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A model for mapping carbon dioxide emissions during freight transports at Höganas AB, Sweden

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Packaging Logistics
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Masoud Zanganeh Magnus Persson

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Sammanfattning

Titel: En modell för kartläggning av koldioxidutsläpp från godstransporter på Höganäs Sverige AB.

Rapportens syfte är att ta fram en modell som kartlägger och visar de totala koldioxidutsläppen som genereras genom godstransporter till och från Höganäs AB. Modellen som utvecklats ska kunna användas för framtida miljökalkyleringar samt även fungera som ett verktyg för att upptäcka nya sätt för miljöbesparingar.

Under arbetes gång har tyngdpunkten för utförandet av modellen varit att den ska vara enkel att använda, att användaren enkelt ska kunna uppdatera modellen med aktuella värden och att modellen ska ge en snabb översiktbild av relaterade utsläpp.

Valet av datorprogram för att skapa modellen i föll på Microsoft Excel då det är ett vanligt använt datorprogram som många behärskar och det krävs inte att ytterligare datorprogram ska installeras för att kunna använda modellen.

För att enkelt kunna uppdatera modellen har generella emissionsfaktorer framtagits för de olika transportslagen. Det får till följd att det kan uppkomma avvikelser för specifika transporter. Därför bör modellen främst ses som ett kalkyleringsverktyg för de totala utsläppen för företaget och inte ett verktyg för att beräkna enskilda transporter. För enstaka transporter bör data för aktuellt fordon användas för att få ett korrekt resultat.

Utifrån framtagen modell samt kalkyleringar framkommer det tydligt att den region som står för den största andelen koldioxid är Asien som står för cirka 62 % av de totala exportutsläppen.

De regionerna som har sjötransport som huvudsakliga transportmedel är de regionerna som har lägst utsläpp per tonkilometer. Men på grund av avstånden så är det samma regioner som har högst utsläpp per ton. Som ovan nämnt är det Asien som utgör den största regionen för utsläpp av koldioxidhalter, vilket innebär att transporter dit bör vara prioriterad vid diskussioner kring förbättringsalternativ gällande reduceringar av koldioxid.

Övriga upptäckter samt rekommendationer från denna studie ska främst delges som underlag för framtida riktlinjer. I enlighet med författarnas rekommendationer, skall framtagen modell och dess kalkyleringar främst användas inom:

- Miljöanalys vid nomineringar av rederier för kommande perioder
- Underlag vid granskning av nya logistiska lösningar
- Underlag för intern/ extern emissionsutvärderingar
- Användas i marknadsföringssyften

För att bibehålla modellens användbarhet krävs regelbunden uppdatering av dess databas för att kunna återge sanningsenliga emissionsvärden. Författarna rekommenderar att uppdateringar bör ske i samband med företagets nomineringsperioder då sannolikhet för ändringar i distributionsnätet är som störst.

Abstract

Title: A model for mapping carbon dioxide emissions during freight transports at Höganäs AB, Sweden.

The purpose of this report is to develop a model that identifies and reveals the total carbon dioxide emissions generated throughout in- and outbound freight transport made by Höganäs Sweden. The developed model is to be used for future environmental calculations and also act as a tool for discovering new areas of environmental improvements.

During the developing process of the model a key issue was to maintain simplicity and user friendliness with the user being able to easily update the model with current values and give a quick overview of related emissions.

The choice of computer software to create the model in landed upon Microsoft Excel as it is commonly used computer software which is well known and has no need to install additional software in order to use the model.

Being able to easily update the model, general emission factors has been used for the different modes of transport. A consequence in this matter is the probability for occurring deviations when measuring specific transports. Therefore, the model should primarily be viewed as a calculation tool for total emission values by the company and not a tool for calculating emissions on individual levels. For single freight transports, specific vehicle type data should be utilized in order to get accurate results.

Based upon model calculations it can clearly be seen that the region accounting for the largest share of CO_2 emissions is Asia, which accounts for approximately 62% of the total emissions that is released during distribution.

The regions which utilize transport by sea as a main mean of transport are those with the lowest emission values per ton-km. Due to the distances, it is these regions that also stand for the highest emission values per ton. As stated above, the region that represents the largest source of carbon dioxide emissions is Asia. Therefore, it is concluded that this region should be prioritized in any discussions around improvement possibilities regarding reductions in greenhouse gas emissions.

Other findings and recommendations from this study will primarily serve as a basis for future guidelines. In coherence with author recommendations, the developed model and its calculations should primarily be used and adapted in areas such as:

- Environmental analysis of freight forwarder selections during nomination periods
- Baseline during evaluation of new logistical solutions
- Underlying documentation during internal / external emission evaluations
- For use in promotional purposes

Please note that in order to maintain the model’s usefulness, the system need to be updated at regular basis to maintain the production of true emission values. The authors recommend that these updates should occur during the company´s nomination periods, where the probability of changes is at greatest within the distribution network.

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Introduction

During this introducing chapter the authors intend to give the reader an insight and understanding regarding the thesis background, problem statement, purpose and delimitations.

Background

Global warming is a crucial environmental issue for the earth and its population. The increasing temperatures due to global warming have had a deep impact upon earth. The polar ice and the glaciers are melting and the water level is continuously rising.[1] Global warming is a result of higher concentrations of the so called greenhouse gases. If you exclude water vapor, the gases that affect the earth most are carbon dioxide, methane, nitrous oxide and ozone, where carbon dioxide stands for the majority. The increased levels of carbon dioxide in the atmosphere are mainly due to the burning of fossil fuels for energy extraction.[2]

Due to these climate changes, governmental legislations have been implemented regarding global emission reductions as a precaution for the upcoming future. The first international agreement to reduce greenhouse gases is known as the Kyoto protocol. The protocol came into initiation on the 16th February in 2005 in agreement with the UN and its members. These membership countries have agreed to reduce their annual global emissions from greenhouse gases by at least 5 percent below the levels from the year 1990 during the commitment period between the years 2008-2012[3]

The initiation of the Kyoto protocol has led to extensive attention in forms of research within the field of CO_2 emissions. This regards not only releases during manufacturing but also emissions occurring during transportation. Along with the intensified focus on Greenhouse gas emissions, companies around the globe are becoming more environmentally aware and have begun reviewing their traditional manufacturing and distribution methods, trying to adapt for the future.[4]
Another decisive force that has come to matter from these regulations is the general interest and demands from customers and shareholders. Companies have learnt that green management theory not only can lead to eco-friendly solutions but also can be applied as a long-term source of income leading up to competitive edges against market competitors.[5]

There are numerous ways and sections where one can commence evaluation and reductions of emission values, but the interest in reviewing a company's carbon footprint regarding distribution is a relatively new term and there are only few existing guidelines supporting companies in this matter.[6] The situation has become even more complex in comparison to the traditional organization structure since larger companies tend to outsource their distribution system to various freight forwarders[7]. To gain further insight in these matters, various studies are made within green logistic theories.

[1] United Nations <www.un.org> 2011-03-04
[2] Swedish Environmental Protection Agency <www.naturvardsverket.se> 2011-03-04
[3] UNFCCC (1998)
[4] McKinnon (1994)
[5] Lumsden (2007)
[6] Browne, M. Cullinane, S. McKinnon, A & Whiteing, A. (2010)
[7] Blinge (2005)

Problem discussion

With the constantly increasing demand on law regulations regarding carbon dioxide emissions, companies are making continuous efforts of reducing its carbon footprint, which is stated by the initiation of this thesis.

The issues stated in this thesis are to map the in- and outbound transport logistics as an origin of trying to find solutions regarding the reductions of carbon dioxide emissions. Being able to fully understand this problem, there is a need to gather knowledge of the origins of CO_2 emissions. This includes a company´s physical logistic flow as well as various elements that together determine the emission magnitude. This type of information is hard to come by and is lacking within the stated company at this moment.

Therefore, to get an overview of the emissions and how reductions can be achieved at Höganäs Sweden AB, a thorough examination and mapping of the logistics network is needed to be performed so that understanding of potential improvement areas can be uncovered. This will be presented in a model which will help Höganäs Sweden AB to get a quick overview of the emissions and where these occur, where they are generated and being able to gather information needed to reduce resulting emission values.

As a result of the discussion above, the problem statement can be described as follows:

A. Develop a model on how to efficiently calculate in- and outbound freight transport emissions, which include:
    - Methods and tools needed for creating an emission model.
    - Collect accurate emission data from suppliers.
    - Make correct assumptions of the transportation flow where data is insufficient in order to achieve an acceptable emission model.

B. Discover future improvement potentials regarding carbon dioxide emissions, with the help of the previous statement findings.

Purpose and objective

The overall purpose of this thesis is to present a model that can be applied as an everyday tool that calculates the total emissions caused by freight transports throughout the Höganäs Group. By focusing on the company’s freight transport activities, the study can provide answers to the following questions:

- How big of an impact does freight transport related CO_2 emission values have during one year at Höganas AB, Sweden?
- Does the model calculate accurate CO_2 values? How large can the deviations be?
- Which variables are needed to be able to calculate the emissions and which delimitations are to be made?
- How can routes regarding freight transportation be adjusted in order to decrease CO_2 emissions?

Focus and delimitations

Carbon dioxide is considered to be the largest contributor to the greenhouse effect and directly related to transport fuel consumptions and therefore is the most prioritised subject in this thesis.

Due to time limits and the complex structure and magnitude of the supply chain network the study will be focused and limited as follows:

A. The supply chain studied and investigated is limited to Höganäs Sweden. Further research and penetration of the supply chain states that information and data from sub-suppliers become harder to gather and less accurate, and therefore potentially has the chance of diminish the credence of the study. Meaning per say that limitations are to be made as follows:

   - Inbound logistic supply chain: last processing point of supplies and raw materials from suppliers that is shipped to Höganäs Sweden.
   - Outbound logistic supply chain [Europe]: Internal- and external transports of finished products from Höganäs Sweden to the final customer unloading dock destination
   - Outbound logistic supply chain [Outside Europe]: Transports of finished products from Höganäs Sweden to primary destinations outside of Europe such as harbours or in certain cases airfields.

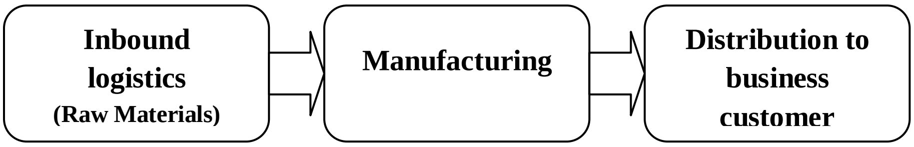

Figure 1: Process map, in/-outbound logistics

B. Average emission values will be used for the different transport types to be able to calculate the total emission without knowing the specific vehicle, train or aircraft used in order to achieve the simplicity needed for the model.
C. Using average emission values can lead to deviations for specific transports. Therefore, the model should not be used as a calculation tool for specific freight transports.
D. The average emission values are based on Höganäs Sweden ABs freight transports and cannot be used by other companies with promise of accurate results.
E. Transport volumes included in the emission calculation are restricted to 1 ton and upwards, i.e. volumes less than stated are not to be used due to the insignificant impact regarding emission totals.

For further reliability and increasing of reality affiliation, data gathered during 2010 are to be used as baseline.

Target group

The main targets of this thesis are the employees of the logistics supply management division at the Höganäs Group concern. Other target groups are mainly researchers and students within the area of logistics, and the general party interests of the public.

Abbreviations

Frequently used abbreviations in this thesis are defined as follows:

CO_2 Carbon dioxide
SO_2 Sulfur dioxide
NO_X Nitric oxides
HSAB Höganäs Sweden AB
GHG Greenhouse gases
EU European Union
NTM Network for transport and Environment
HGV Heavy Freight Vehicle
ERP Enterprise resource planning

CCU Cargo capacity utilization

CEF Constant Emission Factors

VEF Variable Emission Factor

Höganäs Sweden AB – Company Presentation

This chapter provides the reader a brief overview of HSAB and a more detailed presentation of the company itself and its policies.

Company history & organization

As one of Sweden's oldest companies, Höganäs AB was established in 1797, consisting mainly upon coal mining operations. Over the years the company's product range has certainly varied a great deal but largely consisting of diverse coal and clay raw materials. Some eighty years ago a new era was created within the company where transformation and structural changes occurred when a whole new path of production was initiated. The underlying base for change consisted by predictions of great demands for raw materials within the alloyed steel industry. These discoveries shortly thereafter lead to the initiation of a new chain of product development.[8]

Today Höganäs is one of the leading producers of iron and metal powders world-wide for various metallurgical applications, producing nearly a half of million tons of powder annually. The company maintains just above 1600 employees divided throughout 15 different nations around the globe and reported 6.7 billion SEK in turnover for 2010.[9]

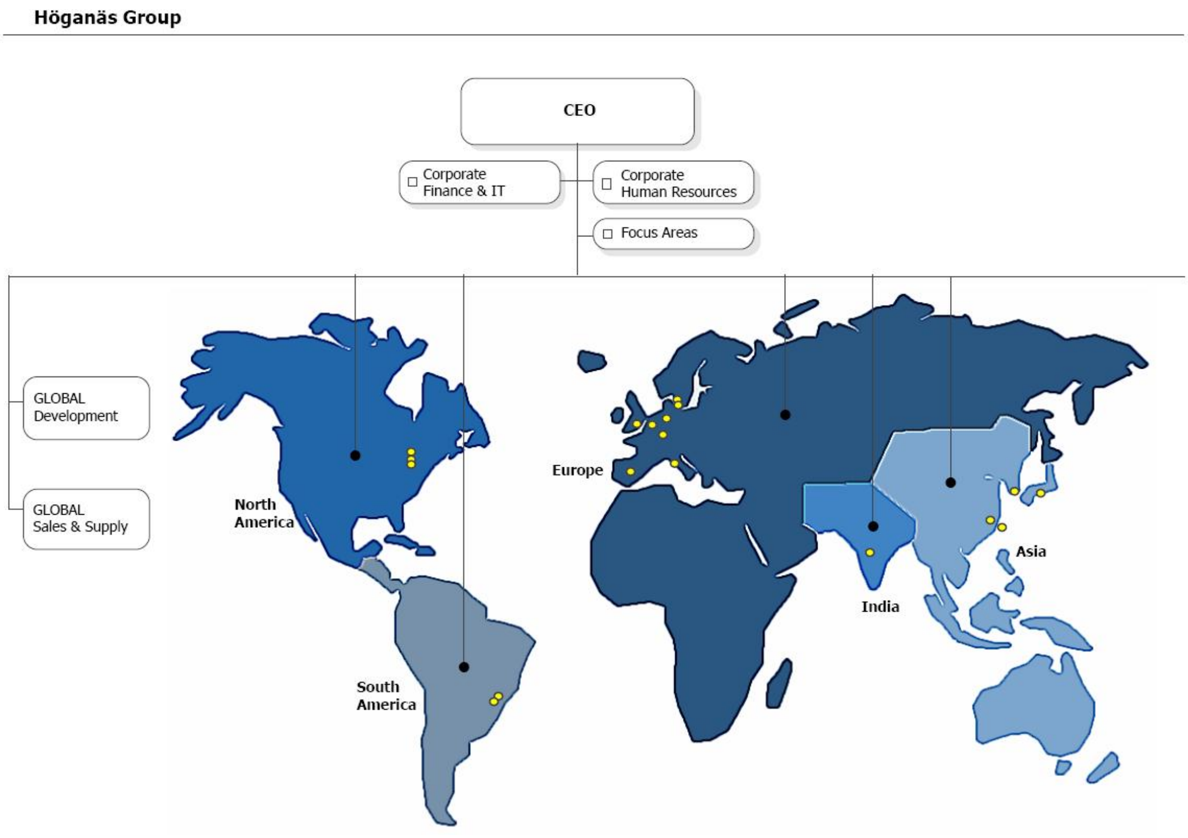

Figure 2: Organizational chart overview Höganäs AB[10]

[8] HSAB Intranet 2011-06-29
[9] Insight. Höganäs newsletter, 1st edition 2011
[10] HSAB Intranet 2011-06-29

Environmental policies

Acknowledging its heavy emissions during manufacturing and freight transportation, HSAB has taken considerable management responsibilities by implementing overriding environmental objectives for all Quality Management Systems concerning manufacturing within the Höganäs group.

