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ENVIRONMENTAL ASSESSMENT OF INTERNATIONAL TRANSPORTATION OF PRODUCTS

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Abstract: Globalization has allowed goods and services to become increasingly available anywhere in the world. International transport is an essential part of globalization. This paper focuses on the evaluation of air emissions accompanying international transport of goods. The main method in performing the assessment of emissions is the Life Cycle Assessment (LCA). However, the case study will only deal with the transport of the product from the manufacturer to the intermediate user as the dealer. Results show that carbon dioxide and nitrogen oxides are the leading pollutants, which affect air quality. The truck is shown to be a heavy polluter in terms of its emission factors and it does not differ much between a European and an Asian country. Alternative fuels from the sensitivity analyses show that it can significantly lower the emissions. Acidification potential is the major environmental impact from the transport of the product.

Key Words: Life cycle assessment, international transportation, air emissions, environmental costs

1. INTRODUCTION

Globalization has allowed goods and services produced in one part of the world to become increasingly available in other parts of the globe. International transportation has been easily accessible as ever. For every action, that we make there is an accompanying reaction. The movement of goods and services has some externalities that come with it. International transportation has become important in society because of the mobility it brings. The world cannot function properly without the use of international transportation for trade with other nations. This dependence on international freight transport has led to its growth. Container ships have become larger than ever, road freight transport has also increased in recent years.

This growth leads to an increase in fossil fuel consumption, which is not sustainable, because oil is a non-renewable resource. The major effect of the increase in fuel usage is on the environment. Pollutants emitted from motor vehicles contribute to the degradation of the environment specifically air quality. With the knowledge that the transport sector is one of the heaviest polluters, it is necessary to measure and study the actual contribution of road transport activities and its products to the environmental impact. An analysis called the Life Cycle Assessment (LCA) is one method to know and assess the total impact of a particular product to the environment. The life cycle model starts from the acquisition of raw materials to the transport of these materials to the manufacturing plant for production. From manufacturing, it is transported to the end user. The final destiny of the product is as waste. The case study in this paper will only deal with the transport of the product from the manufacturer to the intermediate user as the dealer.

Several studies have been done on the effect of transport modes to the environment. Corbett and Fischbeck (1997) showed that ships are a significant source of air pollution. They made a global inventory of emissions from various types of ships and discussed some policy implications. Life Cycle Assessment of vehicles are done by several researchers such as MacLean and Lave (1998), they assessed the environmental and energy implications of a midsized automobile by performing a life cycle inventory analysis. They used the Economic Input-Output Life Cycle Analysis model to analyze the effects on the economy and the environment. Hayami, et.al (1996) also studied the environmental effects of producing one unit of automobile using the input-output analysis. They mentioned that the CO_2 emissions from the transport sector are large. Gaines, et.al (1998) performed a life cycle analysis of heavy duty trucks and proposed various alternative fuels and improved engine and vehicle systems to reduce the emissions from trucks. These studies aggregated the effect of the transport sector in producing a certain product; moreover, they focused on the effect of the product itself. Newstrand (1992) demonstrated some of the potential environmental costs of a modal shift from water transport to other modes of transport. This paper also calculates the external costs from the international transport of a particular product. Related literature are mentioned here. Matthews, et al (2001) estimated external costs of air emissions from transportation facilities and services. The external costs are based on the air emissions of conventional pollutants. Heaney, et al (1999) estimated external costs from interregional transport in rural Ireland. Forkenbrock (1999) estimated four general types of external costs for intercity freight trucking and compared them with the private costs incurred by carriers. He estimated that that diesel-powered heavy trucks transporting 14.80 tons on average in rural areas produce air pollution costs of 0.08 cent per ton-mile.

This paper evaluates the transportation systems involved in exporting a product from one country to another. The environmental cost, time and emissions of different types of pollutants are presented. The research also suggests some alternative solutions to lessen the environmental impact of transporting the product. The costs and time impacts are appraised for the suggested alternative. Life Cycle Assessment is a long process of assessing the inputs and outputs of a product system from cradle to grave. This study will only focus on the actual transport system of the product from its origin and destination. It will also concentrate on the major transport modes used in the transport chain. It will only evaluate the emissions of six types of air pollutants namely carbon dioxide (CO_2), hydrocarbons (HC), nitrogen oxide (NO_x), sulfur dioxide (SO_2), particulate matter (PM) and carbon monoxide (CO), from the major transport modes involved in the shipment. The product will be a car made in Sweden, which is in demand in the world today because of its safety features. This study will not deal with the raw material acquisition, car production process or even the use of the car or the waste management done. Only emissions to air are considered in the study.

The paper is organized into 7 sections. The first part includes the introduction, the 2nd part is the methodology, which discusses the life cycle procedure, the surveys conducted for data collection, the transport chain and the emission model used for the calculation. The third section is the inventory analyses, the results of the calculation are mainly in this section. The fourth section is the impact assessment done based on the results from the inventory analysis. The alternative solution to lower the emissions using sensitivity analysis follows the impact assessment. The total environmental costs from the transport of the product are presented in the sixth section. Concluding comments close the paper in section 7.

2. METHODOLOGY

The goal definition and scoping defines and limits the objectives of the study. Inventory analysis is the detailed description of the product systems and the inputs and outputs of that system. Within the impact assessment, there is a need to characterize the pollutants in terms of the impact they give to the environment then an indexing or valuation is done to combine the results together into one value. Figure 1 shows the LCA framework. The goal is to appraise the transport system in moving products internationally and to show the impact of this system on the environment. The product for the case study is a car manufactured in Sweden. The cars are exported from Sweden to Japan twice a month with about 50 cars per shipment.

