SON CAO

Impacts of HCT vehicles in green logistics

A case study in Finnish Timber trucking

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Abstract

The thesis focused on the topic of green logistics and transportation, particularly about the environmental sustainability and energy efficiency in cargo transportation by road, hence, transport vehicle was the main target of the research. The key objective was to determine the effectiveness of using High-capacity transportation (HCT) vehicles, in term of energy usage and environmental performance. A case study in timber trucking in Finnish wood industry was conducted to be the main approach to resolve the question.

The theoretical part consisted of the definition of green transportation and its importance in today modern logistics system; and the environmental impacts and performances of road cargo transportation in Europe. It also introduced the concept and the description of HCT vehicles as well as the technical differences between them and traditional transport vehicles.

The empirical part of the thesis included the description of the case study: Misawa Ltd. – a wood production company located in Mikkeli, Finland. Data was collected through surveys and interviews to gather numbers and figures in order to calculate environmental performances and fuel consumption of both HCT vehicles and traditional vehicles on the same scale during the company’s transport process. The comparison should be the key result as well as the main instrument to determine the capability of HCT vehicles as a better alternative in sustainable transportation, which was included and emphasized in the discussion and conclusion of the thesis.

Key findings from the thesis have shown that HCT vehicles could bring differences and improvements in terms of both environmental and economic aspect, which could be helpful for companies like Misawa Ltd to determine whether to commit a system change in transportation for an alternative solution like HCT in order to achieve environmental benefits and approach a greener and more sustainable logistics system.

Keywords

HCT vehicles, green logistics, sustainability, transport, truck

CONTENTS

APPENDICES

1 INTRODUCTION

Logistics can be described as a principle of planning, organizing, implementation and management of resources from the original materials to the final products to consumption and end-of-life (El-Berishy et al., 2013). Logistics is a long-time backbone concept of supply chain management, but it is also ever-changing. In a current dynamic business environment, logistics activities need to consider not only customers' demands and profitability but also sustainable development and environmental aspect. The term of sustainability and green logistics has been included as an essential asset in supply chain management and its crucial roles in balancing the business market requirements and environmental issues.

Among main logistics activities, transportation is often seen as the most important process of most logistics services (El-Berishy, Rügge and Scholz-Reiter, 2013). Hence, during the shift towards green logistics system and overcoming related environmental challenges, sustainable and green transportation alternatives must be considered. One of the easy but effective ways to improve performances of transport services is to upgrade the efficiency of transport vehicles. Alternative vehicles are designed with purposes of improving goods capacity, low carbon emissions or efficient fuel consumption. High (or higher) capacity transport (HCT) vehicle is the embodiment of the concept, which would be the main research target of the thesis.

The research aims to analyze and evaluate the potential capabilities of using HCT vehicles in transport services, based on environmental performance assessment (EPA) including two main factors: emission and fuel consumption. HCT vehicles are transportation trucks that are increased in size and dimension in order to be able to carry more volume of goods. It can be called an alternative green improvement for the logistics system as a whole. Cost analysis was also conducted to determine potential losses and benefits from implementing the HCT system, because to overhaul and change a transport system requires a significant amount of money from both government and private companies for road improvement and bridge alterations (Liimatainen and Nykänen, 2016). All in all, findings of the research would help to answer the thesis questions: How effective and energy efficient HCT transport system can be, in term of emission reduction and fuel consumption? Will environmental benefits and cost savings from the change overturn the initial cost of implementation to provide long-term profits and establish a sustainable transport system? A case study about the commissioning company consisting of interviews and analysis was conducted to provide desired answers.

The commissioning party: Misawa Homes of Finland Ltd, which was also our target of the research, is a wood production company who produced, sold and exported spruce lumber. The reason that wood industry in Finland was targeted because the industry is one of major domains of Finnish export, and the inevitable dominance of truck transportation in the industry with 75% of Finnish domestic roundwood was delivered and managed directly to sawmills by trucks (Laitila, Asikainen and Ranta, 2016). Hence, sustainable developments of transport system has been a heating topic, and the results of the thesis could be helpful not only for the commissioning company but also gives a clear view of the bigger picture of the Finnish forest industry’s transportation sector related to upcoming changes and developments.

2 GREEN LOGISTICS AND SUSTAINABILITY

Traditionally, logistics’ purposes are to minimize costs and maximize profits in the care of customers’ satisfaction. However, with a developing awareness of responsibility for the environment, organizations are constantly under pressure to develop environmentally responsible and friendly operations. In other words, they need to consider not only to focus purely on economic purposes but also environmental and social issues of the whole supply chain. As a result, the terms of sustainability and ‘green’ issues were created, which in conjunction led to the born of the concept of green logistics system. The shift to green logistics system also means business practitioners aim to make enterprises ‘sustainable’. To understand why green alternatives and solutions like HCT vehicles are being considered and implemented in supply chain system, understanding of concept and the importance of green logistics and sustainability is necessary.

2.1 Concept of sustainability in Logistics

The concept of sustainability was first introduced in 1972, during the United Nation Conference in Stockholm, as they declared the definition as: “Man is both creature and moulder of his environment, which gives him physical sustenance and affords him the opportunity for intellectual, moral, social and spiritual growth” (El-Berishy et al., 2013). In Brundtland commission in 1987, sustainability development was defined as: “a development which tries to meet people’s present needs without compromising the ability of future generations to meet their own needs” (Cassen, 1987). Early definition was often ambiguous, and the idea of sustainable development could be identified in various ways in different practice areas. Nowadays, sustainability is defined in three main domains: social, environmental and economic. This chapter will discuss the connection of those three pillars in logistics and supply chain management.

2.1.1 The three pillars of sustainability model

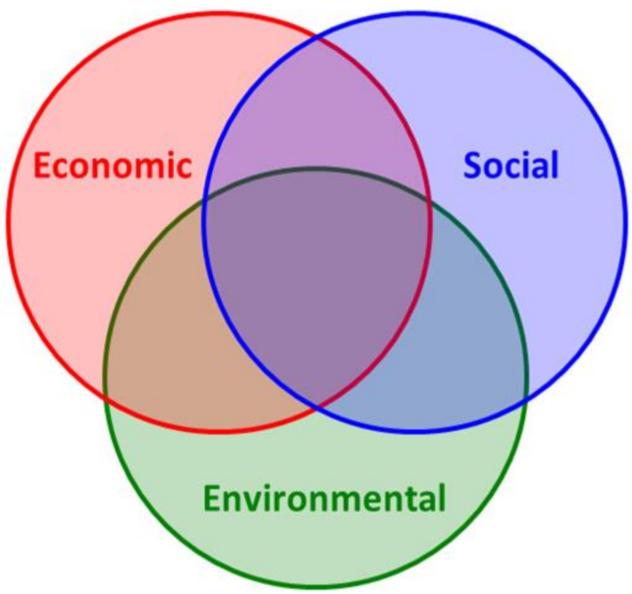


Figure 1. The three pillars of sustainability

As it is illustrated in Figure 1, the three pillars of sustainability are intertwined, which means they are not mutually exclusive but can reinforce and support each other. In other words, this shows the purpose of sustainability is to balance those three components, neutralize the consumption of resources with the impact of that consumption on the environment, economy or social. Naturally, most of common concepts of sustainability are based on ecological roots. In logistics and supply chain management, where the cycle of production, transportation and consumption is involved, the focus was switched to the economic base (El-Berishy et al., 2013). Due to more and more pressure on environmental issues in the modern business, the approach once again was shifted to environmental dimension. To sum up, logistics activities are primarily motivated by environmental considerations, with the focus of trying to satisfy and balance the other two pillars.

2.1.2 Sustainability in logistics transportation

Environmental considerations always aim to a basic principle: to ensure human activities do not disintegrate the environment’s resources, including land, air and water resources (El-Berishy et al., 2013). Logistics activities, at the same time, consisted of various human activities that could result in carbon emissions, waste production or water pollution. Hence, the goals are waste reduction, lowering fossil fuel usage and emissions. Since transportation sector claims a big part of logistics system, related environmental issues are greatly significant. The key strategies are optimization of transport network and increase the efficiency of load capacities routes and vehicles (El-Berishy et al., 2013).