Following general objectives are quoted from the company's environmental manifesto:[11]

- Höganäs aims to develop, maintain and implement environmentally sound production technologies.
- Establish within a Group Management system corporate environmental requirements and standards applicable for the Höganäs Group.
- Implement, certify and maintain an Environmental Management system based on the 14001 standard for all manufacturing units in the Höganäs Group.

Established target and actions plans (See Appendix 1 for complete table) corresponding to HSAB's general objectives have reduced the total manufacturing emissions significantly since the 1980's.

Emission class	Percentage decreased/ ton
CO_2	53%
SO_2	90%
NO_x	46%

Table 1: Emission reductions in manufacturing between1980-2010[12]

Even though measures are well under way regarding the manufacturing process as seen above, the same corresponding effort of freight transports is still yet to come. To fully understand and comprehend the magnitude of these emissions, a close mapping of transport activities has to be made and is to be presented as a part of the calculation model.

[11] HSAB Management responsibility manifesto 2009-01-01
[12] Insight. Höganäs newsletter, 1st edition 2011

Methodology

This chapter states which methods and approaches that are used to secure the purpose of this thesis in best possible way in order to achieve result credibility. This includes scientific approach, data collection and credibility discussions.

Scientific approach

A scientific approach states the approach which is used to reach a conclusion within a certain research area. The approach taken determines and describes the relation between theoretical and empirical framework of the study. The methods of choice are stated as follows.

Inductive, deductive and abductive approach

The inductive approach is a method of drawing theoretical conclusions based upon empirical data. Contrary to the inductive method, the deductive approach origins in hypothesis based on existing theories and models which through case studies later are molded into empirical conclusions and results.[13] The abductive approach can be stated as a junction between previous stated methods. Depending on person of view the method can origin in either of the stated methods, but instead of concluding one way to another it switches between the two approaches. Meaning that it is fully possible to move from theory to empirical and switching back to theory based conclusions and vice versa.

Method of choice

Due to the projects nature and regarding the authors' limited knowledge within the area of study before the thesis commencement, an abductive approach was the most suitable of methods mentioned above. The path of study taken was therefore commenced with a broad scanning of available theoretical framework within green logistics and process mapping. Information gathered from these studies where later used as frame for conducting the empirical study. For the final part of the study comparisons between theoretical and empirical parts were made and complementing, in theory where it was found necessary.

Data collection

Two types of data collecting approaches are to be addressed in this study. These are stated as primary and secondary types of data. Primary data is characterized by material collected throughout interviews, observations and surveys. Secondary data is primarily characterized as material obtained through already released material such as printed literature and articles[14]. A more thorough explanation of these methods is stated in the section of this chapter.

Primary data

Collection of primary data can be categorized by basically two different methods, quantitative and qualitative. A quantitative approach is concerned with collecting and analyzing data in numerical form, in the case of this study characterized by numerous types of structured interviews such as surveys or the utilization of mathematical models and theories. A qualitative approach on the other hand used to create a deeper knowledge within a certain field. These types of studies often consist of semi-/non structured interview approaches, participant observations during case studies or various document analyses.[15] The method where interviews are made in semi structured form consists of a

[13] Eriksson & Wiedersheim-Paul (1997)
[14] Ibid
[15] Bryman (1984)

questionnaire that is followed by its natural course, whilst a completely unstructured interview is more based upon a free flow dialog between the interviewers and its subject. These types of interviews gives the subject a more free approach to express his/her responses, granting a deeper understanding and relevance to the study but on the other hand can be very extensive and also time consuming to conclude.[16]

Secondary data

As explained above secondary data is characterized by different types of literature studies. These have the advantage of providing crucial information fast at a low cost and giving a hint of current knowledge within the chosen research area. Downsides such as lack of source information, usage of methods and purposes are some of the withdrawals that can occur with these types of studies.[17]

Method of choice

Striving to comprehend and develop a real life useable emission model the project began by obtaining various secondary data information such as publications regarding regular-/green logistics and process mapping journals. Secondary research was also applied when obtaining raw data needed regarding the emission model from HSAB's ERP systems. Being able to map and connect the dots from obtained data, various interviews and mail correspondents were conducted with concerned personnel from HSAB logistics division and representatives from the different freight forwarders.

Credibility discussion

Validity

Definition: *"The extent of measuring what one intends to measure"*[18]
The quality of any type of study depends greatly on how data and interview subjects are chosen according to the study's purpose. This ensures that right knowledge will come to use regarding the thesis topic. In this thesis, the validity is achieved through the model itself and how accurate its results and outcomes reflects upon real life emission values. The data gathered throughout this study were obtained in cooperation with individuals with great knowledge and expertise within the specific research area, thus insuring that the developed model was based upon correct assumptions and a solid foundation for current and future emission calculation. Further validity discussions will be addressed throughout the progress of this report.

Reliability

Definition: *"the consistency of one´s measurement (same outcome regardless of used instrument)"*[19]
The reliability of a study suggests that the results shown or concluded are obtained through right measurements and repeated measurements on the studied system (with similar methods and purpose) still would provide the same result.[20] To ensure that the model brought forward was correctly developed, all information gathered by the authors for this study was collected from what considered being reliable sources. Essential theories on process mapping, the benchmarking of models within similar research areas and interviews made were conducted in a sense that strengthened the reliability of the developed model. During this assessment some assumptions and utilizations of mean values were made where solid data could not be obtained. These matters together with further reliability discussions are made further down in this report.

[16] Björklund & Paulsson (2003)
[17] Ibid
[18] Ibid
[19] Ibid
[20] Arbnor & Bjerke (1994)

Theoretical framework

This chapter provides a basic overview of the theories and concepts underlying the study´s structure and discussions made in the subsequent chapters of the report.

Carbon footprint guidelines

Several guidelines are published from different organizations regarding carbon footprinting. These differ a bit in approaches but the main assumptions and methods are similar.[21]
The carbon footprint process can be broken down into five core steps (see

Figure 3).

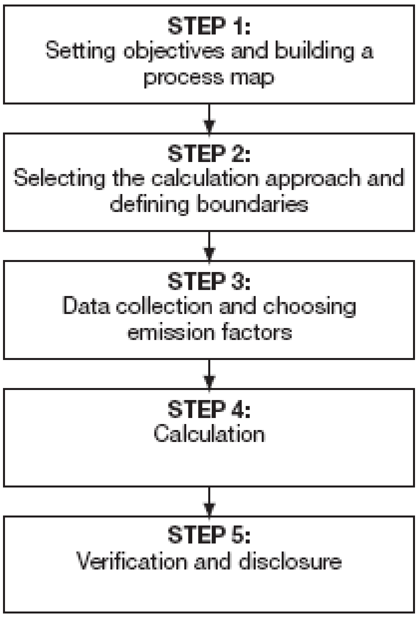

Figure 3: Steps for calculating the carbon footprint[22]

STEP 1: The construction of a process map should include factors that contribute to the carbon footprint. The magnitude and complexity of the process map depends greatly on what type of carbon footprint one attends to map. In this study in particular, focus will lie on in-/ outbound transporting logistics. Initially the process map should be created at a relatively high level and further defined during the calculation process.

STEP 2: During this stage, the extent of the calculations are to be defined. If the calculations regard a specific company or supply chain, the organizational boundaries should be taken into consideration as particularly important. After defining the boundaries, delimitations of the operational boundaries are to be made, grouping them into categories. Delimitations of this study are listed in introduction chapter of this report.

STEP 3: Next step includes collecting data needed for the carbon footprint calculation. It is wise to prepare a data collection plan to specify what information is needed and from whom the information can be extracted. When requesting data outside the organization e.g. freight forwarders, it can be useful to introduce and explain the projects nature and hopefully gaining their active support.

[21] Browne, M. Cullinane, S. McKinnon, A & Whiteing, A. (2010)
[22] The Carbon Trust (2006)

STEP 4: The emission calculation itself is in most cases a straightforward project. Even though sophisticated software can be used, the most common type of tools are basic spreadsheet packages like Microsoft excel and such. The various emission activities defined in the previous steps are in this stage converted into relevant equivalent CO_2 factors e.g. CO_2 per ton kilometers.

STEP 5: Before reporting final calculation findings, one should verify the carbon footprint estimates and confirm information such as accuracy and consistency. This minimizes the risk of errors in decision making based upon wrong judgments in the calculations. If the information gained is to be used internally a self-verification usually is sufficed. This is achieved by asking someone within the organization to independently check information gathered and calculations made in order to detect errors and missing data. If the information is intended for public view it is considered to be wise to implement verification from an independent third party member.

Before the deployment of carbon footprint theories and creation of calculation model can be achieved. One needs to understand the input variables and basic knowledge of logistic operations. Following sections in the report are therefore necessary in terms of insight and knowledge in order to make assessments regarding carbon footprints. The reader will gain insight in basic logistic terminology and operations and thereafter gain knowledge about the different that transport types and distribution systems that were used in the development of the calculation model. The chapter is concluded by some insight knowledge of environmental impact of logistic operations and current law regulations the authors encountered throughout the study

Logistics terminology & green logistics

Logistics can be described as operations such as transport, storage and handling of raw material from its origin to the point of where final sales or consumption is reached. Activities included in the process have for over 50 years been included as core determinants for business performances and fundamental to economic development for producers. It has emerged as an extensive field of study, in ways of both academic studies and professions with the prime purpose of structuring logistics as a way to achieve maximized profitability. The traditional way organizing logistics a mean to reduce economic costs has led to the neglect of other forces of impact such as social and environmental aspects – until recently. Over the past decade mankind's awareness and concern over environmental impacts has increased significantly. This has led to consumers placing higher demands on market suppliers and governments applying pressure on companies to reduce their logistics operations environmental impact, mainly throughout newly established law legislations.[23]

As the consumers gain more insight, the criterion selections become more complex and more extensive information is requested from suppliers. To simplify these exchanges of information, different types of standardized systems has been introduced. An example of such systems is the quality system ISO 9001. A variety of systems regarding the environmental perspective has also been developed. Apart from the different national systems, standardized certifications such as ISO 14000 series and EMAS (Echo-Management and Audit Scheme) etc. has been introduced for this purpose.[24]

In the field of environmental friendly logistics, an unambiguous and established standard definition of environmental logistics has not yet been established and terms such as resource efficient or green logistics does not exist. However breaking down the terms the definition basically means that the logistic structure of a company should be built and adapted in a way that utilizes current resources and technologies, narrowing down negative environmental impacts and usage of natural resources as much

[23] Browne, M. Cullinane, S. McKinnon, A & Whiteing, A. (2010)
[24] Lumsden (2007)

as possible. This could mean e.g. better vehicle utilization, managing ordering systems differently, inventory management, adapting eco-friendly driving techniques and utilizing new fuel technologies.[25]

Logistic network structure

All transportation can be seen, in a logistic network as a system built up by nodes and links and describes the physical flow of freight and resources. A node represents where the flow is stopped such as handling terminals, warehouses, or other points of processing. The links itself represent the flow of all types of freight transports.[26] A more detailed description of a transportation network discussed above can be seen in Figure 4.

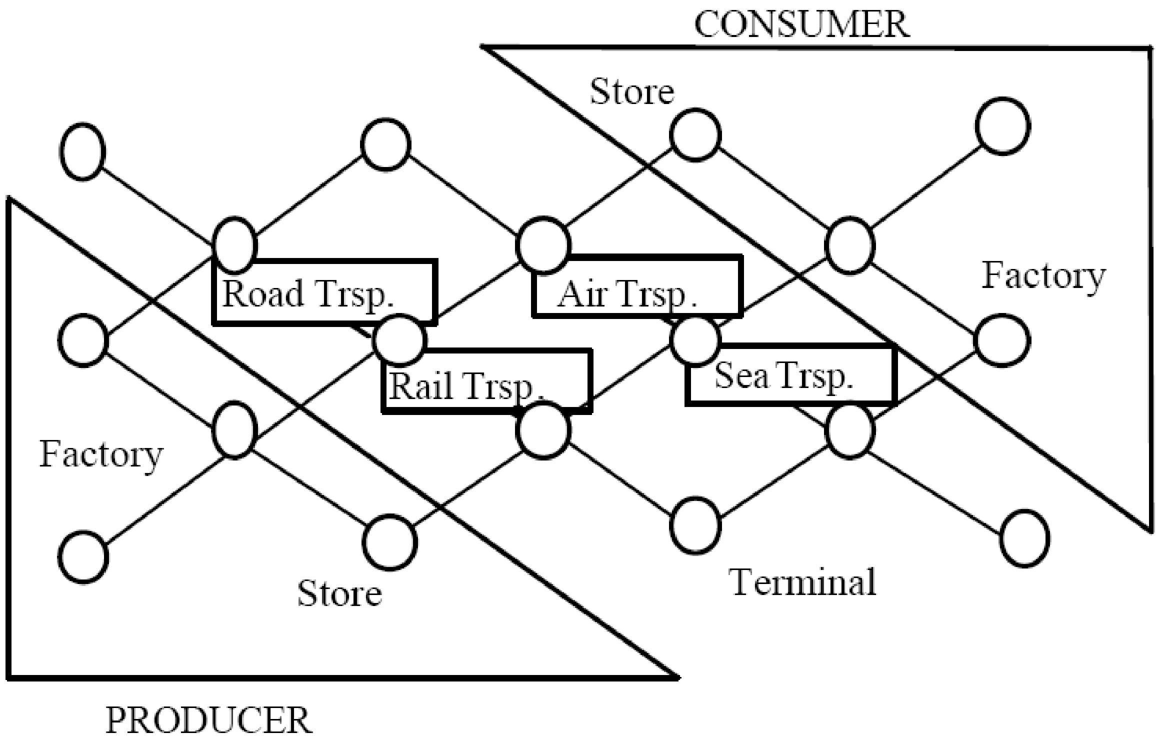

Figure 4: An example of a transportation within a logistic network[27]

The supply chain

A supply chain can be defined as follows: "a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together by the feed forward flow of materials and the feedback flow of information"[28] Different calculations and operations are to be considered when designing a supply chain. These can be roughly broken down into strategic, tactical and operational decisions. Strategic operations include the planning & mapping of serving facilities such as distribution centers and warehouses by number and locations. These are often based upon long term decisions. Tactical decisions however are based upon more short term planning (monthly, quarterly) and include activities such as selection of suppliers and transportation modes. The final stage and decisions made upon day-to-day basis are referred as operational and include activities such as scheduling and routing.[29]

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25 Blinge (2005)
26 Lumsden (2007)
27 Ibid
28 Stevens (1989)
29 Browne, M. Cullinane, S. McKinnon, A & Whiteing, A. (2010)

An illustration of a typical supply chain network can be seen in Figure 5.

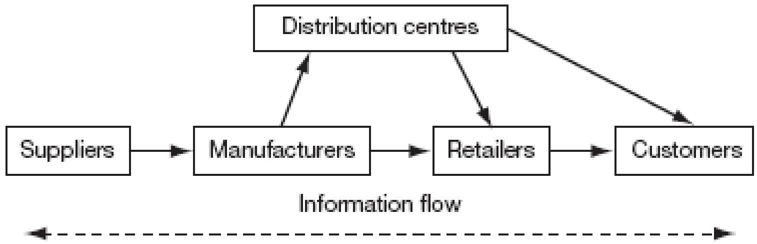

Figure 5: Illustration of a traditional supply chain[30]

Third party logistics

With the current competitive state on today´s market where several manufacturers tend to differ very little regarding product qualification, the means of how and when the product is delivered has become the most decisive factor when gaining competitive advantages. Therefore, most companies have chosen mainly to focus on production, meaning that management of logistic activities regarding transportation often are outsourced to a third party with extensive knowledge and experience within the area. This basically means that the third party actor obtains the responsibility of the logistic chains between supplier and customer.[31]

Figure 6: Description Third party logistics

Transport modes

The different modes of freight transports can be broken down into four different categories: Road, sea, rail and air. Selection of mode can depend on many different variables such as; transport volumes, travel distances, lead times, freight value etc. Determination of choice between the different modes can be said exists as an interaction between capital and transport related costs.[32] A further explanation of the different transport modes in specific is described in this section.