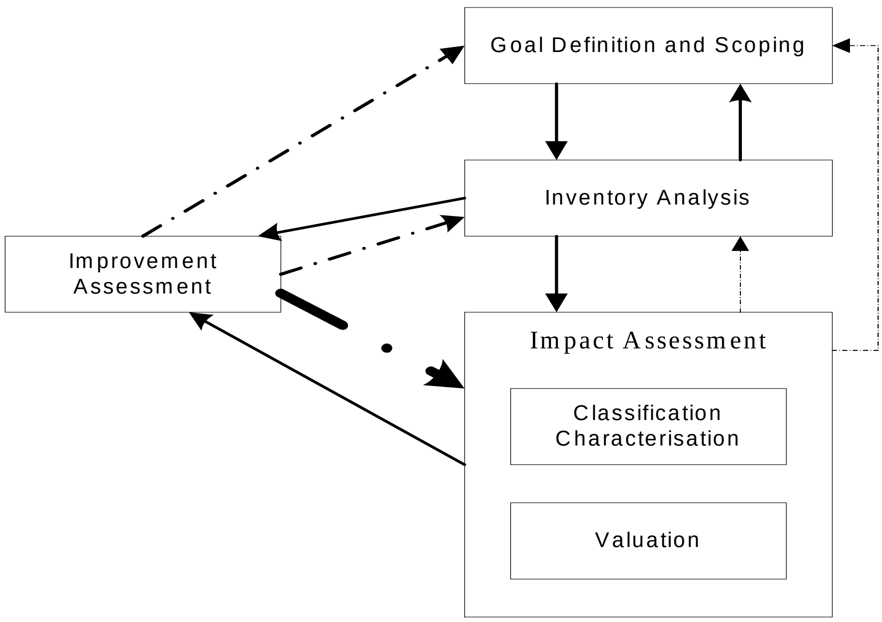


Figure 1. Methodological framework of the LCA. The unbroken arrows show the main route of the assessment. The dotted lines illustrate the iterations that may be necessary. (Blinge, 1998)

Data for the inventory analysis was collected mainly by a questionnaire e-mailed to the company responsible for the export of the cars to Japan, a telephone interview and secondary data collection through the Internet and literature. The company responsible for the export of the cars to the Japanese market is the Hyundai Sweden Shipping Agency AB. The group had made a questionnaire for the agency to answer. The person in charge for the export was not able to answer all the questions so she referred us to Hyundai Merchant Marine Europe located in London, which is the headquarters of Hyundai Shipping in Europe. A telephone interview to the car company was also conducted to get necessary data such as costs required for the inventory analysis. Figure 2 shows the procedure for the inventory analyses.

The functional unit is based on the specified main function of the system under study. All data will be related to the functional unit (Lindors, 1995). Usually in other studies, the unit for emission factor is in grams per load over a certain distance travelled. However, the functional unit used for the emissions is in grams/ car-km. This means that each gram of pollutant emitted is attributed to the product transported over a certain distance.

