data is based on an internal model similar to the one used for creating the four business scenarios, even though most forwarders provide more detailed data. The reason for this is fear of inconsistency. Not using the data considered to be most accurate is of course not desirable and at some point this must change. At that point, PTD should probably use both methods for some time in order to facilitate the transition. At some smaller sites the calculations are made by a staff member, at some the figures are delivered directly by the forwarders. ITBA has a policy for how the measurements should be performed, but this has obviously not been noted or followed throughout the organization. In order to unify the reporting, ITBA must make sure that the affected staff is familiar with the reporting guidelines and that they are comfortable using them.

As seen in the analysis of the scenarios, there is no easy way for ITBA to lower their emissions enough to reach their target; hard work and dedication is needed. What ITBA must do is to reduce the amount of air freight. Depending on to what extent the organization manages to do that, other actions will be more or less necessary. New DC's might have to be implemented, and even production sites might have to be relocated to new facilities, closer to the DC they support. Using local sub suppliers also contributes to lower the emissions. Apart from this, ITBA can lower their CO_2 emissions by selecting forwarders with clear environmental focus, give customers incentive to choose sea- and/or road freight and collaborate with forwarders and other organizations with similar aims. A target should be ambitious but achievable in order in order to have meaning. ITBA's target of a 20% reduction in relation to COS compared to the levels of 2010 is exactly this and is therefore a good target. What ITBA could do is to specify the target as well e.g. set a target for the maximum share of air freight in one year and stipulate a target for the forwarders environmental performance and reporting.

FURTHER RESEARCH

Even though this report can help many different organizations to better understand the driving factors behind CO_2 emissions, it has only been applied on ITBA. If similar studies are performed in other organizations, one might be able to see patterns and draw more general conclusions. This could help governmental- as well as company decision makers to take better environmental actions and address means where they help most.

This report does not provide any substantial economic analysis for the different actions. Uncertainty of future fuel prices and the further implementation of emission reduction certificates make the economic analysis more complex and increase the need for such studies in order to make any decisions. An implemented economic analysis in a model like the one used in this project, could constitute a powerful tool for many organizations.

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Koyen, G. (2011, February 22). General Manager, PTD. (P. Jofred, & P. Öster, Interviewers)

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Poncelet, P. (2011, February 2). Vice President Logistics, Tooltec Division. (P. Jofred, & P. Öster, Interviewers)

Sourbron, P. (2011, February 22). Transport Coordinator, PTD. (P. Jofred, & P. Öster, Interviewers)

Spaak, T. (2011, February 18). Purchaser, Atlas Copco Tools. (P. Jofred, & P. Öster, Interviewers)

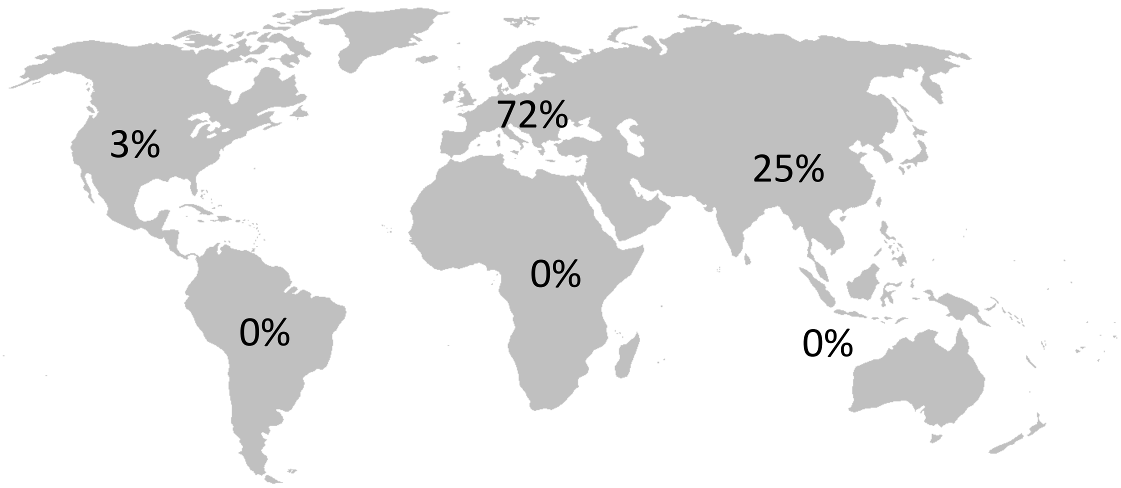
Swahn, M. (2011, March 11). Nätverket för Transporter och Miljö. (P. Jofred, & P. Öster, Interviewers)

APPENDIX

Appendix 1. List of respondents

Name	Title	Business Unit / Organization
Alida Boelen	Process Support Manager	PTD
Anna Gejke	SHE manager (Safety, Health & Environment)	ITBA
Gunter Koyen	General Manager	PTD
Staffan Laestadius	Professor of Industrial Dynamics	Royal Institute of Technology
Thorvald Lindström	Quality & Environmental Manager	AC Tools Tierpsverken
Per Malmborg	Inventory Controller	Atlas Copco Tools
Anna Nepala	Finance Controller	CSW
Jean-Pierre Nerriere	Quality & Environmental Manager	CP Technocenter
Ulf Nylund	IMS Manager	Atlas Copco Tools
Patrick Poncelet	Vice President Logistics	Tooltec Divison
Frank Pauwels	Logistics Manager	PTD
Pieter Sourbron	Transport Coordinator	PTD
Torsten Spaak	Purchaser	Atlas Copco Tools
Magnus Swahn	Managing Director	NTM
Laszlo Vicsay	Quality & Environmental Manager	IT Hungary Kft.
Anna Wedar	Vice President Financial & Administration	Tooltec Division

Appendix 2. Inbound weight distribution by geographical area



Appendix 3. Outbound weight distribution by geographical area