Road

By far the most common type method, as a substantially increased utilization of road transportation has taken place during the last half of this century. The underlying background for this transformation is the increased transport volumes that can be carried due to the development and utilization of larger trucks. Characteristics that make road transportation an attractive solution are namely its reliability, flexibility, adaptability for small scale quantities, making it an ideal solution for efficient door-to-door deliveries. Negative impacts from this type of transports are mainly air and noise pollutions, but also traffic problems occurred as a result due to heavily expanded road traffic.[33]

Sea

Transport overseas is considered to be the most cost efficient type of transport. This is based upon the large loading capacities offered by modern sea vessels which are far superior in comparison to other modes. The wide selection of route options and low variable costs makes sea transport a profitable

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[30] Beamon (1999)
[31] Lumsden (2007)
[32] Ibid
[33] Browne, M. Cullinane, S. McKinnon, A & Whiteing, A. (2010)

choice for any types of cargo. Biggest side-effect regarding overseas transportation is considered to be the long transit times, especially when concerning high-value type of freight.[34]

Rail

The low friction between wheels and rail leads to less force needed to move cargoes, making rail transportation ideal for larger freight volumes at relatively low fuel consumption. However rail transports are limited to existing railroad routes and more than often doesn't offer direct connections between origin and final destination. Rail transports are therefore often needed to be combined with other modes to guarantee completion of deliveries. This requires extra freight handling when mode switches are made, making rail a slower, less flexible transport option. Even though expansion of railroad infrastructural networks require large investments in comparison to road network, great efforts are made to expand existing routes and develop new ones, as rail is considered to be one of the cheapest and most environmental friendly options for transportation.[35]

Air

Air transport is considered to be the fastest way of delivery across long distances but also the most expensive and by far the most environmentally challenging when regarding polluting emissions. Typical types of freight that is transported by air are considered to be cargoes with special demands on fast delivery such as newsworthy items, urgent required materials and high value goods such as electronic components.[36]

A more detailed description of environmental effects and emission factors for each transport mode is described in the later chapters of this report.

Multi-/intermodal transportation

There is often the need of combining several types of transport modes in order to complete a delivery cycle, since in most cases; the utilization of only one mode rarely provides a door-to-door solution. This is called multimodal transportation. Intermodal transportation occurs when switching modes and freight exchanges are made without comprising the freight itself, meaning handling only regards the load carrier. Beneficial effects from these types of operations are usually time efficiency and overall effectiveness. The method however requires precise timing when switching modes and standardized load carriers and pallets to be able to fit the different modes without specified handling of the freight.[37]

Distribution systems

As competition between the different actors of a market grows, key to success for a business often lies within how fast and frequent deliveries can be made from manufacturing plants to the end customer. These measures are not always easy to achieve due to different economical or physical reasons. Therefore, different distribution systems based upon theoretical framework and practical methods are developed to compromise and simplify the distribution relationship between a manufacturer and customer.

Direct delivery

Are the most basic and self-explanatory type of delivery, basically meaning that transports are made from place A to B without hinder. These types of deliveries are very fast and uncomplicated but can be a very expensive and resource demanding way of transport, especially in cases where customer

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[34] Lumsden (2007)
[35] Ibid
[36] Ibid
[37] Browne, M. Cullinane, S. McKinnon, A & Whiteing, A. (2010)

demands production units from different manufacturing plants at the same time leading to a complex distribution network.

One-terminal system

The one-terminal system revolves around a distribution center that handles all distribution of a certain area. The principle is based upon freight arriving from manufacturing plants where it´s further loaded to each customer order specification and later shipped on. The method is well structured but very dependent on time constraints due to coordination between inbound deliveries and re-allocation of freight before redistribution is possible.[38]

Environmental impacts from freight transports

Depending of what type of fuel that is used, emissions made by freight transports may vary entirely. However in the current state most commercial vehicles are driven by diesel based type of fuel. Together with CO_2 emissions, which are a natural side effect during engine combustion, other harmful pollutions such as carbon monoxides, nitrogen oxides and such are also released as a result of incomplete combustion.[39] In case of electrically based transports are utilized, one should consider the energy consumption and pollutions emitted where the electricity was generated.

Accounting world-wide, CO_2 related emissions regarding freight transportation accounts for roughly 8 percent of the total discharges made globally and keep increasing steadily.[40] And it is said that at this rate the transport sector regarding freights by the early 2020s, in the European Union will overshadow the public section including passenger vehicles and buses in form of amounts of energy that is consumed.[41]

Law regulations

As a result due to growing concern about the environment, governmental authorities such as the European Union commission have created certain guidelines regarding emission confinement. Some of these are considered to be mandatory while others are more voluntary and are set more as management oriented guidelines for creating a more environmentally aware business. ISO standards such as the 14000-series and EMAS are some of the tools created for voluntarily purposes. Other factors like emissions from diesel powered heavy duty vehicle are considered more hazardous and are strictly controlled by EU legislations called EURO emission standards.[42] A detailed list of these mandatory guidelines can be seen in Figure 7.

[38] Lumsden (2007)
[39] Holmen & Niemeier (2003)
[40] Kahn, Riberio, Kobayashi (2007)
[41] European Commission (2003)
[42] Browne, M. Cullinane, S. McKinnon, A & Whiteing, A. (2010)

Tier	Date of implementation	CO	HC	NOx	PM
Euro I	1992 (>85kw)	4.5	1.1	8.0	0.36
Euro II	1998	4.0	1.1	7.0	0.15
Euro III	2000	2.1	0.66	5.0	0.10
Euro IV	2005	1.5	0.46	3.5	0.02
Euro V	2008	1.5	0.46	2.0	0.02
Euro VI	2013	1.5	0.13	0.4	0.01

Figure 7: Emission standards for heavy-duty diesel engines (g/kWh)[43]

In cases where road transports of freight with high weight is made, it is wise to consider law regulations regarding the total weight of transports. These differ considerably depending of which country transports are made and what type of road qualities these represent. For instance Sweden is considered to maintain a high overall road infrastructure and has a relative high weight limit of 60 tons, while the United States only has a limit of 36 tons. Standard weight limit in the European Union is legislated to 44 tons.[44]

[43] National Audit Office UK <www.nao.org.uk> 2011-06-06
[44] Professional Traffic Sweden <www.Yrkestrafiken.se> 2011-06-06

Model foundation

Reliable data collection consists as the foundation for the calculation model. This section of the report describes collection methods, sources and problems encountered during this process.

Data parameters

As a first step in collecting data, the identification of which variables are needed in creation of an accurate emission model is essential. The following parameters were identified as a result of initial research and brainstorming sessions between authors and supervisors.

Input variables
Suppliers/Customers
Transport Volumes
Distances
Transportation Modes
Transportation Routes
Modal per route
Unseen route Mark-ups

Table 2: Parameters included in calculation

As seen in the table above following conclusions was made during the sessions. Standard variables necessary for the model were identified as suppliers/customers and following freight volumes, distances and transport modes from/to each of these. Also to increase credibility and veracity of the emission model, further variables such as: taken transport routes, different transport modes used per route and the utilization of unseen route mark-ups during transportation were taken into consideration. During this research many of above stated variables were not obtainable due to lack of knowledge and were therefore assumed in coherence with individuals well familiar within the field of logistics (freight forwarders, HSAB employees, PhD students and such) as well as the use of existing theories within the research area. Even though these variables were assumed, the conclusion of the study showed that the inclusion of these revealed a more accurate and realistic calculation result.

Sources for data collection

After verification of the input variables were made, the data collection process itself was initiated. Core data such as names of suppliers and customers and its associated freight volume bought were gained through the HSAB's ERP-system M3 (Movex). With the help of the company's logistic staff and its customer and supplier database, final addresses were accessed and implemented into already gained data. With given information a core model was presented as baseline.

Next step in the process was to map out distances and transport modes used between HSAB's manufacturing site and associated suppliers and customer locations. Different internet application based distance calculation tools were used depending variables such as locations and transport modes. A summarization of these are listed in table below

Calculation Tool	Area of use
Map24	International Road/Rail Transports
Eniro	Domestic Road/Rail Transports
E-ships.net/ Searates.com	Sea transports
Indian industry	Air transports

Table 3: Tools used for distance calculation

Following section further describes the distance calculation tools stated above.

Road & Rail transports

Two types of distance calculation tools were used during this assessment. For domestic transports it was found most suitable to use Eniro[45] as it is a Swedish developed application with extensive framework regarding domestic infrastructure. After a quick review of existing tools, Map24[46] was the one chosen as it was seen most fit for international transports due to its comprehensive road infrastructure, especially in the European regions.

Sea transports

Due to the diversity of the used shipping harbors during freight transports, only one application tool seemed inadequate due to harbor location database coverage. Therefore, after close studies the authors found a solution that covered the entire in-/outgoing harbor locations by combining two similar internet application tools. These were Searates.com[47] and E-ships.net[48]. The latter application even offered the option of choosing between the routes through The Suez Channel or around The Cape of Good Hope.

Air transports

Since air transports only consisted of a fraction of outgoing transport solutions, only one application tool was sufficient. The tool used to calculate these distances were gained through the Indian Industry air distance calculator[49]

Transport modes & routes

The last step in the data collection process was to lay out the route taken for each shipment and to ascertain which mode of transport that was used during the different stages of the journey. This task turned out to be harder than expected since these types of data were not to be found in any records stored by HSAB. Therefore, the authors turned directly to the source, in this case the different freight forwarders and asking them to fill out a questionnaire created for the purpose. For the complete survey, see appendix 2.

With most of the core data gathered, implementation was made into the created emission calculation model and as an outcome granting an initial calculation result regarding CO_2 emissions caused by transports.

Uncertainties and assumptions during collection process

During the data collection process and when in contact with freight forwarders certain issues regarding the different transportation modes and routes taken for each shipment were brought forth. This section will further explain the issues and state measurements taken to resolve these for each segment.

One of the purposes of the model was that it would be created as such to be applied as an everyday tool for mapping CO_2 emissions, not only for calculating baseline values but also being adapted to handle assignments for future calculations. During the data collection process, a main issue regarding the freight forwarders emerged. After some research it appeared that freight forwarders were to be seen as a highly unreliable variable due to price competitions. Every year nominations are made from the different carriers (mainly road and sea sectors) and with regard to criteria such as (prices, lead

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45 Eniro <www.eniro.se> 2011
46 Map24 <www.map24.com> 2011
47 Searates <www.searates.com> 2011
48 E-ships.net <www.E-ships.net> 2011
49 Indian Industry <www.indianindustry.com/travel-tools> 2011

times, number of containers etc.) carrier selections are made[50]. Although delivery locations remain the same, the routes and transport modes taken may vary considerably. Therefore, following assumptions were made in order to simplify the complexity of the model:

A. Destination routes taken by the freight forwarders varied diversely between the different actors. Therefore, it was hard to proclaim a certain standard route for each shipment since information given only stated starting origin point, location of intermodal ties and final destination point without specific route implementation. For road transports, in agreement with freight forwarders, the assumption that transports following the main European roads to its destination was found most accurate in relation to real case scenarios and therefore the solution applied to the model. Other way of transports were simply measured as a bird's view direct route, from origin to final destination with a percentage add-on developed by actual route case studies made in coherence with freight forwarders.

B. Another problem statement that occurred regarded the selection of heavy duty vehicles during road transports, specifically engine class in the calculation model. According to GDL, which is the current HSAB's main supplier of domestic transportation, most vehicles used consist of the latest EURO class standard. It was also mentioned that the economical lifespan for each vehicle lies around 5 years and thereafter investments in new vehicles are made, meaning within these time periods most of the used vehicles consists of up to date engine classes.[51] The gathering of information from international carriers was considerably harder and in some cases nonexistent and most answers given were highly questionable. The conclusions of the study above based on the underlying facts lead to the assumption that most vehicles consist of EURO class IV engines or higher. The model presented contains room for error margins where one easily could change between different engine/vehicle classes if information changes would be made in the future.

Additional information and calculation methodologies of the different mode sectors are stated in the next chapter of the study.

[50] Kielerzstajn, Torsten & Schönhult, Carl-Johan 2011-04-10
[51] Andersson, Mikael. Head of department, Sea & container shipments, GDL 2011-05-09

Emission calculation methodology

This chapter includes presentation of existing calculation methods and explains the different steps and criteria that were utilized during the development of the emission model.

Existing calculation models to date

With limited knowledge within the project area, the first step towards creating an accurate emission model was to evaluate existing methodologies. Since emission calculation is a relatively new field of research there is no standard model used by all in present day. Instead there are models and theories used more or less frequently by parties of interests. A further description is explained below of the more frequently used methodologies, where most insights and information were gathered by the authors of this study.

NTM

The Network for Transport and Environment is a non-profit Swedish organization that was established in 1993. The aim of the organization is to establish a common based value on how to calculate the environmental performances from different transportation modes. The calculation regards the usage of natural resources and other external effects from freight and passenger transports. The method is mainly developed for market actors of transport services, making it possible for them to evaluate their own individual carbon footprint. The NTM calculation covers all of the usual transport modes such as road, rail, sea and air.[52]

EcoTransIT

The Ecological Transport Information is an internet application that was first published in 2003. The project was originally initiated by IFEU (Institute for Energy and Environmental Research) in cooperation with numerous railway consortiums. The project started out with limits on road and rail but in later stages expanded and also considering environmental impacts from sea and air vessels. The application works as such that instead of showing impacts of single shipment; it compares and analyzes different transport chains with each other and reveals the solution with lowest environmental impact. The inbound parameters regarded in the calculation are energy consumptions, greenhouse gas emissions and air pollutants such as nitrogen oxides (NO_x), Sulfur dioxides (SO_2) and other non-methane hydrocarbons. The internet application is also combined with a route planning mechanism that enables departure and arrival addresses.[53]

[52] NTM (2010)
[53] EcoTransIT World (2010)

Project calculation approach

Road

This section of the report covers calculations of freight transports made by road vehicles. This sector turned out to be the hardest to calculate due to the variety of the different types of vehicles that are available for use and each having different properties such as weight, payloads, engine class, fuel consumption etc.

In Figure 8 below some of the different vehicle types available are displayed.

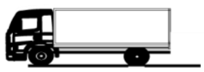
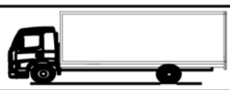
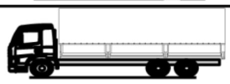
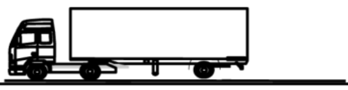
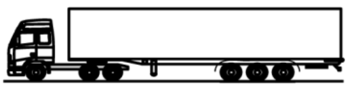
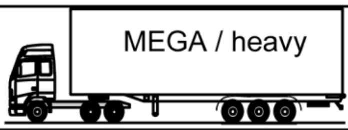
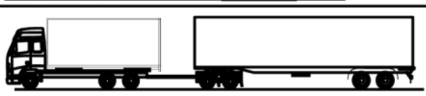
No	Illustration	NTM Nomenclature	ARTEMIS Nomenclature
1	(no picture)	(LCV) Pick-up	LCV Petrol N1-II / LCV Diesel N1-II
2		(LCV) Van	LCV Petrol N1-III / LCV Diesel N1-III
3		(HGV) Small lorry/truck	RT <=7,5t
4		(HGV) Medium lorry/truck	RT >7,5-12t + >12-14t
5		(HGV) Large lorry/truck	RT >14-20t + >20-26t
6		(HGV) Tractor + 'city-trailer'	TT/AT >14-20 + >20-28
7		(HGV) Lorry/truck + trailer	TT/AT >28-34 + >34-40
8		(HGV) Tractor + semi-trailer	TT/AT >28-34 + >34-40
9		(HGV) Tractor + MEGA-trailer	TT/AT >40-50t
10		(HGV) Lorry/truck + trailer or semi-trailer on dolly	TT/AT >50-60t

Figure 8: Different vehicle concepts and types[54]

Although there are ten different types of vehicles presented in the illustration above, not all of them are utilized in the study made at HSAB. As the company manufactures various high-density iron powder solutions in vast quantities, the selection of transport mode is narrowed down and therefore excluding the lighter modes in order to handle needed weight capacity of manufactured goods.