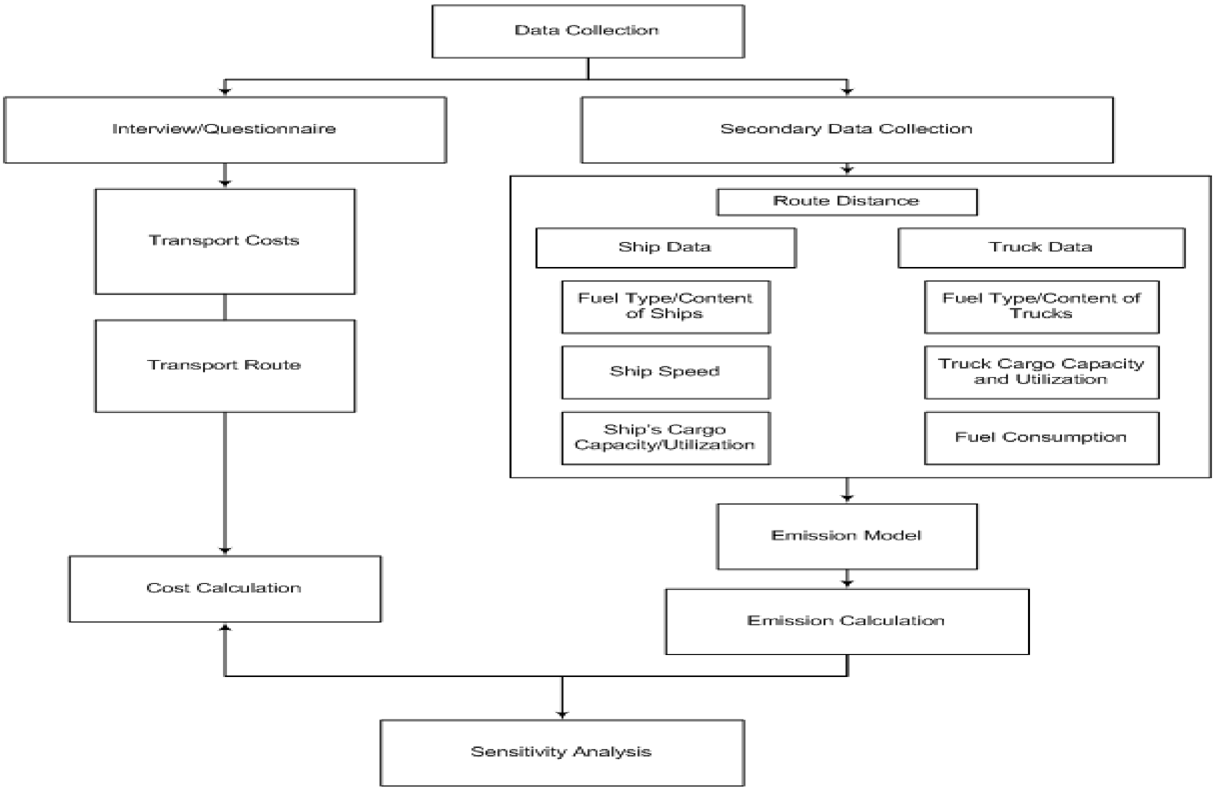


Figure 2 The flow of the inventory analysis stage

2.1 The Transport Chain

The transport of the Swedish cars begins from the factory at Torslanda, Hisingen. A truck transfers them for 12 kilometers from the factory to the Port of Gothenburg. A Roll-on Roll-Off (Ro-Ro) ship transports the cars to Nagoya, Japan. The ship, from the Gothenburg Port, will go to Antwerp, Belgium and then to Southampton in England. From Southampton it proceeds to Jeddah, Saudi Arabia and calls to port in Singapore until it reaches Nagoya, Japan. The map in figure 3 shows the route of the ship from the port in Gothenburg to the port in Nagoya. It usually takes 34 days to travel from Gothenburg to the dealer in Tokyo. The total distance traveled by the Ro-Ro ship from Gothenburg port to Nagoya, Japan is 28,000 kilometers. When the ship arrives at Nagoya port, a car carrier transports the cars to the dealer in Tokyo. The distance traveled by the truck to Tokyo is about 260 kilometers. Therefore, the total distance traveled in the transport chain is 28,272 kilometers.

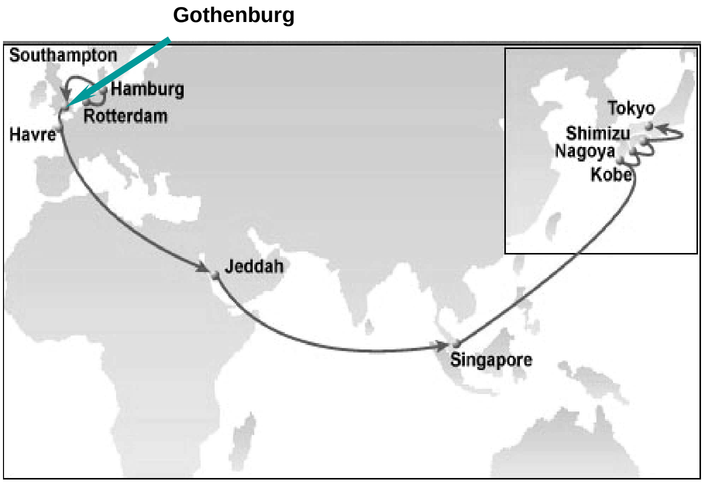


Figure 3 Route of Ship from Gothenburg to Japan

2.2 Emission Models

The following models are the equations used in calculating the emissions for the trucks and ship for the transport chain. Equation 1 is the emission factor formula. The basis of the formula is on the type of fuel a certain transport system is using.

$$EF = C_f * EC_f \quad (1)$$

where: EF = Emission Factor, g/l
C_f = specific emission, g/kWh
EC_f = Energy content of fuel, kWh/l

Equation 2 is the formula for calculating the total emissions of truck transport. The total emissions are based on the carrying capacity of the truck as well as its emission factor and fuel consumption. The cargo capacity used in the inventory analysis was assumed to be the number of cars a truck could carry instead of the weight in tons.

$$E = (FC * EF) * d * (1/C_c) * (1/U) * L \quad (2)$$

where: E = Total Emissions, g
EF = Emission Factor, g/l
FC = Fuel Consumption, l/km
d = Total distance, km
C_c = Cargo Capacity
U = Cargo Utilization, %
L = load

Equation 3 shows the formula for computing the emissions for ship transport. The total emissions for ship transport are based on the type of engine that the ship uses as well as the cargo capacity and speed of the ship.

$$E = (C_f * \frac{EP}{S}) * d * (1/C_c) * (1/U) * L \qquad (3)$$

where: E = Total Emissions, kg
C_f = specific emission, g/kWh
EP = Engine Power, kW
S = Speed, kph
d = Total distance, km
C_c = Cargo Capacity
U = Cargo Utilization, %
L = load

The calculation of emissions in the next section uses the above models.

3. INVENTORY ANALYSES

The inventory analyses in a life cycle assessment comprise a detailed description of the system and the calculations. The case study will only deal with the transport of the product from the manufacturer to the end user or the intermediate user as the dealer. Figure 4 shows the model of transporting the product from the factory to the dealer.