The economic section has two objectives: to maximize the value, profit and financial performances of logistics activities, and to reduce internal/external logistics cost by optimizing network and utilizing resources (El-Berishy et al., 2013). Efficiency means economic sustainability. However, because it is not isolated from social and environmental dimension, corporations need to take into account external logistics cost related to environmental and social issues.

In comparison to the other two dimensions, social dimension of sustainability in logistics is quite neglected (El-Berishy et al., 2013). However, it still can affect the economic system in several ways. In logistics and supply chain, some social aspects are quite important such as: employment accessibility or customer satisfactory. In transportation, it could be safety issues, traffic or visual quality.

To come down to specific solution for implementation of those strategies, sustainability criteria need to be identified and evaluated in each logistics network in order to have clear pictures and evidences for future plans and solutions. Table 1 shows an example list of critical criteria under three aspects of sustainability in the sector of transportation.

Table 1. Sustainability criteria in logistics transportation (Mahmoudi et al., 2019)

Dimension	**Criteria**
Environmental	- GHG emissions - Air quality - Noise pollution - Energy use - Water pollution - Space/land consumption - Fuel consumption
Economic	- Travel time - Travel cost - Mobility cost - Affordability - Profitability
Social	- Accessibility to employment - Customer satisfaction - Safety - Visual quality - Traffic congestion - Social interaction

Solutions and alternatives can be developed based on several of those criteria. Our research target is the upgrade of transport vehicles -HCT truck, thus criteria like GHG emissions, energy, fuel consumption, travel time and cost and should be the main focus. All in all, sustainability is the benchmark of any logistics system and it should also be the baseline of any implementations of changes or upgrades in the system.

2.2 Green Logistics

This chapter discusses the necessity of green logistics implementation in modern business by identifying the definition of the phrase “green logistics”, studying the connection between sustainability and green logistics. In addition, since the target research lied in transportation area, the topic of green transportation was also discussed and emphasized.

2.2.1 Definition of Green logistics

There are several ways to explain the term of green logistics. To put it in the simplest way, green logistics is an integration of environmental goals into traditional logistics operations (Sureeyatanapas et al., 2018). Environmental goals in logistics are, as it was mentioned above, resources conservation, waste reduction or efficient energy usage through products flow, storage and transportation. Several examples of green logistics agenda are alternative renewable fuels usage, optimization of transport route, recyclable packaging or improvement of transport modes (Sureeyatanapas et al., 2018). Hence, HCT vehicles could be called as a green logistics activity as the concept is to improve the capacity and capabilities of traditional vehicles.

To sum up, ‘’green’’ as it stands for environmental concerns, combining with traditional logistics goals of reducing costs and increasing products value, creates green logistics. Green logistics is an additional value that can be offered to customers, be used to gain an edge over competitors and, most importantly, contribute towards environmental benefits.

2.2.2 Green logistics and Sustainability connection

From the definition of green logistics, it is inevitable that the three pillars of sustainability serve as the benchmark for green logistics system (Figure 2).

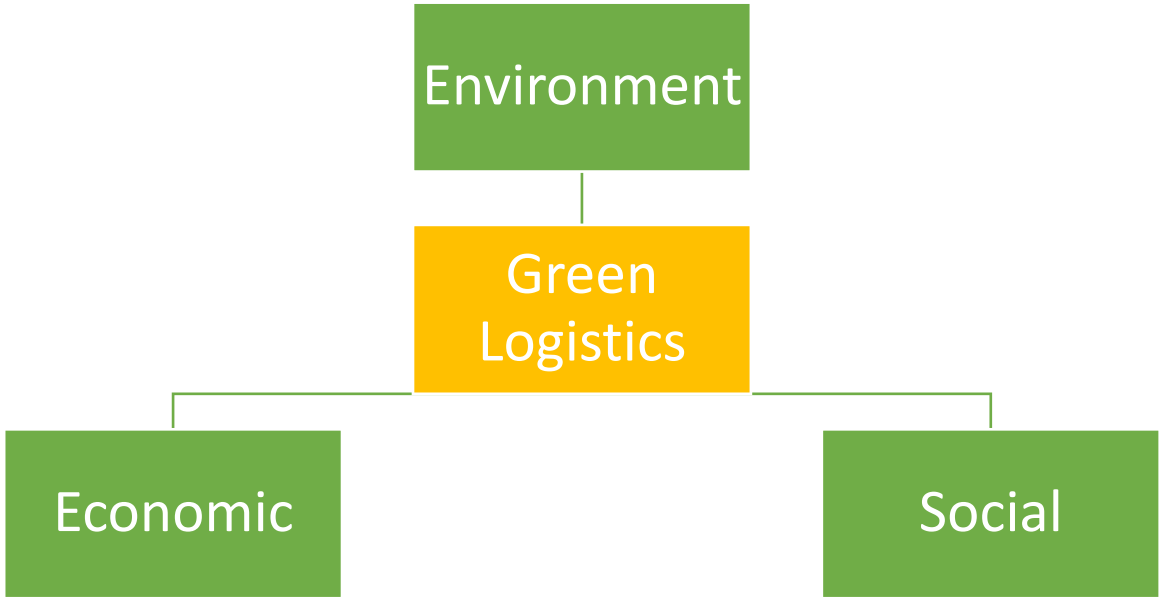


Figure 2. Green logistics and sustainability framework

In the past, logistics activities covered processes of warehousing, packaging, transportation and management to meet customer requirement (social) at minimum cost (economic), but with environmental concerns are on the rise, the environmental aspect is treated as a factor of the cost as an external cost of logistics (Seroka-Stolka, 2014). Green logistics, therefore, has a purpose of balancing all three pillars of sustainability, or in other words, implementation of green logistics is an approach that makes enterprises sustainable and profits in a long-term project.

2.2.3 Green freight transportation

Growing freight transport has enabled the region's economic progress – but also endangered environmental sustainability. Green freight is a set of strategies, policies and practices targeted at the movement of goods with minimal environmental, climate and public health impacts (McKinnon, 2015). This is achieved by reducing freight transport's air pollutant and greenhouse gas (GHG) emission intensity across all modes, including road, rail, marine, inland waterway and air. Green freight also aims to facilitate economic development through improved energy efficiency, fuel security, and overall freight sector efficiency and competitiveness. These strategies may be developed and implemented in partnership by government, the private sector and other stakeholders.

HCT vehicles can fit into three of the strategies: reduce freight transport, improve vehicle utilization and increase energy efficiency (Table 2). By increasing the size and load capacity of transport vehicles, travel times and kilometers traveled will be reduced because an HCT truck can carry much more volume of goods per trip. Therefore, energy and fuel usage are also indirectly improved in efficiency.

Table 2. Green Freight Strategies (McKinnon, 2015).

Aspects	**Explanation**
Reduce freight transport intensity	De-coupling economic growth and freight growth (without adversely affecting development prospects) by reducing tonne-kilometres in an expanding economy
Greener transport modes	Road to rail, inland waterways or maritime transport, relying on intermodal facilities and infrastructure as well as incentives and regulation
Improve vehicle utilization	Reduction of empty truck trips and optimized loading of vehicles can reduce vehicle-kilometers travelled
Increase energy efficiency	Raising fuel duties, subsidizing driver training schemes, enforcing speed limits, enacting higher standards for new vehicles, incentivizing scrappage of older vehicles
Switch to less polluting energy sources and vehicles	Renewable fuels, electric vehicles etc.