The general formula used to calculate the total emissions for road transport is stated as follows.

[54] NTM (2010)

$$Emissions\ [\ CO_2\ kg] = Emission\ factor\left[\frac{CO_2\ kg}{tonne * km}\right] * Distance\ [km] * Volume\ [tonne]$$

The emission factor depends on various parameters such as vehicle type, engine class, payloads, driven road characteristics and the type of fuel that is utilized. The style of which a vehicle is driven also has a significant impact on fuel consumptions and therefore on the emission factor and released emissions in total.

Engine class

The fuel consumption depends mainly on type of truck, Fuel/Engine combination, Load Capacity Utilization (LCU) and the road type. Table 4 displays of fuel consumptions for various parameters are revealed.

Vehicle type			**Fuel Consumption [l/km]**					
		Fuel/Engine combination	Freeway		Rural roads		Urban Roads	
			LCU		LCU		LCU	
			0%	100%	0%	100%	0%	100%
Small lorry/truck	Truck < 7,5t	Diesel, Euroclass I-V	0,122	0,137	0,107	0,126	0,110	0,134
Medium lorry/truck	Truck < 7,5-12t + 12-14t	Diesel, Euroclass I-V	0,165	0,201	0,152	0,197	0,171	0,228
Large lorry/truck	Truck 14-20t + 20-26t	Diesel, Euroclass I-V	0,204	0,273	0,199	0,284	0,244	0,352
Tractor + citytrailer	TT/AT 14-20t + 20-28t	Diesel, Euroclass I-V	0,201	0,294	0,205	0,318	0,255	0,402
Lorry/truck + trailer	TT/AT 28-34 + 34-40t	Diesel, Euroclass I-V	0,226	0,360	0,230	0,396	0,288	0,504
Tractor + semitrailer	TT/AT 28-34 + 34-40t	Diesel, Euroclass I-V	0,226	0,360	0,230	0,396	0,288	0,504
Tractor + MEGA-trailer	TT/AT 40-50t	Diesel, Euroclass I-V	0,246	0,445	0,251	0,495	0,317	0,634
Lorry/truck + Semitrailer	TT/AT 50-60t	Diesel, Euroclass I-V	0,282	0,540	0,334	0,608	0,369	0,783

Table 4: Description of fuel consumption depending of road characteristics[55]

Information from the freight forwarders assigned by HSAB suggested that the most common vehicle type used is the Tractor + semitrailer solution due to transport requirements. For emission model simplicity, this suggested solution was applied to all calculation cases regarding road transports except transports made between manufacturer sites and warehousing.

As seen in Table 4, road type also leaves an impact regarding fuel consumption. When the trucks are loaded, the differences between the different road types are greater. If no specific data for the road distribution is mentioned, information given in Table 5 can be used for domestic transportations.

[55] NTM & ARTEMIS (2008)

Freeways	Rural Roads	Urban Roads
21,0%	56,7%	22,3%

Table 5: Allocation percentage between different HGV road traffic activities (Sweden)[56]

Fuel

In order to obtain correct carbon dioxide emission data, the information of how many grams emitted from each liter of fuel is needed. In the table below, the carbon emissions for various types of fuel is stated. Note that Environment Class 1 (EC1) is considered to be domestic standard for Sweden.

FUEL DATA		Diesel EC1	Diesel	Petrol EC1	Petrol
		Sweden 5%Fame	Europe Low sulphur	Sweden 5% ethanol	Europe
Calorific Value	[MJ/l]	35,3	35,8	32,2	32,8
Energy content	[MJ/l]	0	0	1,1	0
Energy content	[MJ/l]	35,3	35,8	31,1	32,8
CO2 Total	[kg/l]	2,54	2,62	2,32	2,34

Table 6: Emission values for most common HGV fuels[57]

FAME is an abbreviation for fatty acids which are based on various oilseeds. The most common ingredient is canola oil that it esterifies to the methyl ester, RME. FAME is a product that is biodegradable and therefore more accessible to microorganisms.

Almost all vehicles related to HSAB transports uses diesel as fuel and therefore, for calculation simplicity, the assumption that all vehicles are diesel driven was made.

The CO_2 Total in Diesel can also be calculated by multiplying the carbon content in mass-% with the fuel density and the molecular weight relations given that all carbon is transformed into CO_2 and the small amount of CO, hydrocarbons and particles are neglected.

Weight relations:

$$CO_2 = C + O + O = 12 + 16 + 16 = 44$$

The equation to calculate kg CO_2 / liter fuel:

$$Emission\ \left[\frac{\text{kg CO}_2}{\text{liter fuel}}\right] = \text{carbon content } [\%] * \text{density } [\text{kg/l}] * \text{weight relations}$$

And diesel specific:

$$Emission\ \left[\frac{\text{kg CO}_2}{\text{liter fuel}}\right] = 86\% * 0{,}820 * \frac{44}{12} = 2{,}59\ \left[\frac{\text{kg CO}_2}{\text{liter fuel}}\right]$$

Distances

The distances between the different locations in the model were developed by entering the postal codes in Eniro.se for Sweden and Map24.com for the rest of the world. Since the truck also

56 ARTEMIS (2008)

57 Swedish Petroleum Institute <www.spi.se> 2011

must be transported to its starting location, it is recommended that a surcharge of 20% is added to the emission calculation factor.[58]

Calculations

To calculate the fuel consumption, information from Table 4 and Table 5 is needed. For direct transport and frequent shipments, load capacity utilization (LCU) of 75% can be used according to NTM. The fuel consumption is linearly dependent of the LCU. In Table 7 is the fuel consumption for different types of roads shown for chosen criteria (Tractor + semitrailer, Diesel, Euro-Class I-V).

	Freeways	Rural roads	Urban roads
LCU 0%	0.226 l/km	0.230 l/km	0.288 l/km
LCU 100%	0.360 l/km	0.396 l/km	0.504 l/km
LCU 75%	0.3265 l/km	0.3545 l/km	0.45 l/km

Table 7: Fuel consumption for different types of roads.[59]

From the information above, average emissions for Sweden and Europe can be done which is shown in Table 8.

	Sweden	Europe
Emission [CO2 [kg] / (ton * km)]	0.0564	0.0581

Table 8: Average emissions per ton*km.[60]

Calculation example for Freeways in Sweden

Freeways LCU 75% = **0.3265 l/km**

CO_2 [kg] / km = Fuel consumption [l/km] * CO_2 [kg/l] = 0.3265 [l/km] * 2.54 = **0.82931 CO_2 [kg] / km**

Emission factor [CO_2 [kg] / (ton * km)] = 0.82931 CO_2 [kg] / km * 120% / 20 ton =

= **0.0497586 [CO_2 [kg] / (ton * km)]**

Difference from average value

% = ((0.0498- 0.0564) / 0.0565) **= -11.7755%**

If a truck only use freeway for a transport, the real emissions will be 11.78% lower than the calculated emissions in the model. Below are all differences, calculated as the example above.

	Freeway	Rural Roads	Urban Roads
Sweden	-11.78%	-4.21%	21.60%
Europe	-11.66%	-4.08%	21.76%

Table 9: Deviations from average emission factor for different road types in Sweden and Europe.

Urban roads consist to have the largest deviation with 21%, but it is very unlikely that a vehicle driver prefers the use urban roads, simply because of the increase in both fuel consumption and time. The main purpose of the thesis is not to calculate the emission for specific route, but to give the average

[58] NTM (2010)
[59] See Appendix 4.1 for detailed calculations.
[60] See Appendix 4.2 for detailed calculations.

emissions. Therefore, the emission factors above can be assumed to be accurate even though there can be a 21% deviation on a specific transport.

Rail

In this thesis, only European railways are taken into consideration. Train transports are carried out by national railway operators within each country. Meaning that all countries have different values of fuel and electricity consumptions and the share of diesel and electrical trains can vary a great deal depending on location and countries.

The data and calculation methods in this chapter are only used for cargo trains pulled by either diesel or electrical engines.

Important parameters to calculate an emission factor are:

- Diesel or Electrical Trains
- Gross and net weight
- Topography (affects the energy demand)
- Type of freight
- The country of operation

Parameters not taken in consideration are driving behaviors, aerodynamic profiles, speed and number of starts and stop since it is hard to get these types of information.

Cargo capacity utilization

The first table presents Cargo capacity utilization for different types of train.

Train size	Train gross weight	Cargo type	Cargo capacity utilization
Short Train	500 ton	Bulk	60%
	500 ton	Average	50%
	500 ton	Volume	40%
	500 ton	Shuttle Train	50%
Average Train	1000 ton	Bulk	60%
	1000 ton	Average	50%
	1000 ton	Volume	40%
	1000 ton	Shuttle Train	50%
Long Train	1500 ton	Bulk	60%
	1500 ton	Average	50%
	1500 ton	Volume	40%
	1500 ton	Shuttle Train	50%

Table 10: Cargo capacity utilization for cargo trains[61]

According to EcoTransIT, an average of 1000 tons is used as guideline when calculating on emissions regarding train transports within Europe. The freight transported to and from HSAB is considered as bulk freight; therefore a **CCU of 60%** will be used in this chapter.

[61] EcotransIT (2010)

Topography and electricity/fuel consumption

The topography has a major impact on the electricity and fuel consumption. Therefore, Europe is divided into three types of topography. These are flat terrain, hilly terrain and mountainous terrain. Countries considered flat are Denmark, Netherlands and Sweden. Countries consists of mountainous terrain are Switzerland and Austria. Rest of Europe is hilly terrain.[62] In the tables below, the electricity and fuel consumption for different topographies are shown.

Traction	Topography	Gross weight range	Electricity consumption
Electrical	Flat terrain	500-1500 ton	$540*W_{gr}^{-0,5}$
Electrical	Hilly terrain	500-1500 ton	$675*W_{gr}^{-0,5}$
Electrical	Mountainous terrain	500-1500 ton	$810*W_{gr}^{-0,5}$

Table 11: Electricity consumption for different topographies [Wh/gross ton * km]

Traction	Topography	Gross weight range	Fuel consumption
Diesel	Flat terrain	500-1500 ton	$122,46*W_{gr}^{-0,5}$
Diesel	Hilly terrain	500-1500 ton	$153,07*W_{gr}^{-0,5}$
Diesel	Mountainous terrain	500-1500 ton	$183,69*W_{gr}^{-0,5}$

Table 12: Fuel consumption for different topographies [g/gross ton * km]

From the two tables above, calculations are made to develop following electrical and fuel consumptions.[63]

[62] Ibid
[63] NTM (2010)

Train size	Train gross weight	Cargo type	Terrain		
			Flat	Hilly	Mountainous
			[kWh/km]		
Short Train	500 ton	Bulk	12	15	18
	500 ton	Average	12	15	18
	500 ton	Volume	12	15	18
	500 ton	Shuttle Train	12	15	18
Average Train	1000 ton	Bulk	17	21	26
	1000 ton	Average	17	21	26
	1000 ton	Volume	17	21	26
	1000 ton	Shuttle Train	17	21	26
Long Train	1500 ton	Bulk	21	26	31
	1500 ton	Average	21	26	31
	1500 ton	Volume	21	26	31
	1500 ton	Shuttle Train	21	26	31

Table 13: Electricity consumption different types of trains and topographies [kWh/km]

Train size	Train gross weight	Cargo type	Terrain		
			Flat	Hilly	Mountainous
			[l/km]		
Short Train	500 ton	Bulk	3,29	4,11	4,94
	500 ton	Average	3,29	4,11	4,94
	500 ton	Volume	3,29	4,11	4,94
	500 ton	Shuttle Train	3,29	4,11	4,94
Average Train	1000 ton	Bulk	4,65	5,82	6,98
	1000 ton	Average	4,65	5,82	6,98
	1000 ton	Volume	4,65	5,82	6,98
	1000 ton	Shuttle Train	4,65	5,82	6,98
Long Train	1500 ton	Bulk	5,7	7,13	8,55
	1500 ton	Average	5,7	7,13	8,55
	1500 ton	Volume	5,7	7,13	8,55
	1500 ton	Shuttle Train	5,7	7,13	8,55

Table 14: Fuel consumption different types of trains and topographies [l/km]

Emissions caused by electricity generation

The following table has been adopted from the EcoTransIT project. The table present CO_2 emissions for the electricity supply for railway transports within European countries.

Country	CO_2 [kg/kWh]
Austria	0,01
Belgium	0,26
Czech Republic	0,71
Denmark	0,48
Finland	0,21
France	0,11
Germany	0,66
Hungary	0,55
Italy	0,49
Luxembourg	0,26
Netherlands	0,43
Norway	0
Poland	0,94
Slovakia	0,18
Slovenia	0,37
Sweden	0
Switzerland	0
EU average	0,41

Table 15: CO_2 emissions for regional electric train supplies regarding European countries[64]

[64] EcoTransIT (2010)

The CO_2 Total in Diesel can be calculated by multiplying the carbon content in mass-% with the fuel density and the molecular weight relations given in such that all carbon is transformed into CO_2, and that the small amount of CO, hydrocarbons and particles are neglected (Same as Road).

Weight relations:

$$CO_2 = C + O + O = 12 + 16 + 16 = 44$$

The equation to calculate kg CO_2 per liter fuel:

$$Emission \left[\frac{\text{kg CO}_2}{\text{liter fuel}}\right] = \text{carbon content [\%]} * \text{density [kg/l]} * \text{weight relations}$$

And diesel specific:

$$Emission \left[\frac{\text{kg CO}_2}{\text{liter fuel}}\right] = 86\% * 0.820 * \frac{44}{12} = 2.59 \left[\frac{\text{kg CO}_2}{\text{liter fuel}}\right]$$

Calculations

Calculation of emission factors regarding electric and diesel trains:

Example electric train

An electric train in Denmark with the total gross weight of 1000 tons and a load factor stated as 60%. (Denmark is considered flat)

Electricity consumption = $540*W_{gr}^{-0.5} = 540*1000^{-0.5} = 17.07$ [Wh / gross ton * km].

Electricity consumption per net ton = 17.07 / 0.6 = 28.45 [Wh / net ton * km].

There are losses in transmissions which will increase the electricity consumption by ~10% according to EcoTransIT. The cause of these losses is considered to be resistive, transformation losses and frequency modulation.

$$Total\ electricity\ demand\ =\ 28.45\ /\ 0.9\ =\ 31.61\ [Wh\ /\ net\ ton\ *\ km].$$

From Table 15, Denmark has an emission factor of 0.48 CO_2 kg/kWh regarding railway transports.

Therefore, giving the emission factor = $31.61\ [Wh\ /\ net\ ton\ *\ km]\ *\ 0.48\ [CO_2\ kg/kWh]\ =$

$$=\ \mathbf{15}\ [\boldsymbol{CO_2\ g\ /\ net\ ton\ *\ km}]$$

Country	CO2 g / net ton km
Austria	0,47
Belgium	10,28
Czech Republic	28,07
Denmark	15,18
Finland	8,30
France	4,35
Germany	26,09
Hungary	21,74
Italy	19,37
Luxembourg	10,28
Netherlands	13,60
Norway	0,00
Poland	37,16
Slovakia	7,12
Slovenia	14,63
Sweden	0,00
Switzerland	0,00
EU average	**16,21**

Table 16: Emission factor regarding electric trains in European countries

Example diesel train

A diesel train in hilly topography with total gross weight of 1000 tons and a load factor stated as 60%.