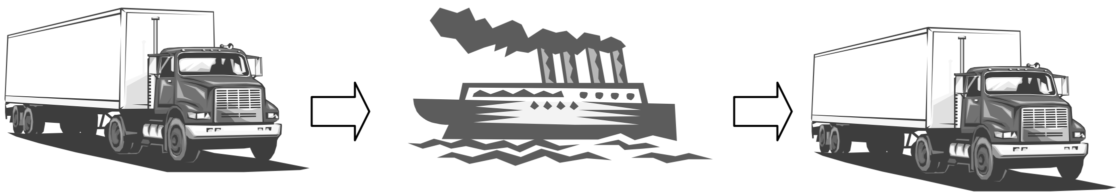


Figure 4 Transport chain model for the LCA analysis

3.1 The emission calculation for truck transportation in Gothenburg

The truck, which transports the Swedish cars to the port of Gothenburg, is a Volvo F16 truck, which has an engine, built in 1989. The truck's diesel engine runs on the Swedish MK-1 diesel. The energy content of this Swedish diesel is 9.77 kWh per liter while its sulfur content is 0.001 % by weight. Since this engine was from 1989 it is under the category EURO 0. The number of cars a vehicle carrier can bring is used for cargo capacity instead of the maximum weight in tons because the capacity of the vehicle carrier is constant for the type of car that is transported. The truck can carry 10 cars therefore five car carriers are needed to move fifty cars.

Table 1 shows the calculation for emission factors for each type pollutant. Table 1 uses Equation 1 to calculate the emission factor for the Volvo F16 truck. Note that L or load here is meant to be the number of cars transported but in general, it can be in the actual product weight. The specific emission or energy of engine in gram/kWh is dependent on the type of engine, the manufacture date and the speed or revolutions of the engine. The values of specific emission/energy of engine in the table are exclusively for the type of engine used in the truck, in this case, the Volvo F16 truck. The emission factors used in the following tables are reliable because they are based on the engine manufacturer's data and government standard as well as the energy content of the fuel type used. The energy of engine data was taken from the Network for Transportation and the Environment in Sweden.

Table 1. The emission factor for truck transport in Gothenburg

Emission element	CO_2	NOx	SO_2	HC	PM	CO
Energy of engine: (gram/kWh) [1]	665.5	12	207	0.5	0.27	1.2
Efficiency of engine: (%)	40	40	40	40	40	40
Conversion to fuel: (grams/kWh(fuel))	266.2	4.8	82.8	0.2	0.108	0.48
Energy Content of Fuel: (kWh/litre)	9.77	9.77	9.77	9.77	9.77	9.77
Emission factors: (grams/litre)	2600.77	46.89	808.95	1.95	1.05	4.68

Source: Author's Calculation
[1]http:www.ntm.a.se

Table 2 presents the calculated emissions using the assumed fuel consumption for the truck as 0.4 liters/km. Carbon dioxide, a greenhouse gas, has the largest emission rate compared to the other pollutants. The total emissions are calculated in Table 2.

Table 2 Emissions calculated for truck transport in Gothenburg

Emission elements	CO_2	NOx	SO_2	HC	PM	CO
Fuel Consumption: (litre/km)	0.4	0.4	0.4	0.4	0.4	0.4
Emission Factor: (grams/litre)	2600.77	46.89	808.95	1.95	1.05	4.69
Cargo Capacity: (cars)	10	10	10	10	10	10
Cargo Utilisation: (%)	100	100	100	100	100	100
Emission Rate: (g/car-km)	104.03	1.88	32.36	0.08	0.04	0.19
Total Distance Travelled: (km)	12	12	12	12	12	12
Total Cargo Capacity: (cars)	50	50	50	50	50	50
Total Emissions: (grams)	62,418	1,125	19,416	48	24	114

Source: Author's Calculation

3.2 The emission calculation for the ship transportation

The ship used in transporting the cars from the port of Gothenburg to the port of Nagoya is a Roll-On Roll-Off ship with a service speed of 19.5 knots or 36 kilometers per hour. The ship was built in 1988 with a shaft horsepower of 11,950 brake horsepower, this brake horsepower is converted to kilowatts (kW). The distance traveled by the ship from Gothenburg to Japan is approximately 28,000 kilometers. To get the specific emission or energy of engine in g/kWh, the middle speed from the table in the network for transportation and environment homepage was used. The emission factor calculated is dependent on the number of vehicles in the Ro-Ro ship. The Ro-Ro ship carries 6,000 units of cars, 3,100 units of mini-van, 540 units of trucks and 415 units of buses. The emissions are allocated to each of the vehicles inside the ship. It was assumed that each vehicle is equal in terms of the contribution to the emissions. The product of the total distance traveled and the number of cars transported is multiplied to the calculated emission rate to get the total emissions in kilograms.

Table 3 shows the total emissions calculated for transporting the 50 cars by a Roll On – Roll Off (Ro-Ro) ship. Note that there is no available data for SO_2. The table shows that the emission rate of each type of pollutant is much lower than those of the trucks in Gothenburg and Japan have. The carbon dioxide emission rate of the ship is 4.45 times lower than the emission rate for truck. For the other pollutants, the ship's emission rates are 5 to 11 times lower. This means that the ship engine is more efficient than the truck engine.

Table 3 The Emission Calculated for Ship Transportation

Emission elements	CO2	NOx	HC	PM	CO
Energy of engine (g/kWh)[1]	620	14	0.2	0.4	1
Engine Power (kW)	8914.70	8914.70	8914.70	8914.70	8914.70
Speed (kph)	36	36	36	36	36
Cargo Capacity (veh)	10055	10055	10055	10055	10055
Cargo Utilization (%)	80	80	80	80	80
Emission Rate (g/car-km)	19.086	0.431	0.006	0.012	0.031
Distance from Gothenburg to Japan (km)	28000	28000	28000	28000	28000
Number of vehicle (car)	50	50	50	50	50
Total Emissions (kg)	26720.95	603.38	8.62	17.24	43.10

Source: Author's Calculation
[1]http:www.ntm.a.se

3.3 The emission calculation for the truck transport in Japan

The total distance from Nagoya to Tokyo is about 260 kilometers; this value is used, to get the total pollutant emissions in grams. The diesel engine for this case uses low-sulfur diesel, similar to that used in Gothenburg. The fuel consumption is 2.8 km/liter. The values for the energy of engine (g/kWh) are taken from the Motor Vehicles Exhaust Standard, Japan's Ministry of Environment, wherein the average values for a diesel truck are used.