3 ROAD TRANSPORTATION AND ENVIRONMENT

The environmental impacts of logistics transport are significant because transport is a major user of energy and simultaneously creates air pollution through emission along with other environmental problems through fuel consumption. The transportation sector is a great contributor to climate change, accounting for as much as 22% of the energy related world GHG emissions (Dente and Tavasszy, 2018). Among all means of transport, road freight transport is the most widely used transport mode in the world, which is also the major factor of traffic congestion and air pollution. On the other hand, road freight plays an important role in door-to-door supply chain system, especially at the start and in the end of the chain - first and last miles of logistics transport (Engström, 2016). As road freight transport's presence in logistics system is necessary while being a major cause of concerning environmental problems, yearns for green transportation and its alternative innovations are understandable and needed to be studied. This chapter discussed this mostly under cases from Europe and particularly Finland. One of the cases being discussed will also be our research target: Woods and timber transport in Finnish forest industry.

3.1 Impacts of road freight transport

The impacts of road freight transport can be divided into four categories (see table 3) which are mostly based on the aspect of three pillars of sustainability: environmental, social and economic.

Table 3. Negative externalities in freight transportation (Denant-Boemont et al., 2018)

Group	**Externalities**
Social	Noise pollution, accidents and visual intrusion
Economic	Congestion, road damages, and longer travel times
Ecologic	Climate change and biodiversity destruction
Environmental	Water pollution and waste products

The environmental effects of road freight are severe and hard to tackle. GHG emission can lead to extreme weather changes, pollution or sea level rise, and those aftermaths are simultaneously at the local, regional and global level (Engström, 2016). It is estimated that 30–40% of all road transport emissions comes from road freight transport (Engström, 2016). As a result, European Commission has established a goal for reducing 60% of transport GHG emissions 2050 and a 20% reduction from 2008 level by 2030 (European Commision, 2012).

Following the target from European commission, Finland also aims to reduce 15% of GHG emissions in the transport sector from the 2005 level by 2020 (Liimatainen et al., 2012). This means a reduce of around 2.8 million tons of CO_2 from freight transport. 0.3 million tons of that amount is predicted to be contributed by improving the energy efficiency of vehicles (Liimatainen et al., 2012), therefore, HCT transport will also be a factor to contribute to the designated goal.

Congestion is also a costly problem. Not only it affects the economy (more than 1% of GDP in EU), it also increases total level of emission and reduces society value and services reliability (Engström, 2016). In addition, noise pollution and visual damages are inevitable.

3.2 Timber trucking in Finland

Truck-trailers dominate the transportation of wood supplying the forest and energy industries in Finland. In 2004, around 75% of Finnish domestic roundwood was delivered and managed directly to sawmills by 1280 trucks (Laitila, Asikainen and Ranta, 2016). Roundwood transportation by railway only occupied 22% of the gross volume, while waterway transportation reaches only around 3% (Laitila, Asikainen and Ranta, 2016).

Timber trucking in Finnish conditions has been considered relatively competitive compared to other countries. Timber logistics enterprises estimated values have grown 10% per year (Högnäs, 2001). The competitiveness of Finnish timber trucking is based on long term development work, investments in information and communication (ICT), optimization systems and high net carrying loads.

Roundwood trucks are typically owned by family enterprises situated in the countryside, with the number of about 900 timber trucking entrepreneurs employing 2600 truck drivers, and the average number of trucks per enterprise is less than two (Högnäs, 2001). Figure 3 gives a clearer view, as it showed the number of trucks owned by companies (in total of 300 companies surveyed in a study) in different sector. In forest sector, companies that use 11-20 trucks have a quite similar proportion to ones that own only 2 trucks or 3-5 trucks. The average number, hence, is quite low, shows that a lot of timber business in Finland are small and medium-sized, at least in transportation area. This makes the implementation of green transport practices much more complicated since the budget of those businesses is sometimes not abundant. However, the improvement of vehicles like HCT solution could be easier implemented because of low number of trucks need to be changed.

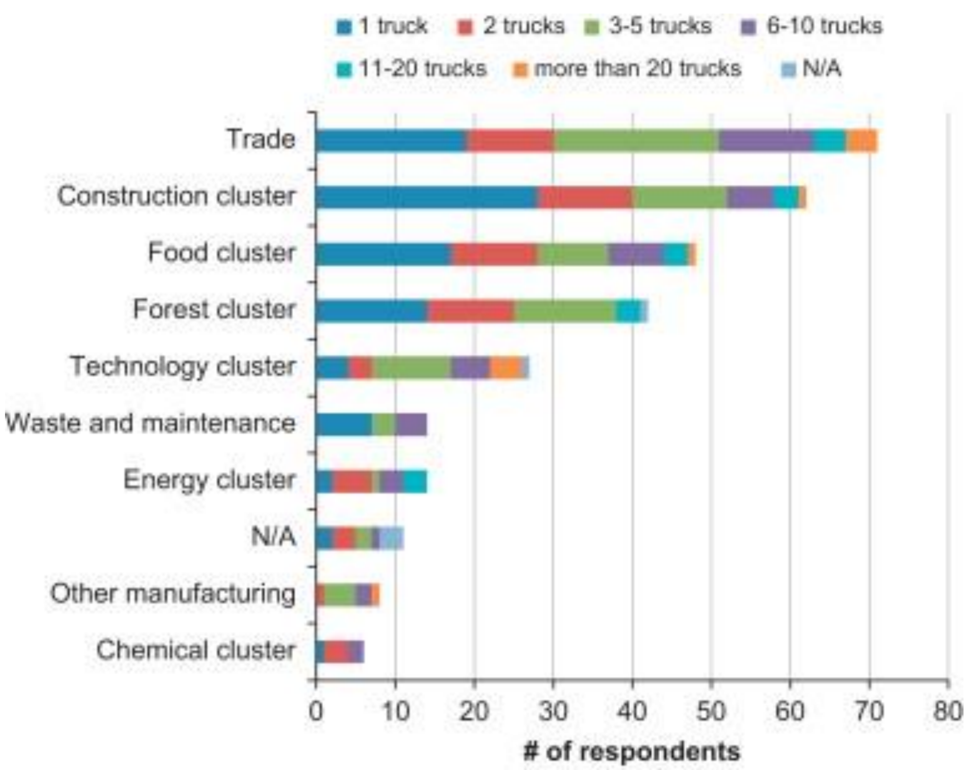


Figure 3. The number and fleet size of respondents (companies) by primary sector. (Liimatainen et al., 2012)

4 TRANSPORT VEHICLES

Transport vehicle, undoubtedly, is the main source of rising concerns, especially environmental problems. In road freight transportation, trucks are obviously dominant transport mean. To increase energy efficiency and reduce environmental problems like emissions, vehicles need to be optimized. Top factors are payload capacity, fuel usage, speed and safety issues. The first one would be our investigating priority since HCT vehicles basically means larger size and bigger capacity. Hence, components of trucks that related to the matter should be looked into, including number of wheelers, axles and particularly trailers. Weight, length and dimension figures were prioritized. This chapter illustrated those types of data of several types of trucks, both traditional and High-capacity (HCT) ones.

4.1 Terminology

Several definitions of related aspects are explained in order to give understandable point of view of transportation trucks:

Axle: is a central shaft for a rotating wheel, either fixed to the wheels, rotating with them, or fixed to the vehicle, with the wheels rotating around the axle (Budynas et al., 2010).

Dolly: Dolly is a two-axle module with a turntable/fifth wheel that in this case is used to couple the truck with a semitrailer or link.

Tractor: A tractor unit has the role of a primary mover, hauling a towed or trailered load. The tractor-trailer combination distributes a load across multiple axles while being more maneuverable than an equivalently sized rigid truck. In timber trucking, these types of vehicles are preferable.

Trailer: trailer is an unpowered vehicle or platform towed by a powered vehicle**.** It is where cargo and goods placed during transportation process (Budynas et al., 2010). In technical term, there are semi-trailer and full-trailer types. **Semi-trailer**

is a trailer without a front axle, which means a large proportion of its weight must be supported by the road tractor. **Full trailer** has both front and rear axle, leading to its ability of supporting its weight alone. Occasionally, it is connected to tractor by a drawbar (Budynas et al., 2010). Full trailer can have a bigger payload, but lack of flexibility unlike semi-trailer.