Fuel consumption = $153.07 * W_{gr}^{-0.5} = 153.07 * 1000^{-0.5} = 4.84$ *[g/gross ton * km]*

Fuel consumption per net ton = $4.84 / 0.6 = 8.07\ [g/net\ ton * km]$

$Density\ [kg/l]\ diesel = 0.82\ [kg/l]$

Fuel consumption per net ton in liter = $8.07 / 820 = 0.00984\ [l\ /net\ ton * km]$

CO_2 kg in 1 liter diesel = $2.59\ kg/l$

Therefore, giving the emission factor = $2590 g/l * 0.00984\ [l\ /net\ ton * km] =$

$= \mathbf{25.49}\ [\boldsymbol{g/\ net\ ton * km}]$

The table below shows the emission factor for different topographies

Topography	CO2 g / net ton km
Flat	20,43
Hilly	25,54
Mountainous	30,65

Table 17: Emission factor (Diesel train) for different topographies

In order to keep the simplicity of the model, it is impossible to have an emission factor for every single country. For the electric train the emission factors varies from 0 to 37 g/net ton*km. Diesel train varies from 20 to 30 g/net ton*km. The parameter regarding the distribution percentage in total, between the electric and the diesel trains was not possible to gain during the study. However, 85-90% of the train transports outside of Sweden in HSAB´s account go through Germany, which has an electricity emission factor of 26 and is very close to the emission factor for diesel trains in comparison.

The average emission factor for electricity train in Europe except Germany and Sweden is 12.7 CO2 g / net ton km. This leads to:

Germany 90% * 26.09 + Rest of Europe 10% * 12.7 **= 24.75 CO2 g / net ton km**

Therefore, an approximation of **25 CO_2 g / ton*km for trains outside Sweden** can be made, even if there are uncertainties if electricity or diesel is used. Sweden is an exception due to the emission values here is stated as zero (See Table 16) and will have **0 CO_2 g / ton*km** as emission factor in the model .

Sea

These sea transport sector can be divided into two different types: ferries and container ships. The ferries are used in short distance transports and are combined cargo and passenger ships. The container ships are used in long distances and contain only cargo loaded in containers.

The ferries used in this case are so called RoRo (roll on – roll off) and RoPax (limited passenger capacity) ferries, where cars and trucks drive onto the ferry via an off-shore ramp.

Container ships can be divided into two different types of ships, feeder ships and larger container ships used for intercontinental cargo transport which will be referred as container ships further on.

Feeder ships are smaller container ships used to allocate the cargo to feeder harbors where the cargo gets loaded on container ships. This is done to streamline the transport chain, because it´s more efficient for the feeder ships to allocate small amount cargo from minor harbors instead of having the large container ships to run on shorter routes. In HSAB´s case, the cargo transports made by feeder and container ships have two different routes. Either the cargo leaves Höganäs with a truck to Gothenburg harbor. In Gothenburg harbor, the cargo is loaded on feeder ships and transported to a feeder harbor in northern Europe. The other route is from Höganäs to Helsingborg harbor where the cargo is loaded on feeder ships and transported to a feeder harbor. From the feeder harbor the container ships transport the cargo to Asia, South America and North America.

However, to keep the simplicity of the model, the feeder ships have been excluded in the model. The main reason for this is the uncertainty of which feeder harbor that is used during transportations. There are no fixed routes or harbors used by the shipping companies; instead the cargo is re-routed throughout a series of larger feeder harbors such as Bremerhaven, Antwerp or Zeebrugge. The chosen port depends mainly on the cost and time efficiency at that certain point of time for each of the larger container ships. This making it almost impossible to keep track of which route that was taken per transport.[65]

To be able to perform calculations for the emission factors a data collection has to be done. There are many different types of ferries, fuel types and engines which make it difficult to estimate the emission factor if there are no chart of the distribution for each type of ferry, fuel and engine in HSABs case. Even if the emission factor is possible to calculate for some type of ferries, the uncertainty is too high to establish the value as accurate enough.

EcoTransIT has a calculator on their website where the user is able to calculate the emissions for sea transport. This tool has been developed from a very large database collected from transport companies with the exact volumes, routes via GPS and fuel consumption. This database is not public and there are no numbers presented by EcoTransIT except the calculation tool.

Therefore, it was decided to use the same emission factors as EcoTransIT use in their calculator. For container ships the values **10 g CO_2/ ton * km** are used and **47 g CO_2/ ton * km** for ferries.

[65] Schönhult, Carl-Johan 2011-04-10

Air

The air transport sector consists of dedicated air cargo freighters (only cargo) or in the cargo hold of passenger aircrafts (combined passenger and cargo). The combined aircrafts are usually called belly freighters. The cargo is loaded shipment by shipment, in special air cargo containers or pallets in order to allow quick loading and good use of space and weight distribution.

Air transport has a great advantage compare to other transport modes in form of speed and reach. In HSAB's case, frequent exports to Asia are made. By sea transport the route to Asia takes over 30 days compare to air transport which only takes one day. However, the downside is the environmental impact where air transport has a relative high usage of energy (i.e. MJ/ton×kilometre).

The emission calculation can be divided into two steps.

1. Calculation for total emissions for the flight
2. Calculation for the emission contributed by each cargo

To be able to perform these calculations there is a need for certain information. Input data consists of the information of the specific aircraft, the distance flown and the cargo weight. Figure 9 describes input, calculations and output data in detail.

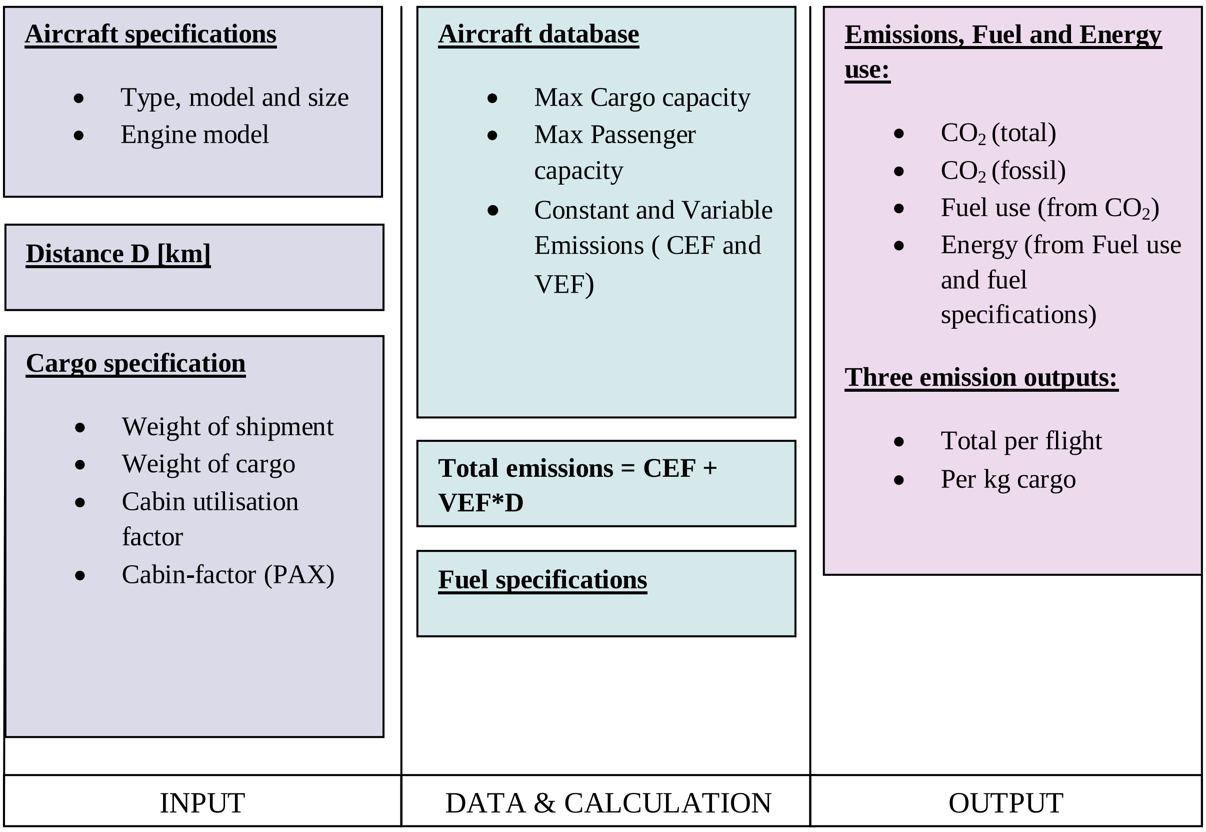


Figure 9: Input data, Air transport calculation

In the DATA & CALCULATION column in the figure above there are three variables to take into consideration when calculating total emissions.

- Constant emission factor (CEF)
- Variable emission factor (VEF)
- The distance (D)

CEF represents taxi out, start, climb to cruise, descend from cruise, landing and taxi in, i.e. every factor that does not get affected by distance.

VEF is the factor which is multiplied with the distance to calculate the fuel consummation in the air.

The calculations for the distances will be explained later in this section.

Figure 10 explains the principals of the **Total emissions = CEF + VEF*D** formula.

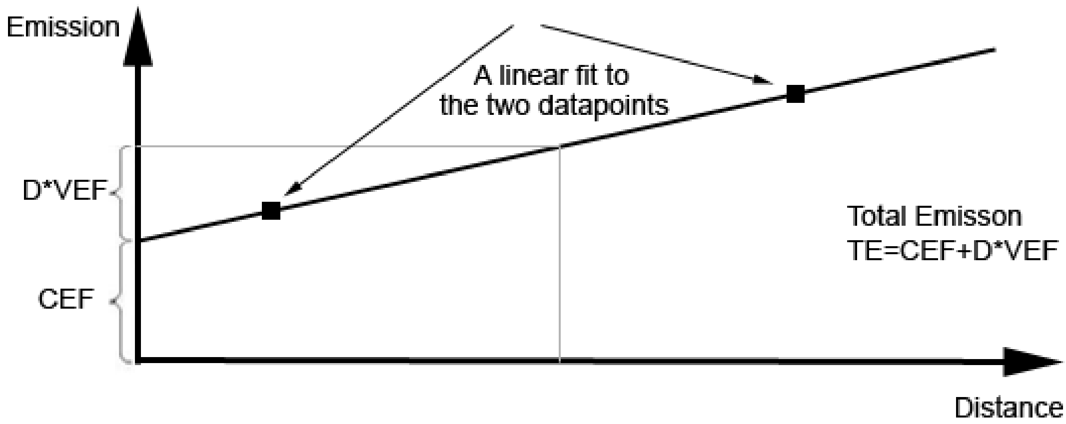


Figure 10: Emission-Distance calculation[66]

HSAB use airfreights when short term deliveries are requested. None of the airfreight transports are originally scheduled and are only used on customer demand or when unforeseen complications occur during the production or planning process of an order that severely affects lead-times. The airfreight transports consists of mainly long distance flights to the regions Asia, USA and the Oceanic's

One of the main criteria for the emission model is that it has to be easy filling in the variables to be able to calculate emissions. Therefore, a general emission factor was developed and applied to all transports within the air sector.

The input data used are taken from the logistic company Airlog which stands for approximately 94% of the air transports that are conducted by HSAB. Airlog uses mainly four different aircrafts during transportation. Airbus 330-300 and Airbus 340-300 which are used at routes trafficked by SAS and Finnair. Airbus 340-400 and Boeing 787 are used by Korean, Air China and China Airline. All of these aircrafts are so called belly freighters.

NTM have data tables for different aircrafts, but only for Airbus 330-300 and Airbus 340-300 of the four different aircrafts used by Airlog. In the table at NTM Airbus 340-300 are equipped with the old engine CFM56-5C3, but in the reality they have been replaced with the more effective CFM56-5C4 engine. Airlog also gave the information of an average pay load factor at 90% for their flights.[67]

The table shown below is data from NTM for Airbus 330-300 and Airbus 340-300 with different payload factors.

[66] NTM (2010)
[67] Rosenkvist, Johan. Managing director, Airlog 2011-03-25

Aircraft	Max Payload Load	Max Pax Load	Cabin Factor	Max Cargo Load	Cargo Factor	Max Distance	CO2	CO2
							CEF	VEF
	[kg]	[kg]	[%]	[kg]	[%]	[km]	[kg]	[kg/km]
A340-300	47320	23933	65	13000	50	14998	8987	23,11
A340-300	47320	23933	90	13000	50	14846	9401	23,32
A340-300	47320	23933	65	13000	100	14830	9439	23,35
A340-300	47320	23933	90	13000	100	14167	9850	23,47
A330-300	46695	30391	65	20000	50	9237	8059	23,67
A330-300	46695	30391	90	20000	50	8193	8701	23,68
A330-300	46695	30391	65	20000	100	7863	8905	23,68
A330-300	46695	30391	90	20000	100	6819	9553	23,7

Table 18: Data gathered concerning Airbus series 330-300 and 340-300[68]

In order to check if there is any linear connection between Pax Load + Cargo Load and **CEF** and **VEF** a calculation was made. **CEF** and **VEF** were divided by the total load in order to get [kg emissions / kg load] and [kg emissions / (kg load * km)]. The result for each payload factor is presented in Table 19 below.

	Total Load kg	**CEF** [kg emissions / kg load]	**VEF** [kg emissions / (kg load * km)]
A340-300	22056	0,41	0,00105
	28040	0,34	0,00083
	28556	0,33	0,00082
	34540	0,29	0,00068
A330-300	29754	0,27	0,00080
	37352	0,23	0,00063
	39754	0,22	0,00060
	47352	0,20	0,00050

Table 19: CEF & VEF specifics for A330-300 and A340-300[69]

The table shows there is no linear connection between Total Load and CEF or VEF. Therefore, an assumption had to be made. Cargo Factor is said to be 90%, but the Cabin Factor is unknown. A reasonable assumption would be to pick alternative three for both aircraft. The Cargo Factor is somewhat lower (90% against 100% in the table), while Cabin Factor can be assumed to be higher than the 65% stated in the table.

For Airbus 340-300 the values for **CEF** and **VEF** will be 0.33 [kg emissions / kg load] respectively 0.00082 [kg emissions / (kg load * km)] and for Airbus 330-300 the values will be 0.22 [kg emissions / kg load] respective 0.00060 [kg emissions / (kg load * km)]. In order to get a general emission factor, an average of the values for the two aircrafts will be used in following calculations. The average **CEF** is 0.28 [kg emissions / kg load] and the average **VEF** is 0.00071 [kg emissions / (kg load * km)].

Next step regards distance calculation. As said before, one of the main criteria for the emission model is that it has to be easy filling in the variables to be able to calculate the emissions, therefore it is not

[68] NTM (2010)
[69] Ibid

possible to get detailed information for each flight i.e. Airlog used ten different airports to send cargo from Europe in 2010 but in the model only an average distance is used.

To develop an average distance only the three most trafficked airports were used. The three airports were Copenhagen, Frankfurt and Helsinki which were used by 77% of the flights. The distance between the three airports and the final destinations were calculated on the website http://www.indianindustry.com and then divided by three to get an average distance. Following results were shown.

Country	Volume [Ton]	Average Distance [km]
Adelaide	0,40	15429
Melbourne	3,00	16300
Sao Paulo	53,64	9842
Other than AirLog	4,35	9842
Shanghai	35,67	7783
Other than AirLog	0,03	7783
Mumbai	15,07	6808
Other than AirLog	8,00	6808
Tehran	0,50	6815
Osaka	20,07	7966
Tokyo	81,80	8298
Busan	8,01	7644
Incheoni(Seoul)	8,50	7382
Other than AirLog	7,00	7382
Mexico City	0,03	9574
Kuala Lumpur	1,00	11625
Bangkok	9,85	8284
Istanbul	0,60	2145
Taipei	1,00	8347
Orlando	0,04	7643
Campbellsburg(Louisville)	2,00	8794
New York	8,25	6203
Hollsopple(Pittsburgh)	36,22	6711
Quebec (DHL)	6,00	6637
Delhi (Grencarrier)	0,50	7562
Randburg (Other)	0,01	8774
Guelph (Other)	5,00	6822
TOTAL	**316,54**	

Table 20: Average calculated distances regarding HSAB air transports.

To obtain the average distance per flight all distances are multiplied with the specific volumes and divided by total volume (316.54 tons). The average distance for all flights for HSAB is 8124 km.

The airline and logistic companies always strive to have as few stopovers as possible, therefore is the CEF part only multiplied by 1, i.e. no regards to stopovers are made in the calculation.