Table 4 Emission factor for truck transport in Japan

Emission Elements	CO2	NOx	SO_2	HC	PM	CO
Energy of Engine (g/kWh)	628	4.5	-	2.9	0.25	7.4
Efficiency of Engine (%)	40	40	40	40	40	40
Conversion to fuel (g/kWh(fuel))	251.20	1.80	-	1.16	0.10	2.96
Energy Content of Fuel (kWh/liter)	10.94	10.94	10.94	10.94	10.94	10.94
Emission Factors (g/l)	2748.13	19.69	-	12.69	1.09	32.38

-no data available
Source: Author's Calculation

Table 5 Emissions for truck transportation in Japan

Emission Elements	CO2	NOx	SO_2	HC	PM	CO
Fuel Consumption (l/km)	0.357	0.357	0.357	0.357	0.357	0.357
Emission Factor (g/l)	2748.13	19.69	-	12.69	1.09	32.38
Cargo Capacity (cars)	50	50	50	50	50	50
Cargo Utilization (%)	100	100	100	100	100	100
Total Distance (km)	260	260	260	260	260	260
Emission Rate (g/car-km)	98.17	1.05	-	0.27	0.05	0.33
Total Emissions (kg)	1275.916	9.142	-	5.891	0.507	15.034

-no data available
Source: Author's Calculation

The emission rate of carbon dioxide is 6 % lower than the truck from Gothenburg has, however, the emission rate of hydrocarbons; particulate matter and carbon monoxide are much higher compared to the truck used in Gothenburg.

4. IMPACT ASSESSMENT

The impact assessment is the third component of the LCA. It aims to analyze and assess the environmental impacts of the interventions identified in the inventory analysis (Lindfors, 1995). The impact assessment is divided into three subsequent sub-components: classification, characterization and valuation. Classification is a qualitative step, wherein the different inputs and outputs of the system are assigned to different impact categories. Characterization is a quantitative step wherein the relative contribution of each input and output to its assigned impact categories is assessed. Valuation is either a quantitative or qualitative step in which the relative importance of the different potential environmental impacts from the system are weighed against each other, the use of this sub component is an optional step.

4.1 Classification

This section will discuss the impacts of the emissions presented in the previous section. The impacts presented are based on the emission levels and costs. Figure 5 shows the impact of the pollutants to the environment.

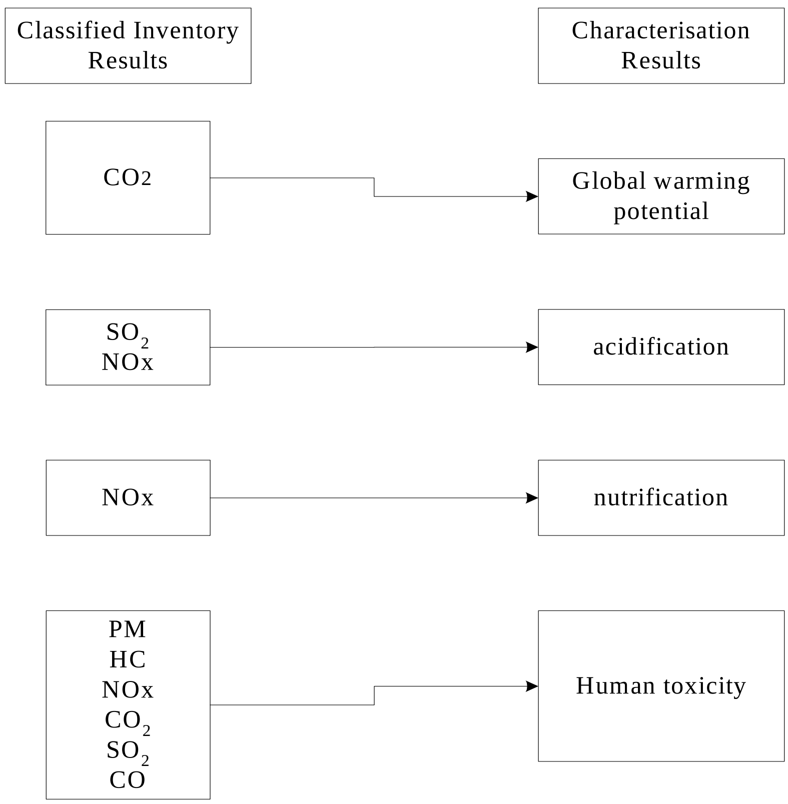


Figure 5. Impact of the pollutants to the environment.

Each type of pollutant can be grouped together to see the effects they have on the environment. Carbon dioxide, CO_2 is a greenhouse gas, which can cause global climate warming that may have disastrous effects. The Global warming potential is measured relative to the effect of 1 kg of CO_2. Sulfur dioxide, SO_2 and nitrogen oxides are two of the pollutants, which cause acidification when mixed with water in the air. Acid rain is one effect of acidification, which causes plants to wither and buildings corroded. NOx also causes nutrification, a phenomenon that depletes the nutrients of the soil, thereby decreasing agricultural productivity. The nutrification potential is measured relative to the effect of 1kg of phosphate. The pollutants in the study cause detrimental health effects as shown in the figure. NOx when inhaled affects the respiratory system and it increases susceptibility to infections among others, SOx, likewise affects the lungs. Carbon monoxide, an odorless gas affects the nerve, heart and vascular systems and even causes death when inhaled indoors in large amounts. Hydrocarbons (HC) and particulate matter (PM) are both cancer inducing and irritates the throat and eyes as well. The human toxicity potential is measured as the human body weight that would be exposed to the toxicologically acceptable limit by 1 kg of substance.