HCT vehicles: The concept of high capacity is very simple, which is to increase the amount of goods per one operation of transportation which will lead to the reduction in the total time travel, fuel consumption amount as well as air emission to environment. Bigger trucks with bigger payload capacity could lead to less trips, less fuel usage and less emissions. HCT is the embodiment of that concept.

4.2 Dimensions and weights of truck

Since HCT transport's focusing point is about size and load capacity, dimensions and weights of traditional (currently used) trucks should be mentioned. Size and weight of a transport vehicles must have to always follow regulations and policies from governments. Figure 4 and 5 show us the standard weights according to Finnish regulations for dimensions and gross weights of semi-trailers and full trailers respectively.

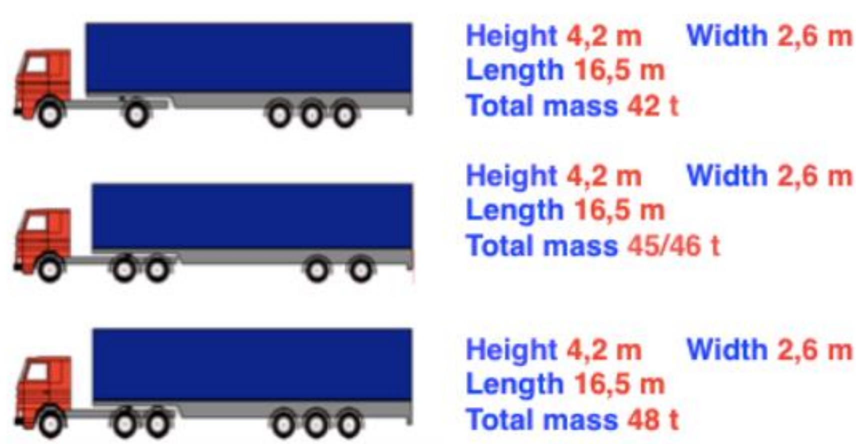


Figure 4. Semi-trailers size and weight (Source: Logistiikan maailma)

Maximum length of semi-trailer in Finland is 16.50 meters and a maximum permissible gross weight is 48 tons with six axles. In previous of Europe, the largest permissible gross weight of semi- trailer combination is only 40 tons with five axles.

Figure 5. Full- trailers size and weight (Source: Logistiikan maailma)

Maximum length of the full-trailer combination is 22.00 meters. The maximum length of a modular full trailer is 25.25 meters. The maximum permissible mass for full trailer combination is 60 tons if the combination has at least 7 axles. The maximum length of the cargo space in module combination is 21.42 meters.

As we can see, the maximum gross weight is 60 tons with maximum 25.25 meters in length. However, Finnish government has been encouraging the adaptation of HCT system in long haul transportation through new legislation and regulations, and we can expect those figures for transport vehicles will be changed drastically.

4.3 HCT models

HCT vehicle, as it was mentioned, is all about increasing the load capacity during transport processes, therefore, indirectly leads to increase in energy efficiency per one transport trip which would be a great improvement for environmental and economic matters.

In fact, HCT vehicle is not a newly discovered idea, but one that has been widely adapted into freight transportation in Europe. In Finland, the idea has been an upward trend since October 2013 that HCT trucks can be implemented freely for transport operations (Liimatainen and Nykänen, 2016) New limits of gross weight for transport trucks were increased to 64 tons, 68 tons or even 76 tons (see table 4). The government is willing to push the limit even higher in the future, with the set goal is 104 tons in gross weight (Liimatainen and Nykänen, 2016)

Table 4. New limits of mass (tons) and axles of the vehicle combinations in Finland (Palander, 2017).

Old mass limit	New mass limit	Axles	Old payload	New payload	Increase %	Degree of change
60	64	7	40	44	10	Temporary[a]
60	68	8	37	45	22	Permanent
60	76	9	35	51	46	Permanent
60	90	12	27	57	111	Temporary[a]
60	104	13	25	69	176	Temporary[a]

a

Temporary mass increase which is in force until the end of April 2018.

Data and figures of new HCT vehicles were pulled out from Finnish transport Agency and truck and logistics companies like Scania Finland (Figure 6).

Figure 6. Scania 104 ton- timber truck

5 MATERIALS AND METHODS

A case study was picked for the research as a source of materials and a method to study the question at the same time. Figure 7 described the framework research structure of the thesis and way of approach to the case study. Data and materials were collected (gathering) from the case study and its related objects. From the end products of the first step, calculations and comparisons (data handling) were carried out to produce final results. Last steps would be analyzation of those results to draw final conclusions.

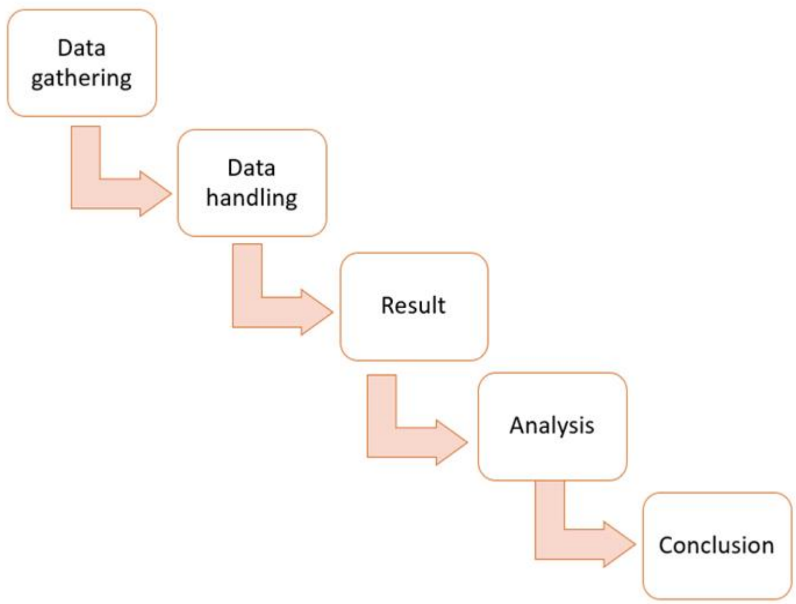


Figure 7. Research method framework (Timespan of data:1 Year).

5.1 Data collection

Data and information for the thesis was collected from two main sources of materials: from our case study which is also the commissioning company: Misawa Homes of Finland, and from logistics companies and truck service providers.

Because our case study of Misawa company is the main source of materials, most of information and data was collected from there. Inevitably, most materials were collected with a focus on transport process in the case study as the topic of the study is about transport. Hence, transport routes, vehicles or fuel types are main targets that needed materials and data.

The secondary source of materials (logistics companies and truck service providers) was needed for information and data about HCT vehicles which was supplementary materials for our case study, to determine, predict or estimate probability of HCT vehicles implementation in the case study of the company.

Methods of data collection from both sources are similar. Stake (1994) identifies three types of data collection methods in case study research, two of them were used during the data collection process:

- **Interviewing**: Researchers will learn about the person or persons that are part of the case by speaking with these people. Talking with informants is called interviewing. The types of interviews conducted by researchers vary in degree of formality (informal interview to semi-structured to structured interviews).

- **Collection of Artifacts and Texts**: Researchers may also learn about a bounded system by collecting and studying artifacts (e.g. written protocols, charts, flowsheets, educational handouts) - materials used by members of the system or case being studied.

Interviews were conducted with targets to acquire background and foundation for the case study including information about the company, transport routes and vehicles used. Data and figures were also collected through interviews. The process was divided into two main parts: Interviews with company case study and interviews with transportation agencies and companies. The time span of valid data is 1 year (most data from the company is from last year 2018). In addition, a lot of data came from guidelines. protocols or handouts from European Commission, logistics companies or truck service providers (collection of artifacts and texts).