The emissions for a flight are as follows:

$Total\ emissions\ =\ CEF\ +\ VEF\ *\ Distance$

With the numbers from above, the values in HSAB's case is

$0.28\ + 0.00071 *\ 8124 = 6.018\ kg\ emission\ C02\ [kg\ /\ kg\ load\ *\ flight]$

This gives 0.0007408 emission $C0_2$ [kg / kg load * km]

Rewritten to the unit [g / ton load * km], the specific emission factor for the flights made by HSAB will be **740.8 $C0_2$ [g / ton load * km].**

To be sure this emission factor is accurate, calculations were made to see that the deviations from the *Total* emission = CEF + VEF * distance formula are not too large.

	Total Volume	CEF	VEF
A340-300	28556	0,33	0,00082
A330-300	39 754,15	0,224001770	0,000596

Table 21: Values for CEF and VEF from relevant cases

Worst case scenarios are when the routes are extremely short and extremely long.

Calculations for shortest route, 2145 km, using a A340-300 aircraft with $Total\ emission\ =\ CEF\ +\ VEF\ *\ distance$ formula.

$Total\ emission = CEF + VEF * distance = 0{,}33 + 0.00082 *\ 2145 = 2.084\ kg$

Calculations using our emission factor of be 740.8 $C0_2$ [g / ton load * km]

$Total\ emissions = Emission\ Factor * distance = 740.8 * 2145 = 1589016$ kg $C0_2$

Using kg in the first calculation, the second result has to be divided by 1 000 000 to get correct unit. Total emission using our emission factor is **1.589.**

The difference in percent is 24% less emissions if using the emission factor. The table below shows the numbers for shortest respectively longest flights for both aircrafts.

	Distance	Emission (CEF and VEF)	Emission (using emission factor)	Difference %
A340-300	2145	2,08	1,59	-24
A330-300	2145	1,50	1,59	6
A340-300	16300	13,66	12,08	-12
A330-300	16300	9,93	12,08	22

Table 22: Differences in using formulas shortest and longest flights

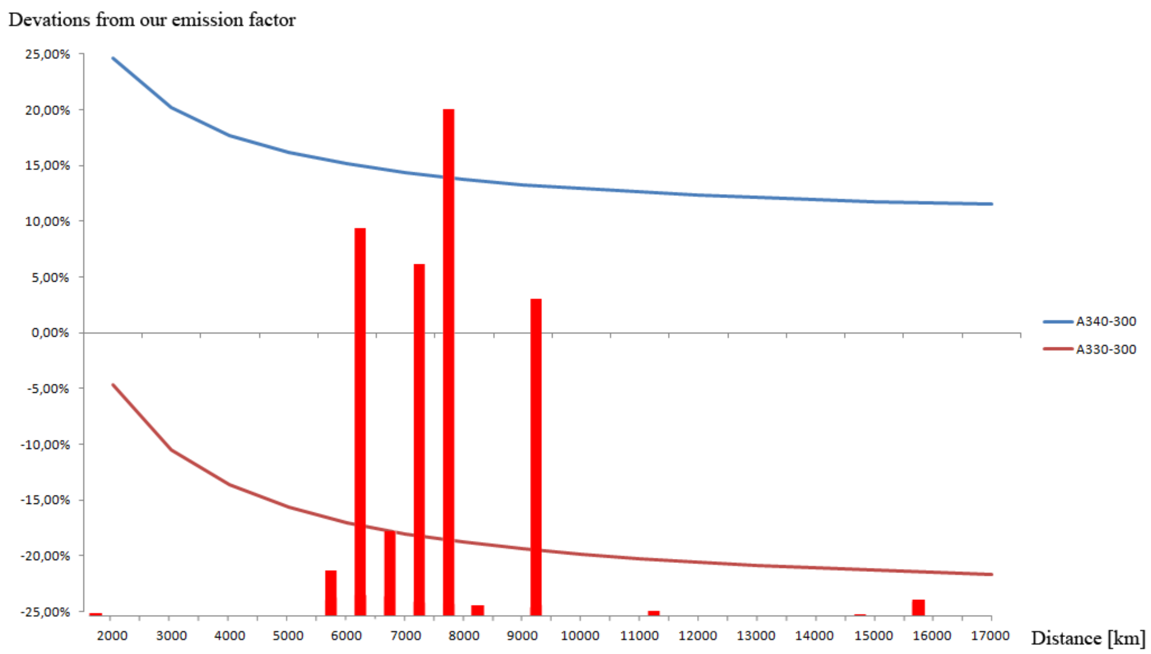


Figure 11: The figure shows the volumes and how the different types of aircraft differ from the average emission factor depending of the distance.

Figure 11 shows the deviations from the average emissions factor depending of the distance. The two lines shows the real emissions for the two different aircrafts calculated with the $Total\,emission = CEF + VEF * distance$ formula. Aircraft A340-300 has higher emissions than the average emission factor and the A330-300 has lower emissions. To get a correct average emission factor, the distance from the two lines to the 0.00% line should be equal.

As seen in Figure 11 and in Table 22, for 2000 km flights with the A340-300 aircraft the real emissions are approximately 25% higher than the calculated emissions. For 16000 km flights with the A330-300 aircraft the real emissions are approximately 20% lower than the calculated emissions.

However, the Figure 11 also shows the volumes transported by distances. As seen in the figure, a large amount of the total cargo is between 6000 km and 10000 km where the two aircrafts lines are at the same distance from the calculated emissions line. This gives the average emissions factor can be assumed to be correct if both types of aircrafts are used equal number of times, but for a specific flight the calculated emissions in the model can be 25% lower than the real emission.

If only one of the two different types of aircrafts is used, the difference between the emission factor calculations and real emissions can be approximately -15% to +15% for all flights in total.

The emission factor used in the model will therefore be 740.8 $C0_2$ [g / ton load * km].

The Emission Model

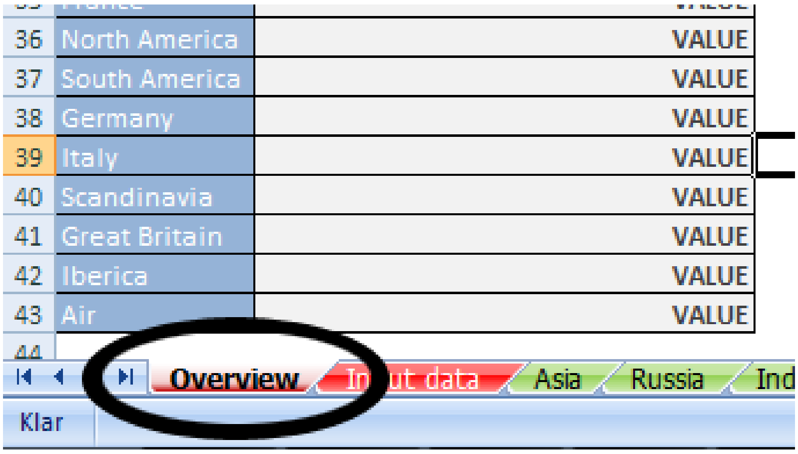
The description and interface of the developed model are shown in this chapter. The sentence of this section is to show the reader some insight and knowledge upon the model structure and set-up.

The Model

This part of the thesis contains a more detailed explanation of the model done in Microsoft Excel. The model can be divided into three parts, overview, input data and the part that contain all customer information sorted by each region.

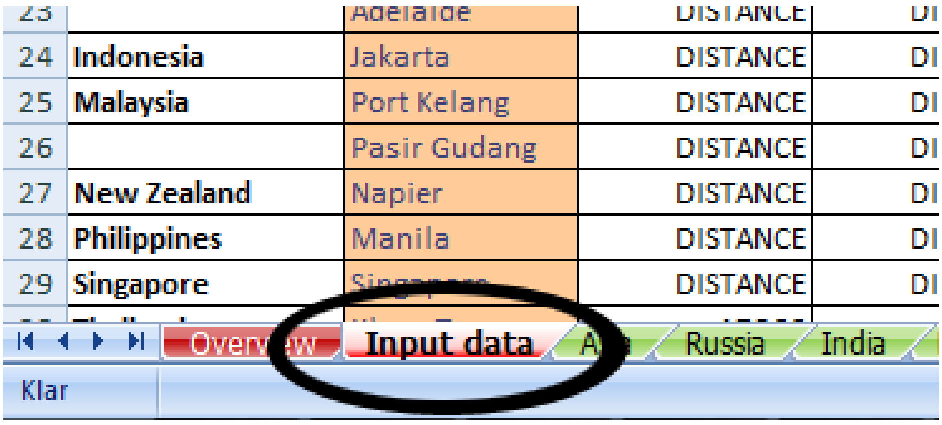
Overview sheet

The first sheet is the Overview sheet which shows global distribution emissions values, inbound logistics emissions values, emissions for each mode of transport, emissions per volume transported for each region, emissions shown as CO_2/Ton-kilometer and emissions for inbound freight transports.



Input data

In the Input data sheet the user is able to change input values for the model. The most important feature is the emission factor table. The values for each emission factor have been presented in previous chapters, but can easily be changed for future changes such as improved transportation methods and more efficient motor characteristics.



Note: If the emission factor values are changed, all the values in the model are automatically aligned as such.

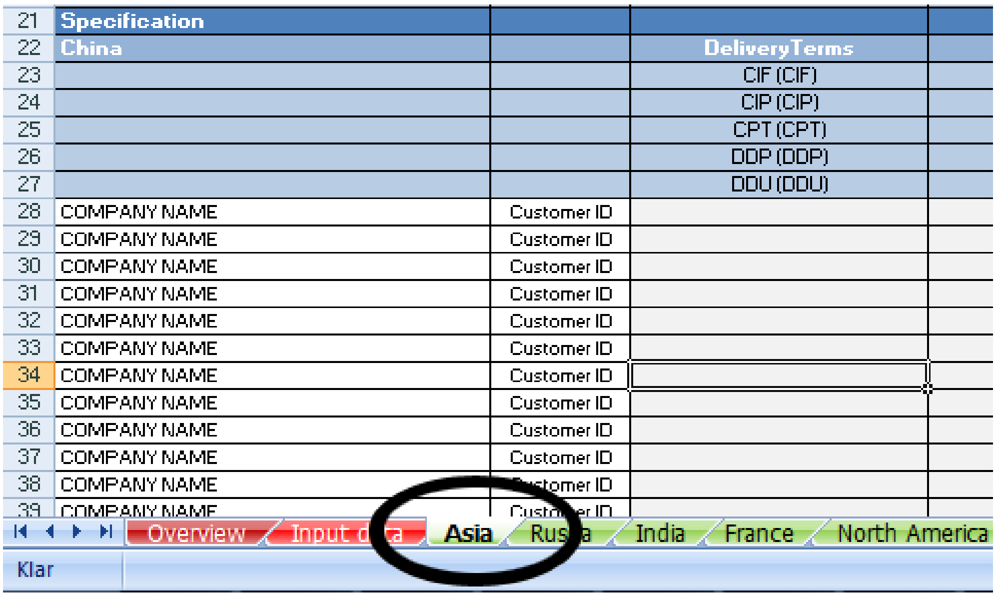
The other feature in the Input data sheet is the sea distance calculator. Since HSAB is transporting large volumes of shipments to Asia, it is of highest importance that distances between these two continents is accurate. These distances are basically divided into two different routes that one could take, either through the Suez Channel or the around the African continent. The route that is chosen depends upon a variety of different factors. These can include parameters such as transport fees when sailing through the Suez Channel, oil prices, pirate threats outside Africa's east coast and customer delivery demands.

The top right table, the user can divide in percentage how much of the annually shipments goes through the different routes. When changing these values, the average distances for all transports from Europe to Asia are automatically changed.

The user is also able to change the add-on percentage of the different transport routes since taken routes rarely are direct from starting origin to final destination. These values are explained and calculated in the chapter regarding emission factors.

Region sheets

There are eleven regional sheets, a sheet for air export and one for all incoming freight shipments. The air export has its own sheet because the utilization of air transports is never originally scheduled and differ variously from year to year, both regarding in volumes and/or destination wise.



21	Specification			
22	China		DeliveryTerms	
23			CIF (CIF)	
24			CIP (CIP)	
25			CPT (CPT)	
26			DDP (DDP)	
27			DDU (DDU)	
28	COMPANY NAME	Customer ID		
29	COMPANY NAME	Customer ID		
30	COMPANY NAME	Customer ID		
31	COMPANY NAME	Customer ID		
32	COMPANY NAME	Customer ID		
33	COMPANY NAME	Customer ID		
34	COMPANY NAME	Customer ID		
35	COMPANY NAME	Customer ID		
36	COMPANY NAME	Customer ID		
37	COMPANY NAME	Customer ID		
38	COMPANY NAME	Customer ID		
39	COMPANY NAME	Customer ID		

In every region sheet there are columns with customer names, volumes, sub-destinations and final destinations. The destination columns contain two to four columns depending of the need to have different transport modes for the same shipment. See Figure 12 for example.

Figure 12: illustration of route between Sweden and Italy

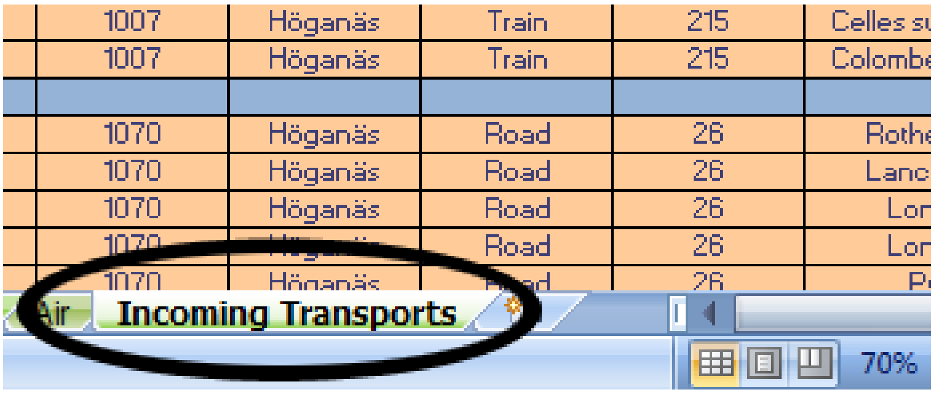
In every region sheet there is a small compilation table under the main table. The main reason for the compilation is to simplify the creation of the Overview sheet.

Air Sheet

The Air Sheet contains all air transports done during 2010 in HSAB´s accounting. The Air sheet only contains one column for destinations, which makes it a bit smaller than the regional sheets. The emission factors and the distances have been explained in other chapters. Where it is stated "Other than AirLog", another supplier is utilized. Note that AirLog are used for approximately 95% of the utilized air shipments.

Incoming Transport Sheet

The last sheet contains all incoming transports where the majority of shipments are distributed to Höganäs. The sheet has the same build up as the regional sheets except destination origin is at the supplier's address location and HSAB is stated as the final destination.



Results

The focus on this chapter lies upon the emission model results based on calculations upon data gathering and process mapping development. The results from the model are described and illustrated so that the reader will be given some deeper insight within HSAB's distribution system.

Overview

Figure 13 and Table 23 shows total emissions for each region. The Asia region is the region with highest amount of emissions with 62% of total emissions for outbound freight transport.