4.2 Characterization

The potential contribution to the impact i from the input or output j, C_{ij} can be calculated as the product of the emitted amount or mass of input or output E_j, and the weighing factor. The equation is shown as follows:

$$C_{ij} = E_j W_{ij} \tag{4}$$

The weighing factor, W_{ij} or equivalency factors for the different impacts in the classification of impacts are shown in Table 6. These values were taken from the CML, provisional method, for human toxicity in Lindfors, et al (1995).

Table 6 The Equivalency factors for characterization

	CO2	NOx	HC	PM	CO
Global Warming Potential (kg/kg)	1.00	-	-	-	-
Acidification (kg/kg)	-	0.70	-	-	-
Nutrification (kg/kg)	-	0.13	-	-	-
Human Toxicity (kg/kg)	-	0.78	0.377	-	0.012

-no data available
Source: Lindfors, 1995

Multiplying the emission results from the inventory analyses by its corresponding equivalency factors, we will get the characterization results as shown in Table 7. The table presents the total impacts to the environment due to the transport of 50 cars from Sweden to Japan.

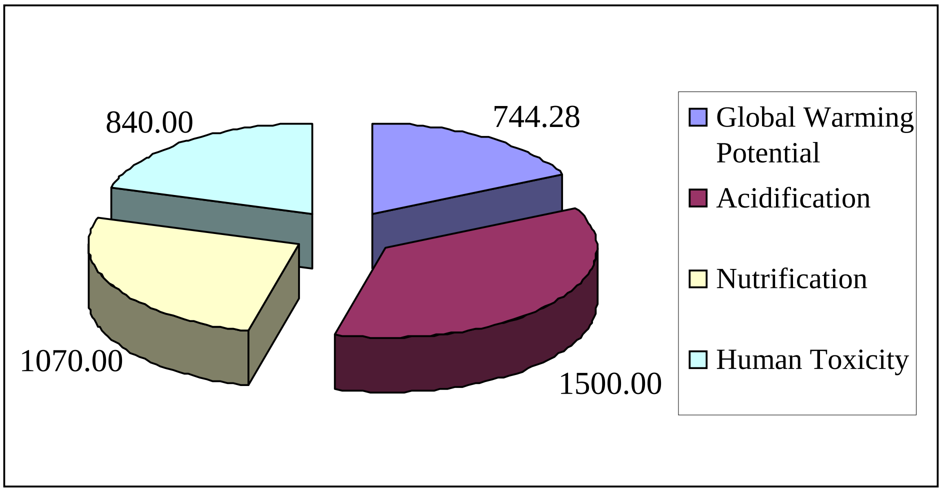
The contribution of carbon dioxide to the total environmental impacts is significant. Carbon dioxide has the largest amount of emissions compared to other pollutants; it contributes to almost 98% of the total emissions in the whole transport chain. The ship is the biggest contributor to the emissions not because of the poor quality of fuel or the efficiency of the engine but merely because of the distance traveled by this mode. The ship's diesel engine is already the most efficient engine because it has the lowest emission factor for each pollutant compared to the trucks. Another pollutant in the analysis, which is a problem, is nitrogen oxide. Nitrogen oxide affects the respiratory system and increases susceptibility to infection. This gas also needs to be controlled.

Table 7. Characterization Results for the transport of a product

	CO_2	NOx	HC	PM	CO	TOTAL
Global Warming Potential (kg)	28059.29	0.00	0.00	0.00	0.00	28059.29
Acidification (kg)	0.00	429.55	0.00	0.00	0.00	429.55
Nutrification (kg)	0.00	79.77	0.00	0.00	0.00	79.77
Human Toxicity (kg)	0.00	478.64	5.49	0.00	0.70	484.83

Source: Author's Calculation

In order to see the effect of the environmental impacts due to the transport of the car in terms of global emissions, the characterization scores are compared to global emissions. This is done by dividing the scores by the global figures for common environmental problems. The normalization values are found in the table in UNEP (1996). The results are shown in Figure 6.



Note: Author's Calculation (values in ((a*10^{-12}))

Figure 6. Normalized Score of the Environmental Impacts for the transport of the cars

The results show that for transporting a car, much of the environmental impact is on the acidification potential because of much NOx and SOx emitted in the air. Knowing the potential environmental impacts from the transport of the car, an alternative solution is proposed to minimize the impacts, as presented in the next section.

5. ECOPLAN

The alternative solution proposed for this case is the use of compressed natural gas for the truck transport and a speed reduction of 3 knots for the ship transport. Compressed natural gas as an alternative fuel is used because the technology is already available and it is ready to be put in operational use. CNG is a clean-burning alternative fuel for vehicles with a significant potential for reducing harmful emissions especially fine particles. In diesel engines, a major part of the fuel remains unburnt, making up particulate emissions. Nylund and Lawson (2000) finds diesel combustion emits 84 grams per kilometer (g/km) of such components as compared to 11 g/km in CNG and the level of GHGs emitted from natural gas exhaust is 12% lower than diesel when the entire life cycle of the fuel is considered. CNG run vehicles also have quieter operation, less vibrations and less odor than equivalent diesel engines. Another reason for the choice is that the same diesel engine can be used but only converted to take in natural gas. The converted engine will have equivalent - or better- power and torque characteristics than the original engine (Watt, 2001). The emission factors for a CNG engine is shown in table 8. Table 8 also presents the emissions calculated.