5.2 Case study

All in all, the research method in the thesis could be defined as case study research, which is a flexible approach. Case study is defined by individual cases, not by the methods of inquiry used (Stake, 1994, p.236). In this case, the target will be a wood production company. Because the research was being made in Finland, and wood/timber industry is one of the most dominant sector in Finnish economy while road transportation is being used in the industry primarily, it is a perfect research target to study about HCT vehicles.

5.2.1 Overview

Misawa Homes of Finland Ltd. Is a wood production company located in Mikkeli, Finland. The company is a branch and shareholder of Misawa Homes Group in Japan, which is a home-modeling company using wood as a main material. The Finnish branch has produced and sold KD spruce lumber as well as exported goods to Japan since 1994. Ownership is 96% in Japan, and the sawmill production goes 100% to the shareholders.

Misawa Homes builds homes based on three pillars of operation: creating spaces that foster children's character development, creating communities in which customers build assets and protecting the global environment. Hence, the implementation of HCT vehicles into transport process might be in their interest.

The company is a small-to medium sized business with 34 employees in total. The company is focusing on wood production, procurement and sales. The transportation process is conducted in joint with other logistics company: Kuljetusliike Kanerva Oy. Timber is produced and transported from Mikkeli sawmills to three different locations.

Table 5. Overview of Misawa Homes of Finland.

Location	Mikkeli, South Savo
Capital	3 230 000 €
Employees	34 (production 28, office 6)
Production	Around 80000 m^3 annually
Vehicles	4-6 trucks (semi and full trailers)

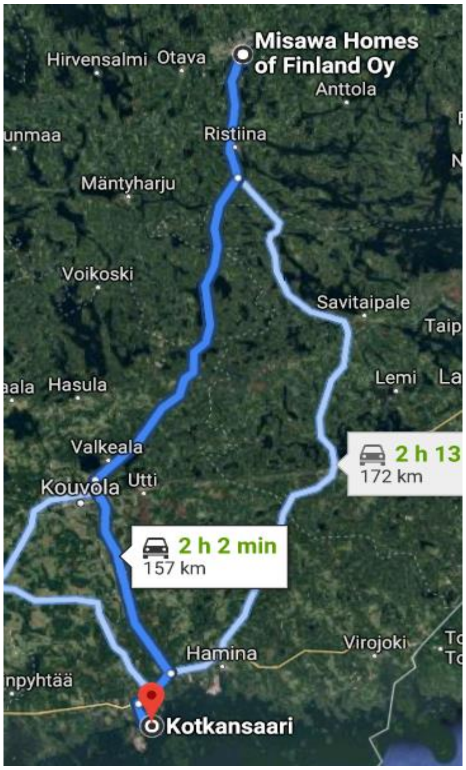
5.2.2 Research targets

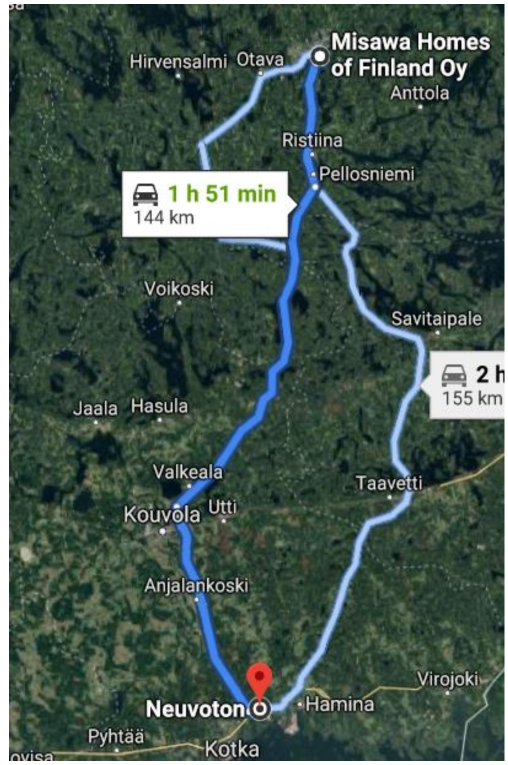
Research targets are what data collection process aims for. To study transportation process and its vehicles, we need to target amount of production, transport routes, vehicles and types and prices of vehicle fuels. Data and information of these targets needs to be retrieved from the company case as well as other transport agencies and companies.

5.2.3 Production and transport routes

Woods are procured and transported from Mikkeli sawmills to three different locations: Kotka port, Neuvoton and Iisvesi (Figure 8,9 and 10). Total production of woods from last year was 75 130 m3, with delivery volumes were as follows: Kotka Port 54 816 m3, Neuvoton 13 990 m3 and Iisvesi 1 614 m3.

The distances to three locations are approximately similar: to Kotka port is 157 km, to Neuvoton is 144 km and to Iivesi is 124km. Estimated driving times range from 1 hour and a half to over two hours. The come-back trips take the same time amount of time. However, all the returning trips are empty-running, which means the trucks do not transport back any kind of goods, which is a huge down point in efficiency.





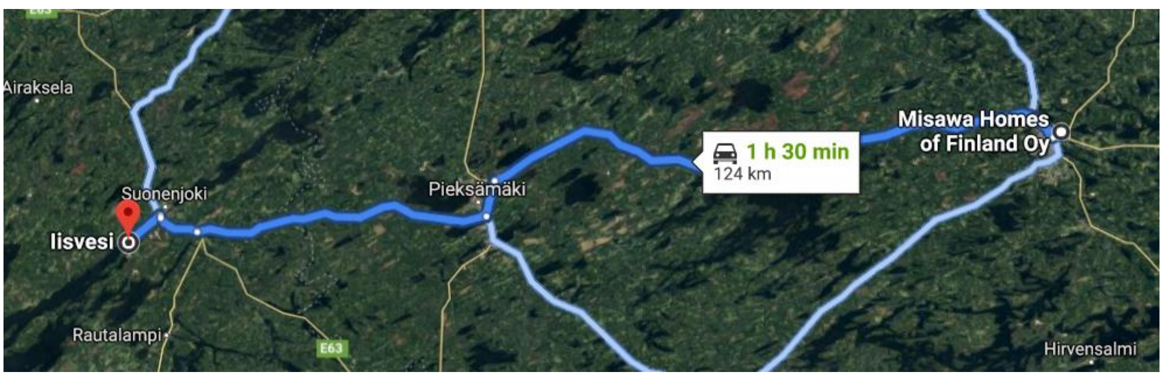


Figure 8,9 and 10. Transport routes to Kotka port, Neuvoton and Ivies (Source: Google Map)

5.2.4 Transport vehicles

The company is using both semitrailers and full trailers combination for transportation. For the routes to Kotka port they use 4 semitrailers (48 tons), while the trip to Neuvoton and Iivesi has the service of one full trailer (Table 6).

Table 6. Trucks distribution in Misawa

Destination	Truck	Weight	Payload capacity	Length
Kotka port	4 semitrailers	48 tons	28 tons	16.5 meters
Neuvoton	1 full trailer	60 tons	40 tons	24 meters
Iivesi	1 full trailer	60 tons	40 tons	24 meters

Details on figures and dimensions of vehicles that the company is using would be needed in order to make comparisons and analyzation between them and HCT alternatives. The targets of HCT vehicles were 74 tons (two models) and 90 tons vehicles. The figures and pictures were taken from interviews with vehicles manufacturing companies like VolvoTrucks and Scania as well as from handbook from transport agency published in 2012.