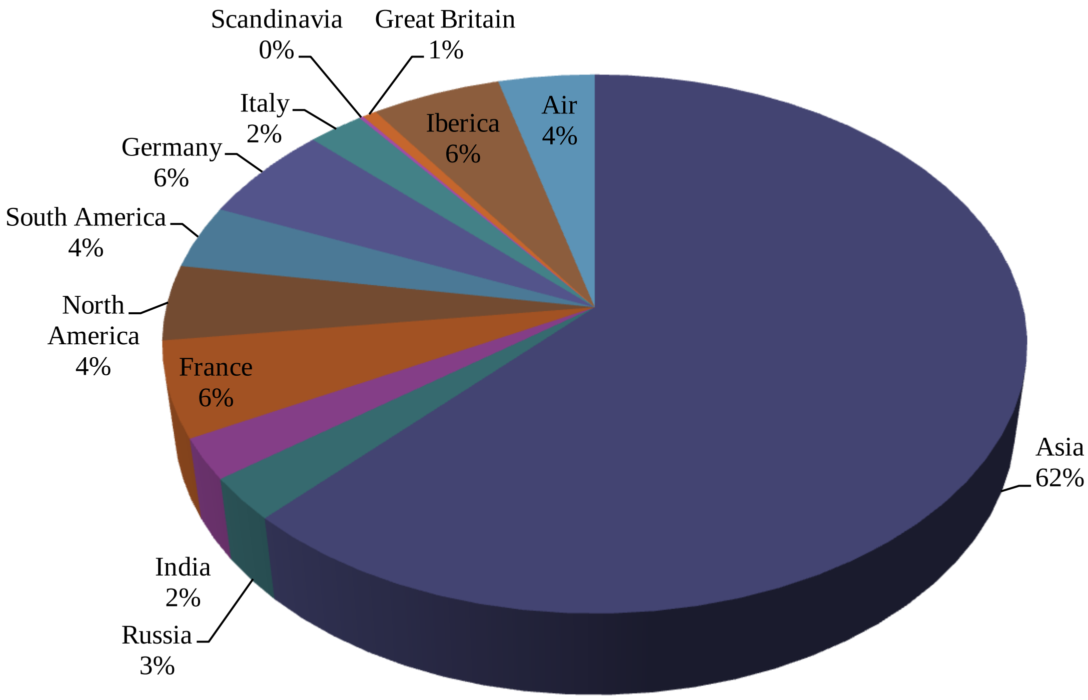


Figure 13: Overview chart, global [CO_2] emission distribution percentage

Region	Freight volume (Tons)	CO2 Pollution (Tons)
Asia	128299	31142
Russia	16491	913
India	7786	1234
France	13478	2758
North America	30530	2258
South America	15303	1912
Germany	51058	2216
Italy	20125	980
Scandinavia	4740	77
Great Britain	4093	171
Iberica	22795	1456
Air	317	1845
Total	**315015**	**46961**

Table 23: Overview, global distribution emission values

Figure 14 and Table 24 shows freight volumes for each region regarding inbound freight transports. Sweden has the largest amount of freight volume, but Mauritania has the largest amount of emissions with 7551 tons CO_2. These two regions have the largest impact on Höganäs AB total emissions for inbound freight transports.

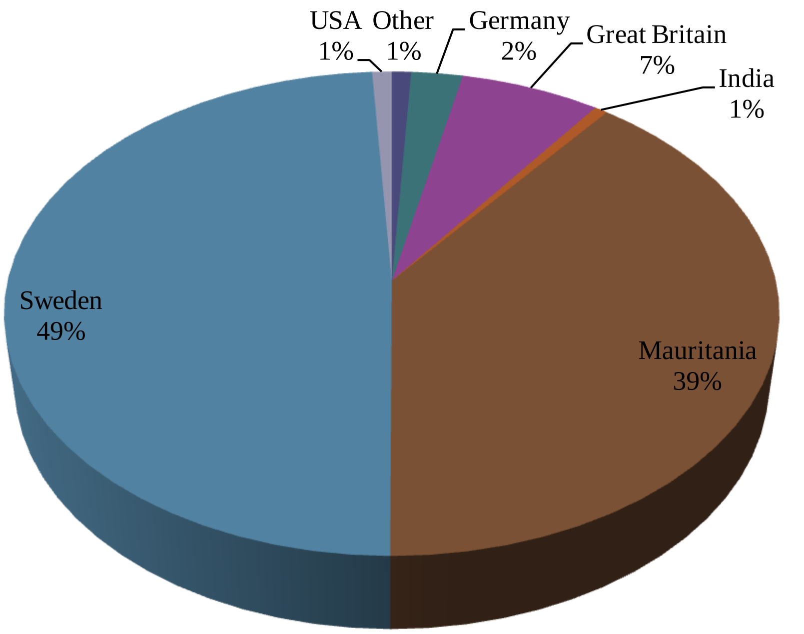


Figure 14: Overview chart, global [CO_2] emission inbound logistics percentage

Region/Country	Freight Volume (Tons)	CO2 Pollution (Tons)
Austria	220	7
Belgium	67	3
Brazil	69	9
Switzerland	392	28
Chile	339	50
China	2	0
Germany	16376	554
Denmark	1318	15
France	301	5
Great Britain	35549	911
India	1315	199
Italy	1015	44
Mauritania	84001	7551
Netherlands	4	0
Norway	583	39
Sweden	343405	7190
USA	3949	288
South Africa	375	58
Total	**489280**	**16952**

Table 24: Overview, inbound logistics emission values

Figure 15 and Table 25 illustrates the total emission value for each mode of transport. Sea Intercontinental shows the largest emission value, which can be explained by the large volume quantities of goods that is transported to Asia.

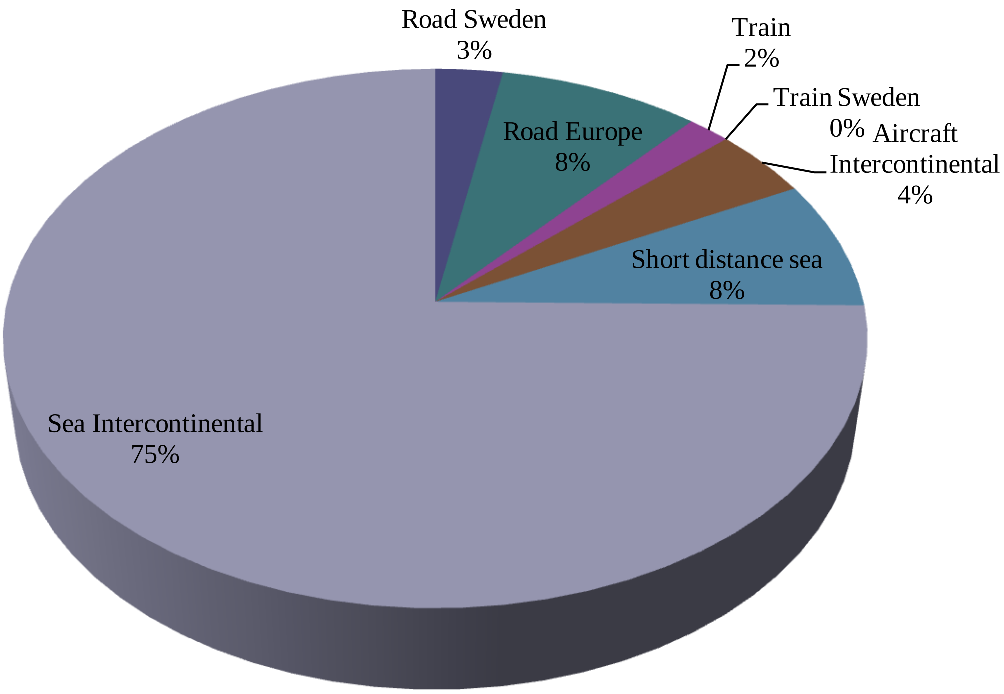


Figure 15: Emission percentage per transport mode regarding distribution

Type	Emissions(ton)
Road Sweden	1 261
Road Europe	3 773
Train	801
Train Sweden	0
Aircraft Intercontinental	1 845
Short distance sea	3 389
Sea Intercontinental	32 834

Table 25: Total emissions for each mode of transport.

Figure 16 and Table 26 shows the emission kg CO_2 per volume (ton) transported for each region, which can be translated to the cost in emission per transport to each region.

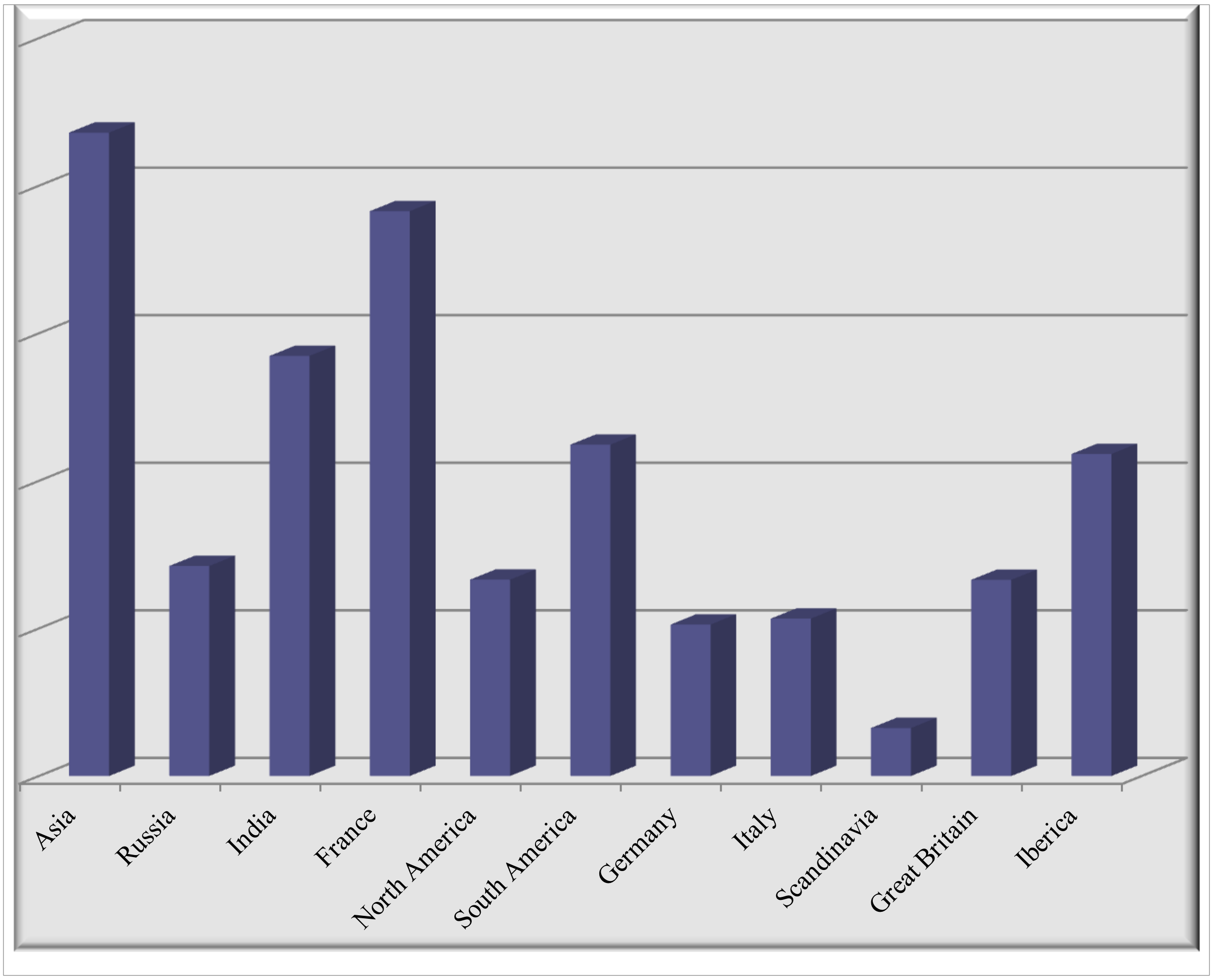


Figure 16: Emission CO_2 per volume transported for each region.

Region/Type	CO_2 (kg)/Volume(ton)
Asia	243
Russia	55
India	158
France	205
North America	74
South America	125
Germany	43
Italy	49
Scandinavia	16
Great Britain	42
Iberica	64
Air	5830

Table 26: Distribution emissions for each assigned cargo destination [CO_2 value per ton]

Table 27 and Figure 17 shows CO_2 /Ton-kilometer, in other words, how effective it is to transport goods to the different regions from an emission perspective. The regions with lowest emission per volume-kilometer are the regions where Sea Intercontinental is the main mode of transport.

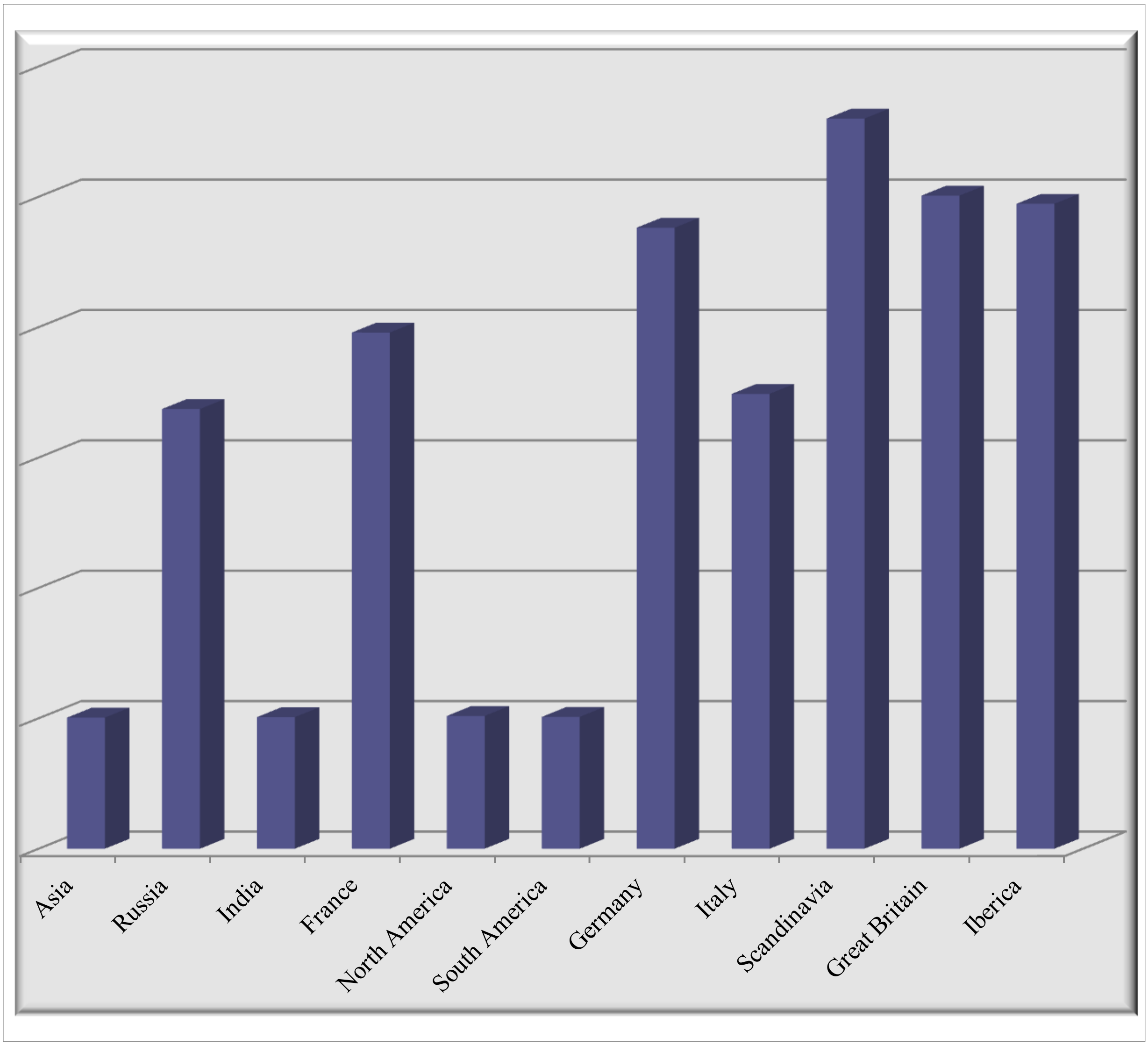


Figure 17: Emissions shown as CO_2 /Ton-kilometer.

Region/Type	Emission(kg)/Volume(ton) * km
Asia	10
Russia	19
India	10
France	39
North America	10
South America	10
Germany	41
Italy	32
Scandinavia	56
Great Britain	31
Iberica	29

Table 27: Distribution emissions shown as CO_2 /Ton-kilometer

Figure 15Figure 18 and Table 28 illustrates the total emission value for each mode of transport regarding inbound freight transports.