Table 8 The alternative result for use of natural gas engine in Gothenburg

Pollutant	CO_2	NOx	HC	PM	CO
Emission factor (g/kWh): Natural Gas	0.98	2.0	0.2	0.05	0.30
Emissions Calculated: (grams/car-km)	0.15	0.31	0.03	0.01	0.05
Total Emissions: (grams)	91.92	187.58	18.76	4.69	28.14

Source: Author's Calculation

The ship transport emits the most pollutants in the air because of the distance traveled by the ship, which makes it a heavy polluter. A natural gas engine could be proposed for the ship but the use of this type of engine has a limited trip range, which might not be applicable at this time. Energy consumption, and thus also emissions, are affected to a large degree by speed. Energy consumption for vessels is proportional to the speed squared. This means that if we want to double the speed, we also increase energy consumption fourfold. Therefore, the solution proposed is the change in speed of the ship from 20 knots to 17 knots. This reduction in speed will incur a delay for the ship of 3 days so that the total travel time from Gothenburg to Tokyo will be 37 days. Reduction of speed will incur a delay but this delay can be recovered through more efficient handling in the ports. The results are shown in Table 9.

Table 9 The alternative result for lower speed for ship transport

Pollutant	CO_2	NOx	HC	PM	CO
Speed (kph)	31.025	31.025	31.025	31.025	31.025
Emissions Calculated: (grams/veh-km)	16.832	0.380	0.005	0.011	0.027
Total Emissions: (kg)	23565.21	532.12	7.60	15.20	38.01

Source: Author's Calculation

Similar to the Gothenburg side, the truck transport in Japan will use a natural gas engine. Table 10 shows the use of the natural gas engine in Japan.

Table 10 The alternative result for use of natural gas engine in Japan

Pollutant	CO_2	NOx	HC	PM	CO
Emission factor (g/kWh): Natural Gas	0.98	2.0	0.2	0.05	0.30
Emissions Calculated: (grams/car-km)	0.15	0.31	0.03	0.01	0.05
Total Emissions: (kg)	1.99	4.06	0.41	0.10	0.61

Source: Author's Calculation

Figure 7 shows the comparison of total emissions for the present situation and the ecoplan. The solution that the group proposes is a combination of natural gas use and reduction of speed for the ship. The solution caused a time delay of 3 days, which can be recovered by efficient handling in the ports. It is seen in the ecoplan column that emissions for all types of pollutants reduced to as much as 41% for hydrocarbons while carbon dioxide has a reduction of 19%. The environmental costs will be discussed in the next section. However, high vehicle cost, shorter driving range, heavy fuel tank, expensive distribution and storage network and potential performance and operational problems compared to liquid fuels are some of the drawbacks of CNG (Watt, 2001).