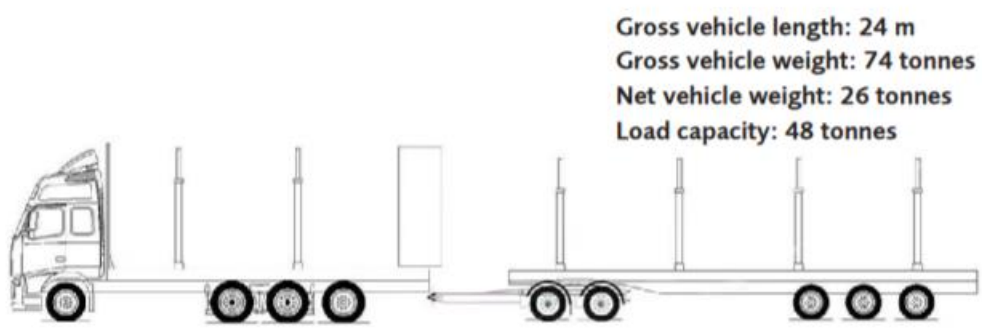


Figure 11. HCT vehicle – 74 tonnes with 48 tonnes load capacity (Löfroth and Svensson, 2012).

Figure 11 and figure 12 both show the model of vehicles with the gross weight of 74 tonnes. However, the load capacity is different with the former one has 48 tonnes payload capacity while the latter reaches 52 tonnes. The last HCT model has a relative ly bigger dimension: 90 tonnes gross weight with 52-ton capacity (Figure 13).

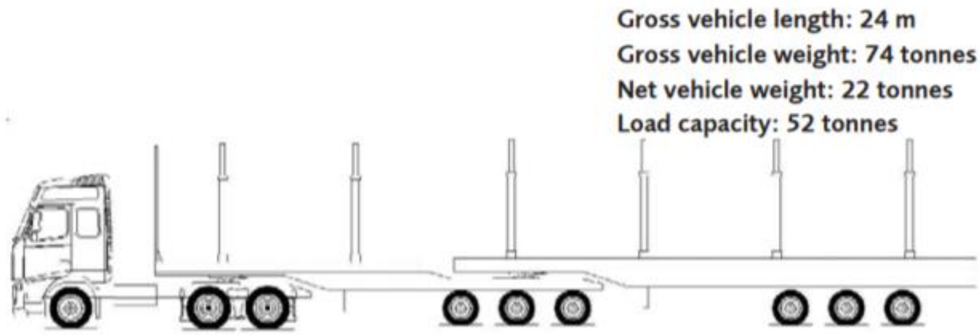


Figure 12. HCT vehicle – 74 tonnes with 52 tonnes load capacity (Löfroth and Svensson, 2012).

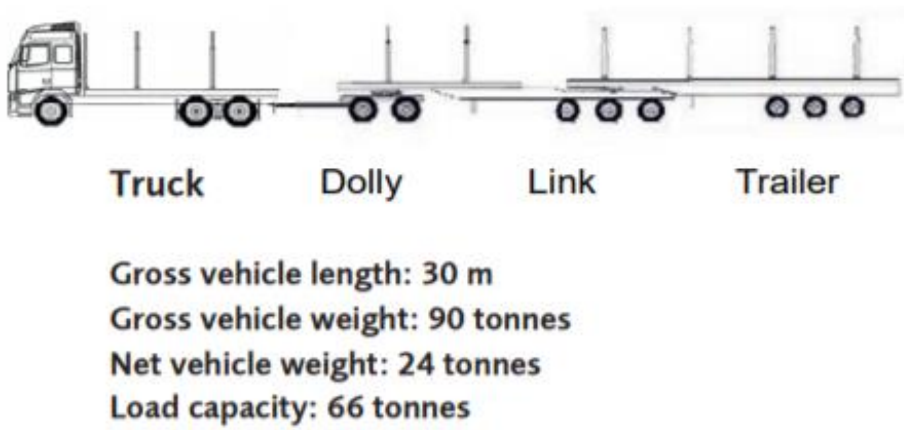


Figure 13. HCT vehicle – 90 tonnes with 66 tonnes load capacity (Löfroth and Svensson, 2012).

5.2.5 Fuel consumption and cost

The information of vehicle fuels that the company transport using is also necessary in order to calculate emission and fuel consumption. We interviewed the company for finding the name of vehicles fuel (Table 7). From that, energy content, density and carbon emission data were looked up according to EURO 6 (European Union directive to reduce harmful pollutants from vehicle exhausts).

The name of the fuel is MK1, a popular biodiesel fuel which uses methanol (converted to sodium methoxide) to produce methyl esters (commonly referred to as Fatty Acid Methyl Ester – FAME) as it is the cheapest alcohol available (Anneken et al., 2006).

Table 7. Data of vehicles fuel used (Löfroth and Svensson, 2012).

Type	Energy content (kWh/m^3)	Density (kg/m^3)	CO_2 emission factors (kg/l)	NO_x emission factors (g/km)	PM emission factors (g/km)
MK1	9800	815	2.54	0.61	0.010

CO_2, NO_x and PM are the three main pollutants to determine environmental performances of vehicles. The MK1 is used with the company traditional vehicles, hence, we will assume the HCT alternatives will use the same type of fuel in order to secure an easier calculation and analysis. Data in the table 7 was used for both types of transport trucks.

The price of vehicles fuel always varies in different months of the year. According to Statistics Finland, the average price of MK1 is around 1.384 €/L.

5.3 Data handling

Before going to the data handling and calculation parts, to illustrate the information better, the three targeted HCT models will be referred as model A, B and C (Table 8).

Table 8. HCT models names

Names	Gross weight	Load capacity
HCT model A	74 tons	48 tons
HCT model B	74 tons	52 tons
HCT model C	90 tons	66 tons

The calculation focused on calculation kilometers traveled, total trips, emissions performances, fuel consumption, and financial cost. All calculations must be performed on both cases company’s vehicles and HCT ones. At the same time, all calculations also must be done on three cases of transport routes of the company: Kotka port, Neuvoton and Iisvesi. The calculation formulae were mostly based on European Commission guidelines.

5.3.1 Total trips and total traveled distances

The increase in load capacity from HCT vehicles could lead to reduction of kilometers travelled which equals to less emissions on the roads. To calculate total transport trips needed, total volume of wood product needs to be divided by total load capacity of one trip.

One thing must be noted is that we assume in HCT vehicles case, the number of vehicles used will be the same as in the company case in order to give a fair comparison case. Three of HCT models used in the research (two models of 74 tons and one models of 90 tons) would be regarded as model A, B and C respectively.

From the total trips' figures, we can calculate total distances that transport vehicles travelled in total. The numbers could be calculated by multiplying number of trips with transport routes distances. Because one trip in this case consists of both departing and returning journeys, therefore, we also need to multiply the trips by 2. In addition, in the Kotka case, 4 vehicles were in the use (while the other two routes only used one vehicle each), which means the numbers need to be multiplied by 4 in order to determine the total numbers.

To recognize the difference between traditional vehicles and HCT ones for a better comparison, differences between total traveled distances that covered by different types of vehicles were also calculated.

5.3.2 Fuel consumption

The showcase of kilometers differences during transportation is not only about pointing out the efficiency and timesaving of HCT vehicles, but also is an important factor to calculate total fuel consumption. In general, total fuel consumption is calculated by the formula:

- *Fuel use (liters) = total distance (km) * fuel efficiency (liters/km)*

The most important aspect to be considered in this calculation is that the fuel efficiency varies between fully loaded transport and empty trips. The fuel consumption of fully loaded trips and empty-runnings must be calculated differently. Total fuel consumption numbers will be the sum of those two factors. Since all the returning trips were reported to be empty in the company case (there were some special cases, but they were negligible), the distances of both cases will be the same (both are qual to total traveled kilometers divided by 2).

Fuel efficiency numbers were retrieved from the Transport agency handout. When the rig was fully loaded, fuel efficiency varied between approximately 0.6 and 0.7 liters/km. When empty, fuel efficiency varied between 0.35 and 0.43 liters/km with the difference in fuel efficiency between driving empty and driving fully loaded was approximately 0.27 liters/km (Löfroth and Svensson, 2012).

5.3.3 Environmental performances-Emission

Emission levels during transport process – the most important part in the research, were calculated. Three main pollutants are targeted: Carbon dioxide (CO_2), Nitrogen Oxide (NOx) and Particulate matter (PM).