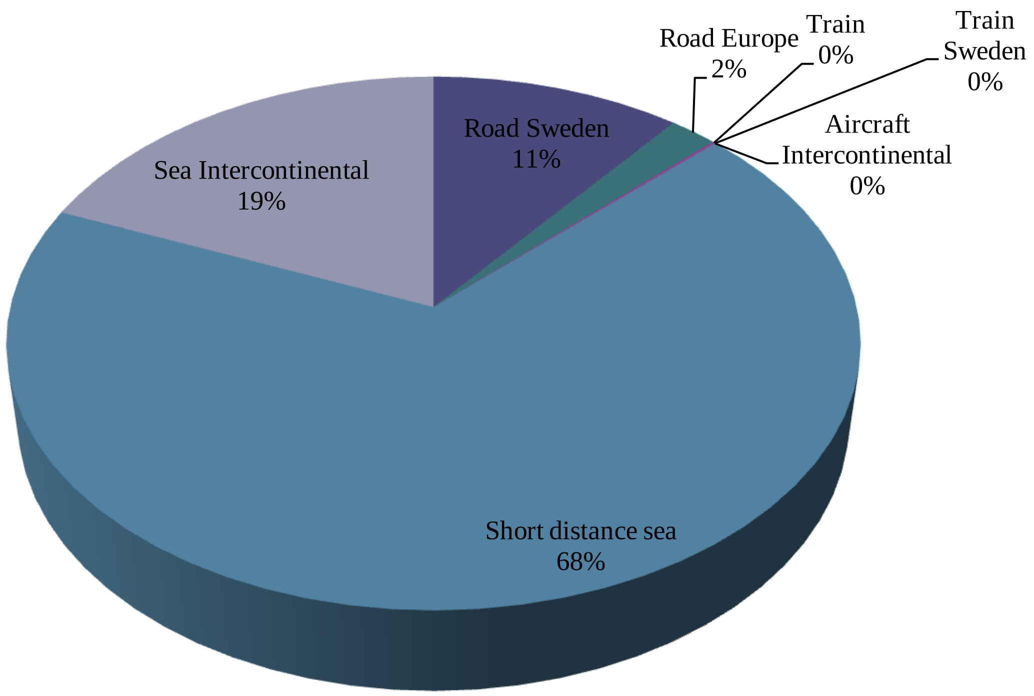


Figure 18: Emission percentage per transport mode regarding inbound freight transports

Type	Emissions(ton)
Road Sweden	3 054
Road Europe	582
Train	39
Train Sweden	0
Aircraft Intercontinental	0
Short distance sea	19 295
Sea Intercontinental	5 315

Table 28: Total emissions for each mode of transport.

Conclusion and discussion

The main findings upon reviewing the presented results are stated in this final chapter of the study. Furthermore the chapter will discuss model recommendations, limitations and possibilities for further research advancement. The chapter is initiated by a brief summary of the thesis study

The purpose of this thesis was to present a model that can be applied as an everyday tool that calculates the total emissions caused by freight transport throughout the Höganäs Group. A partial objective was also to give recommendations of possible means to reduce CO_2 emissions.

From the theoretical framework gathered by the initiation of this study, a model was brought forward with the purpose of identifying a company's carbon dioxide emissions during in\- outbound logistics. The created calculation tool is a result of adapted process mapping methodology, powered by data gained through interviews and intern ERP-systems. The results from the calculation tool provide insight of freight transport within HSAB and shows areas of potential for future environmental opportunities.

The model

The model was created in the computer software Microsoft Excel. As regularly used software, this fulfills the requirement that the model should be easy to use.

In order to maintain simplicity of the model, the information and input values collected by the user are limited to specific sections of the model to prevent the possibilities for result errors. Volumes and distance values are static parameters that have to be manually corrected by user when modifications are made in distribution systems in order to reflect accurate results.

The model is served primarily as a tool to calculate overall emission values throughout the company's transportation network. Other parameters affecting emission values are types of transports used and its specific engine class and characteristics. An example is that there for instance are two different aircrafts in this thesis with two different emission values. In order to maintain the easy handling operations for end-user, an average emission factor for these has been calculated. This can lead to deviations in real-life affiliation depending on which aircraft is used. The deviations in this case can be as high as 25%, but it is only on rare occasions. Same values for road transports are up to 21%. Due to these deviations, the model therefore should not be utilized for singular transport purposes. To obtain more information regarding the calculated emission values for each mode of transport, please refer to the chapter regarding "Project calculation approach".

When calculations in the model are made, the user obtains illustrative information regarding each sales region. Information in terms of total emission values, emissions per volume, emissions per volume-distance and emission for each mode of transport are shown in directly within the model. To read more about the model and how to edit and/or add to the customer base, please refer to Appendix 3 section of this report.

Main findings

After reviewing the result section of this study, it can be concluded that the total emission value regarding freight distribution at HSAB lies around 45 000 tons of carbon dioxide. Note that the Asia region stands for nearly two-thirds of the total emission count. The high emission value released from Asia region can be explained by the long distances from Sweden to Asia and the huge amount of cargo the company sends to this region on a yearly basis. In 2010 HSAB exported more than 315 000 tons of material where 128 000 of these were exported to Asia.

To be able to see where improvements can be done to reduce the CO_2 emissions, a more detailed insight than the traditional overview chart is needed. Table 26 in previous chapter shows as an example how much emission every ton cargo causes to a specific destination. Asia consists as the largest contributor which is no surprise since distances to Asia are the longest.

Table 27 displays carbon dioxide values as emission (kg)/volume (ton) * km. This shows the emission efficiency for transportation to a certain region. A low emission value equals the utilization of transport modes with low CO_2 emission factors. Looking at this table shows that the region with the highest emission count is Scandinavia. This can be explained by the high utilization of truck and trailer within this region. Regions where sea transport is the main mode of transportation have the lowest emission values, i.e. Asia, India, South America and North America.

The total emission value for incoming goods are only a third in comparison to emission values regarding exported goods even though HSAB imports 150 000 tons more than they export. This is a result of the large amount of domestic imported freight with short transport distances.

Improvements

Due to the fact that HSAB has outsourced transport activities to various freight forwarders, it is difficult for the company to apply major changes in the aspect of transportation logistics. The most obvious statement is to change mode of transport to a more emission efficient type when it is possible. This has proven to be difficult due to specific customer demands regarding when cargo is to be delivered in a certain way and time and has become obstacles in search of more eco-friendly solutions. Nevertheless, these are important variables to take into consideration, especially when reflecting upon possibilities of changing way of transports. Therefore it is suggested that mutual dialogues are made between the different actors in the supply chain to reach a consensus effort of providing a more environmental effective transport solution where each part is equally committed in order to reach the common goal of reducing its carbon footprint.

A related subject though that is gained throughout the investigations made in this report is the importance of production planning. This insures that each shipment cargo is planned at full capacity in terms of volume when possible and that demanded delivery times are met so that contingency plans including air transported cargo are avoided at all costs due to its high environmental impact.

During the study in coherence with freight forwarders, investigations were made regarding whether if possibilities of enabling trailers as carriers for two containers simultaneously could be an option of reducing number of transports and therefore reducing emission levels. But these investigations were denied by the national road administration due to the consequence of road abrasions. Nevertheless, should this matter be taken into matter and further investigated when future developments and technologies are considered.

Recommendation for further studies

As stated above, the region that represents the largest source of carbon dioxide emissions is Asia. And therefore it is concluded that this region should be prioritized in any discussions around improvement possibilities regarding reductions in greenhouse gas emissions.

Other findings and recommendations from this study will primarily serve as a basis for future guidelines. The new insights can, in order of the authors' recommendations, be used in areas such as:

- Environmental analysis of freight forwarder selections during nomination periods
- Baseline during evaluation of new logistical solutions
- Underlying documentation during internal /external emission evaluations
- For use in promotional purposes

Note that in order to keep the models useful purposes its database needs to be updated regularly to keep producing real life accurate emission values.

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Appendixes

Appendix 1 – General objective target & action plans corresponding to Management responsibilities, Höganäs AB

Area	Objective	Indicator (example)
Natural resources	Reduce the specific consumption of raw materials	Tons used/produced
Energy	Reduce the specific use of energy	kWh/ton product
Emissions to air	Reduce the emissions of dust, metals and gases from production	Specific emissions [Tons emission/ton produced] and where required for local impact reasons, also emissions per year [tons/year]
Emissions to water recipients	Reduce the emissions of metals from production	Specific emissions [Gram metal/ton produced] and where required for local impact reasons also emissions per year [kg/year]
Waste	Reduce the specific generation of waste	Specific waste production [tons waste/ton produced]
Industrial noise	With margin, comply with local legislation or site conditions for emission of noise	dB(A) compared to condition
Environmental risks	Work systematically to reduce environmental risks	
Products and processes	At product and process development, concern is taken to the environmental aspects	

Appendix 2 – Questionnaire used during email survey with Freight Forwarders

Hi,

We are students at LTH that as our master thesis is conduction a study at Höganäs AB were we are mapping in and outbound transport network in order to calculate their total carbon dioxide emission from these activities.

We are on progress of mapping the transport network but we are at the point where we need your help to complete the process. We would be grateful if you could spare us a couple of minutes of your time to answer the following questions.

Question1: To which destinations are transports made in behalf of Höganäs AB?

Question2: Which routes are taken during these transports?

Question3: Which types of transport modes are used during these routes (preferably also engine class of transport mode if that type of information is available)?

Question4: If different transport modes are used, please state where these switches are made.

We are utterly grateful for your time!

Best regards

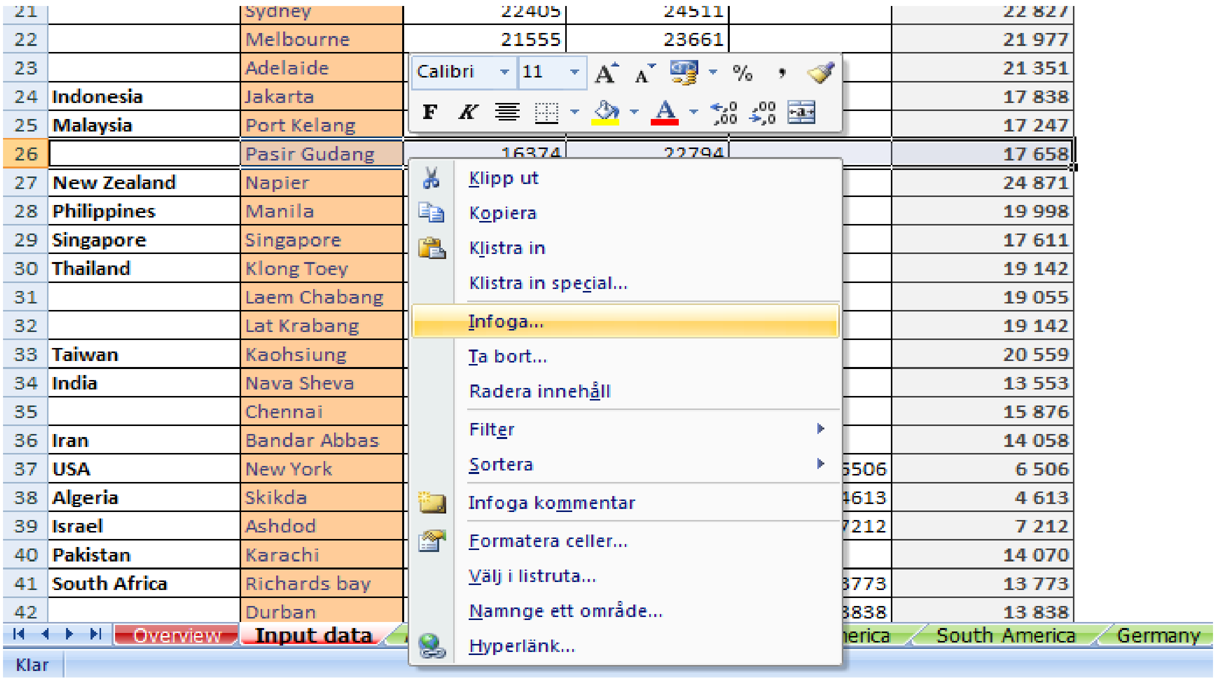
Masoud Zanganeh & Magnus Persson

Appendix 3 – Instruction manual for model

This appendix gives a more detailed description of the model and a manual to make it easier to apply changes.

The first sheet is called “Overview”. This sheet shows the results for all calculations in the model. There is no need to do anything in this sheet since all changes in the model will automatically be updated.

Next sheet is “Input data”. In this sheet the user is able to make some changes. In columns A-F sea distances is presented. When wanting to add a new harbour, the user has to insert the new harbour in the table manually. It is important when inserting a new harbour to insert a new row from column A-F and somewhere between the first row and the last row. See Figure below. Note, do not insert after the last row!



In the upper right corner the user is able to changes the route. Depending on oil prices, delivery time and risk of pirates outside the east coast of Africa, the transport companies can either go through the Suez channel or the whole way around the bay of Africa. Simply change the value in cell right to “Percentage Suez Channel” marked with a red background and the percentage of Good Hope will automatically be changed as well.

The last table in the sheet is the emission factors. The current emissions factors have been presented in the thesis, but if the user wants other values is it just to change the values in the cells and the whole model will be updated. If the name to the left is changed, do not forget to change the name in the list in all region sheets.

The next eleven sheets are the regional sheet. Every region has its own sheet with customer id, volumes, distances and emission variables. If a new customer is to be inserted, the procedure is same as for new harbors. Simple find the right country, the insert the new row somewhere between the first and last customer for the chosen country. Fill in the cells and the model is automatically updated.

Next sheet where changes can be applied is the sheet marked “Air”. To insert a new airport, simply follow the same procedures as for harbors and new customers in the region sheet. The last sheet is the sheet for incoming freight. Same procedure follows for this one as well, only difference is instead of starting origin, HSAB is stated as final destination.

Appendix 4 – Calculations

4.1 - Fuel consumption for different types of roads

Freeways

LCU 0% = 0.226 l/km

LCU 100% = 0.360 l/km

LCU 75% = (LCU 100% - LCU 0%) * 0, 75 + LCU 0% = (0.360 -0.226) * 0.75 + 0.226 = 0.3265 l/km

LCU 75% = 0.3265 l/km

Rural Roads

LCU 0% = 0.230 l/km

LCU 100% = 0.396 l/km

LCU 75% = (LCU 100% - LCU 0%) * 0, 75 + LCU 0% = (0.396 – 0.230) * 0.75 + 0.230 = 0.3545 l/km

LCU 75% = 0.3545 l/km

Urban Roads

LCU 0% = 0.288 l/km

LCU 100% = 0.504 l/km

LCU 75% = (LCU 100% - LCU 0%) * 0.75 + LCU 0% = (0.504 – 0.288) * 0.75 + 0.288 = 0.45 l/km

LCU 75% = 0.45 l/km

4.2 - Average emissions per ton*km

With the distribution of roads in Sweden in Table 5, the average fuel consumption is

Average fuel consumption = 0, 3265 l/km [Freeways LCU 75%] * 21% + 0.3545 l/km [Rural Roads LCU 75%] * 56.7% + 0.45 l/km [Urban Roads LCU 75%] * 22.3% =

= 0.37 l/km

Fuel data from Table 6

Sweden

CO_2 [kg] / km = Fuel consumption [l/km] * CO_2 [kg/l] = 0.37 * 2.54 = **0. 9398 CO_2 [kg] / km**

Europe

CO_2 [kg] / km = Fuel consumption [l/km] * CO_2 [kg/l] = 0.37 * 2.62 = **0.9694 CO_2 [kg] / km**

From the transport companies, average cargo volume is 20 tons. The surcharge for pre-positioning is 20%. The result for Sweden and Europe

Emission factor [CO_2 [kg] / (ton * km)] = 0.9398 CO_2 [kg] / km * 120% / 20 ton =

= **0.0564 [CO_2 [kg] / (ton * km)]** for Sweden

And

Emission factor [CO_2 [kg] / (ton * km)] = 0.9694 CO_2 [kg] / km * 120% / 20 ton =

= **0.0581 [CO_2 [kg] / (ton * km)]** for Europe

To investigate the deviations that may arise, calculations for all separate road types was made to see the difference from the values above.