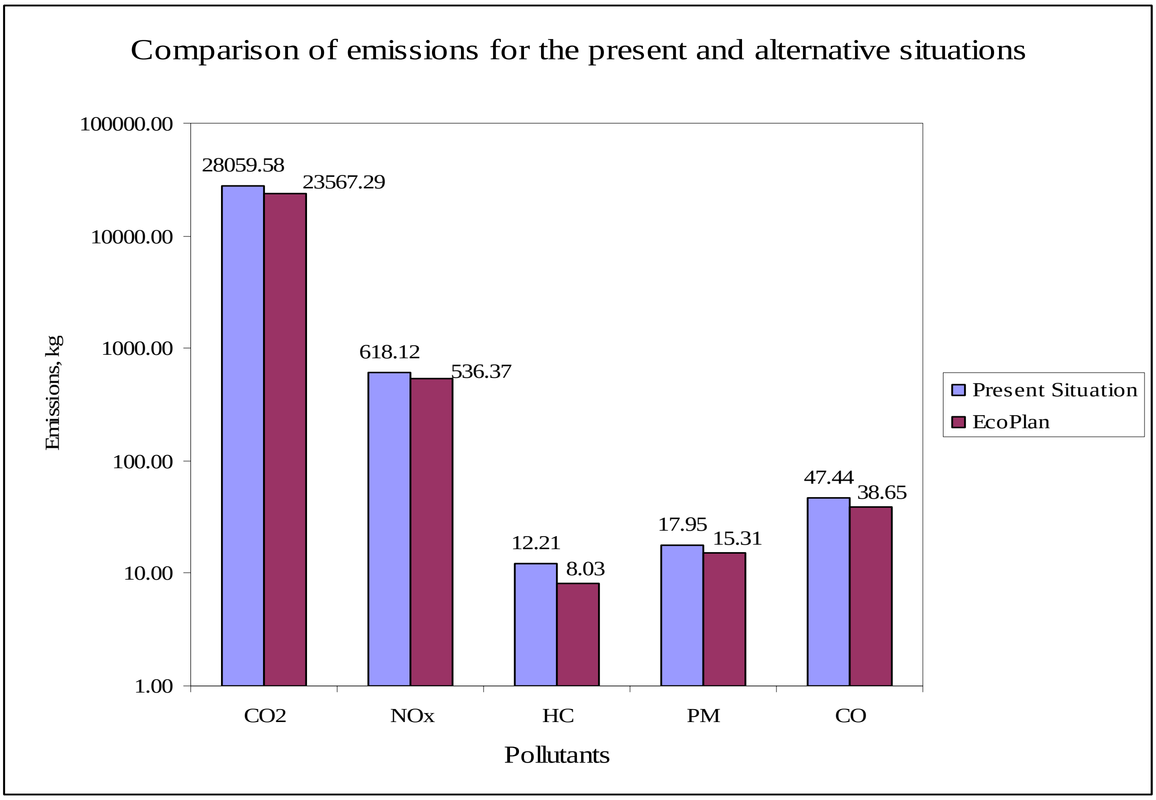


Figure 7 Comparison of Emissions for the Present Situation and the EcoPlan

6. EXTERNAL COST ANALYSIS

Several studies have been conducted to estimate the external costs associated with conventional air emissions (Heaney, et al 1999, Eyre, et al. 1997, Forkenbrock, 1999, ExternE, 1998). The costs are determined based on mortality and morbidity, by determining the medical and lost work cost of premature death, respiratory illness, damage on crops. The damage cost per kilogram of pollutant is shown in Table 12, the values are based on the 1998 European Study ExternE (Holland & Watkiss (1998)). The values are based on the value years of life lost (YOLL) estimated at EUR€1M value of statistical life. The values in Table 12 should be used with caution since several uncertainties are present.

Table 11 Marginal External Costs of Emissions[1]

	EUR€/kg-Emission
CO_2	0.029
NOx	4.2
SO_2	5.2
HC	2.1
CO	0
PM	14

[1] These values are taken from the ExternE study noting the EU-15 average and from Heaney, 1999

The total damage cost for transporting the cars to the dealer in Japan is shown in Figure 8. This impact of these values are the monetary value of the impact on mortality and morbidity. It can be seen that a total of about € 4000 are lost due to the emissions from the transport of 50 cars from Sweden to Japan. A 17% reduction in damage costs is earned with the use of the compressed natural gas as an alternative fuel. The monetary value of nitrogen oxides for the impact on crops is EUR€216.34.

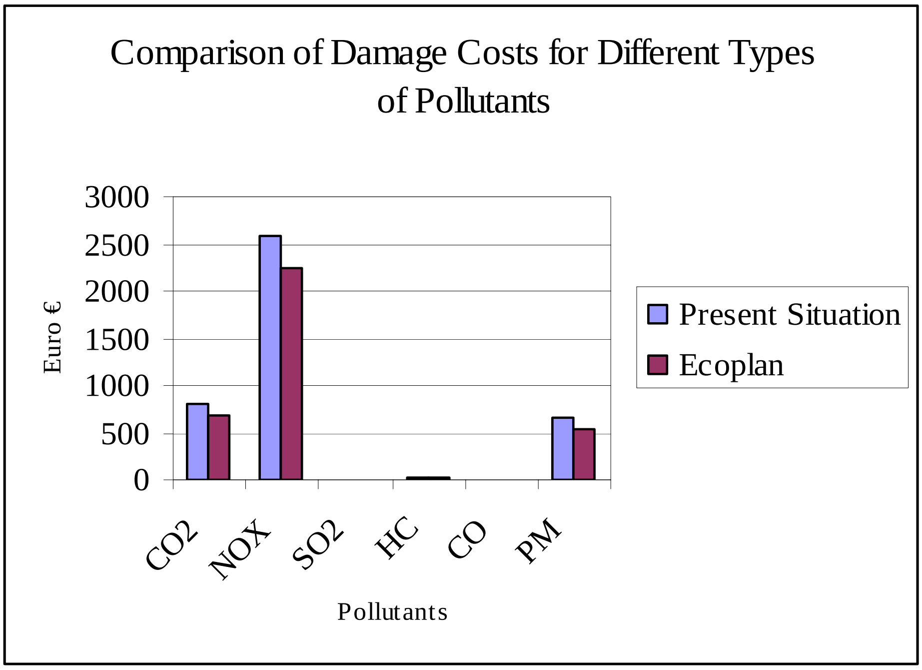


Figure 8. Comparison of Damage Costs for the Present Situation and the EcoPlan

7. CONCLUSION

Life Cycle Assessment as a methodology is holistic because it gives a systems analysis of the product. It analyzes and studies the environmental aspects and potential impacts throughout the product's life. It can be seen that from the pollutant emissions in the transport chain, carbon dioxide and nitrogen oxides are the leading pollutants, which affect the environment specifically the air quality. The truck is shown to be a heavy polluter in terms of its emission factors and it does not differ much between a European or an Asian country. With the use of the natural gas as an alternative fuel, emission levels can be reduced to as much as 19 % for

CO_2 and NOx emissions while costs are higher in the first few years because of conversion costs, we can say that it is worth the risk. The truck can be an environmentally adapted vehicle if its engine is converted to an alternative fuel engine like the compressed natural gas. The costs can be high but tradeoffs should be made to be able to have sustainable development and improved environmental quality. It can be seen that acidification potential due to emissions from nitrogen oxides and sulfur oxides has a high impact in the transport of the vehicles. Control of these pollutants is necessary. The use of CNG as an alternative fuel can control the SOx emissions. Uncertainties in terms of cost calculation still need to be improved. Since LCA is multidisciplinary systems analysis, uncertainties arise in the relationships among the social, technical and natural systems. A further study on this subject especially the use of natural gas in propelling the ship should be done. This type of fuel can easily reduce the CO_2 and NOx emissions by half for the ship alone. Different types of fuel technologies can also be tried.

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