To calculate emission levels of three main pollutants, information about fuel emission factors will be needed (see Table 7). Emission factors have different units in different cases, as CO_2 emission factor is kg/liter while NOx and PM ones are g/km. Thus, different ways of calculation are required. With CO_2, we will need total fuel consumption to find how many kilograms in total volume of fuel used. Meanwhile, total distances results are required for NOx and PM cases. Formula is based on guideline from European Commision guideline for Using official statistics to calculate greenhouse gas emissions (Ec.europa.eu, 2010):

- emissions = activity data * emissions factor

Activity data in the research case, as we mentioned above, would be total fuel consumption or total distances, while the emission factor numbers can be found back in Table 7.

5.3.4 Cost saving

In cost saving analysis, we operated two investigation of two categories: Operational cost savings and Salary/capital cost savings and total fuel spent savings.

Operational costs are the expenses which are related to the operation of a business, or to the operation of a device, in this case, is the transport vehicle. In logistics, operational cost savings interrelate to decrease in kilometers covered by vehicles. Less travel time means less cost. Operational cost might vary because of bigger and heavier vehicles. The operational cost of company vehicles is 0.34 (€/km), while our targets: HCT models have 0.43 (€/km) of operational cost (Liimatainen and Nykänen, 2016) Because the operational cost between two cases are different, the formula to calculate the differences in cost should be:

- $C_o = (M_1 * 0.34) - (M_{A,B \text{ or } C} * 0.43)$

Where: C_o is Operational cost savings (euros)
M_1 is total kilometers of company vehicles covered (km)
$M_{A,B \text{ or } C}$ is total kilometers that HCT models A, B or C estimated to cover (km)

Because fewer trips means less hours to travel, HCT models have a huge potential for salary cost savings. To calculate the salary cost saving, average salary per hour of drivers and time used for travelling are needed:

- $C_s = S_a * H_{re}$

Where: C_s is Salary cost savings (euros)

S_a is salary per person per hour (euros)

H_{re} is total time in hours reduced

Total hours reduced can be calculated by multiple the amount of time that takes to complete one trips with the number of reduced trips.

The average salary of drivers for company is around 22 €/hour. Meanwhile, the trips to Kotka port and Neuvoton take around 2 hours to drive (one way) and to Iivesi it needs 1.5 hours. From those numbers, we can calculate how many hours the HCT models can save during transport process. Finally, the amount of salary cost saving will be determined based on the above formula. One thing needs to be considered is in the Kotka port case, because there are 4 vehicles involved, which means at least 4 drivers are needed, thus, the numbers must multiply by 4 in this case.

Savings on fuel spent should be also considered. In this case study, we assume our new HCT vehicles system will also use the same type of fuel as one that the company is currently using). Hence, the difference will heavily depend upon fuel consumption amount., as in the formula bellowed:

- C_f (Fuel spent cost savings) = average price of the fuel * (M_1 – $M_{A,B \text{ or } C}$)

6 RESULTS

The chapter shows the results of previous calculations which were applied for both case HCT vehicles and traditional ones in the case of Misawa’s transport routes.

6.1 Total trips and total traveled distances

Table 9 displayed total trips needed to transport all volume of wood materials to Kotka port, Neuvoton and Iisvesi routes.

Table 9. Total trips of transport (one way)

	Total trips, Destination: **Kotka port**	Total trips, Destination: **Neuvoton**	Total trips, Destination: **Iisvesi**
Company's vehicles	~173 trips	~124 trips	~ 15 trips
HCT model A	~101 trips	~103 trips	~ 12 trips
HCT model B	~ 93 trips	~ 95 trips	~ 11 trips
HCT model C	~ 74 trips	~ 75 trips	~ 9 trips

Significant differences were spotted in Kotka port and Neuvoton cases, where the amount of wood to be transported is very large. For instance, using HCT models could reduce 70 to 80 transport trips with model A and B, and around 100 trips with model C. The decrease was about half in the Neuvoton case with around 20 to 50 trips short. On the other hands, because of small amount of wood transferred to Iisvesi, increase in load capacities of vehicles will only result in around 2 to 3 trips in difference.

Total distance covered by vehicles are displayed in Table 10. From those data, total distance reduction was deduced as in Figure 14.

Table 10. Total traveled distances in 3 routes (km)

	Kotka port	Neuvoton	Iivesi
Company vehicles	217288	35712	3720
HCT model A	126856	29664	2976
HCT model B	116808	27360	2728
HCT model C	92944	21600	2232

The differences between traditional company vehicles and HCT models in Kotka port routes are much more significant than the other two cases. The kilometers covered by HCT models are almost half the number of company vehicles in Kotka port case. Neuvoton route also showed some considerable changes while the last case in Iisvesi, on the other hand, only presented a reduction of 800 to 1500 km in total

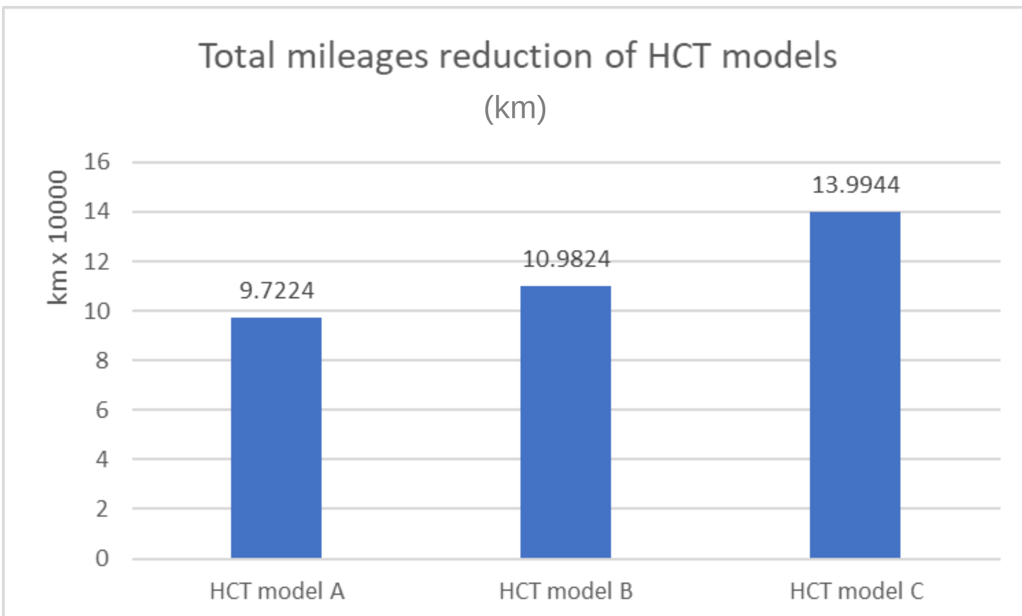


Figure 14. Total kilometers reduction (in all three routes combined) of HCT models compared to company vehicles

Figure 14 illustrated the comparison between HCT model A, B and C in efficiency of travel distance reduction. From the graph, it is very clear that HCT model A and B shared very similar result, around 10000 kilometers saved. Meanwhile, HCT model C saw a slightly better results, with almost 140000 kilometers reduced.

6.2 Fuel consumption

Fuel consumption results are illustrated in each transport routes: Kotka port, Neuvoton and Iisvesi (Figure 15,16 and 17 respectively). The Kotka port route once again showed much more significant number than the other cases, especially when being compared to the Iisvesi case which showed very negligible numbers in general.

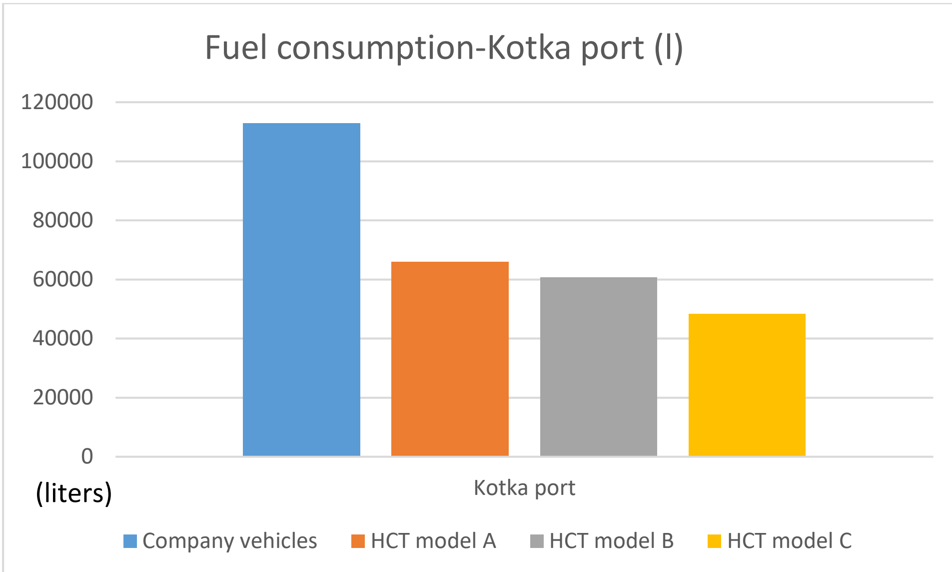


Figure 15. Total fuel consumption – Kotka case

As we can see from the graph, using HCT model A and model B could lead to 40-45% savings of fuel usage, while model C can save almost 60% fuel consumption in Kotka case.

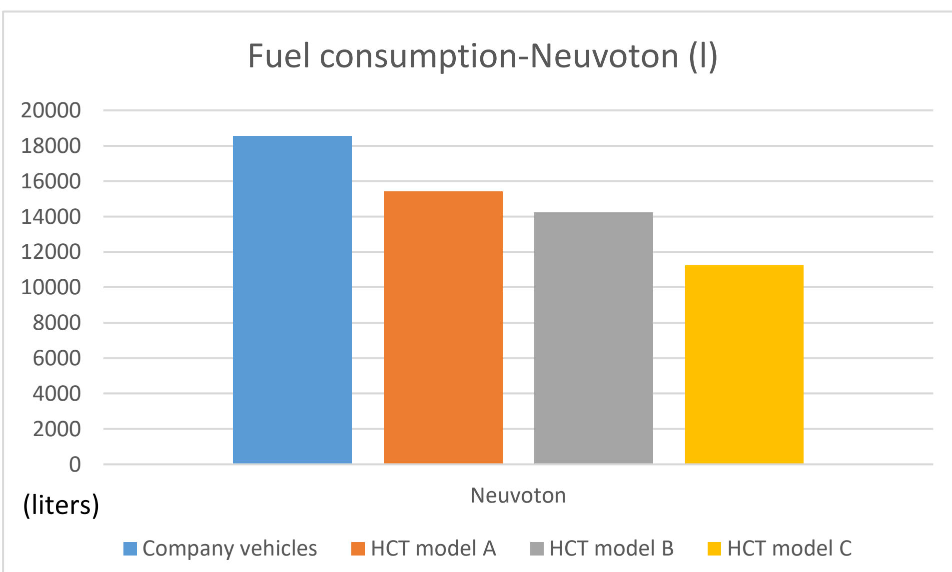


Figure 16. Total fuel consumption – Neuvoton case

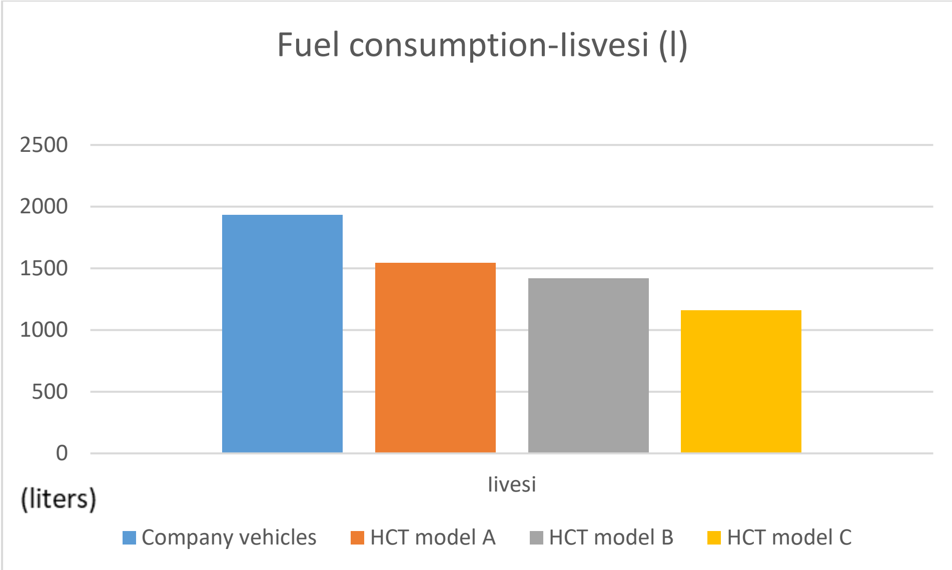


Figure 17. Total fuel consumption – Iisvesi case

Figure 16 and 17 display the results from Neuvoton route and Iisvesi route respectively. Surprisingly, although the total consumption results are different, the ratio between Company vehicles and HCT ones are very similar. In both routes, HCT model A and B experiences a 17-24% drop in fuel consumption and approximately 40% drop in model C cases. The reason for this similarity probably is that same number of vehicles were used in both cases (only one vehicles). Hence, the fuel efficiency and consumption would experience a same trend.

6.3 Environmental performances-Emission

Several unit conversions were performed for a better presentation of emission levels of: Carbon dioxide (CO2), Nitrogen Oxide (NOx) and Particulate matter (PM). For a better presentation, the result of total amount of CO_2 released into the environment will be displayed in tons unit (Table 11), while cases of NOx and PM will be presented in kg unit (Table 12 and 13).

Table 11. Total CO2 emission in 3 routes (tons)

	Kotka port	Neuvoton	Iivesi	Total
Company vehicles	286.99	47.17	4.91	339.08
HCT model A	167.55	39.18	3.93	210.66
HCT model B	154.28	36.14	3.60	194.02
HCT model C	122.76	28.53	2.95	154.24

The environmental impacts of HCT vehicles show dominance, especially with the ability of reducing CO_2 emission reaches to about 180 tons (see Figure 18). While the figures in NO_x and PM cases might be smaller, a sharp decline in emission can still be seen in emission, especially with the numbers in HCT model C (90 ton-vehicles with 66 ton-capacity).

Table 12. Total NO_x emission in 3 routes (kg)

	Kotka port	Neuvoton	Iivesi	Total
Company vehicles	132.55	21.78	2.27	156.60
HCT model A	77.38	18.10	1.82	97.29
HCT model B	71.25	16.69	1.66	89.61
HCT model C	56.70	13.18	1.36	71.23

Table 13. Total PM emission in 3 routes (kg)

	Kotka port	Neuvoton	Iivesi	Total
Company vehicles	2.17	0.36	0.04	2.57
HCT model A	1.27	0.30	0.03	1.59
HCT model B	1.17	0.27	0.03	1.47
HCT model C	0.93	0.22	0.02	1.17

All in all, it is safe to say that the environmental performances of HCT vehicles are far superior to the currently used vehicles in the case study. The decrease in emission is very significant in all three pollutants categories, with around sharp 30-40% reduction in each category. However, we can still see the insignificance in the Iisvesi case and in the PM category (Figure 19). Numbers in those two groups are quite small, in compare to other categories.

Figure 18 and Figure 19 shows the ability of environmental performances improvement (or the emission level reduction) of three HCT models in comparison to company vehicles. HCT model C is always on top with noticeable results, while the model A and B also come close but there are still gaps. Only in PM category, the difference is negligible, as you can see an almost flat line in Figure 19.

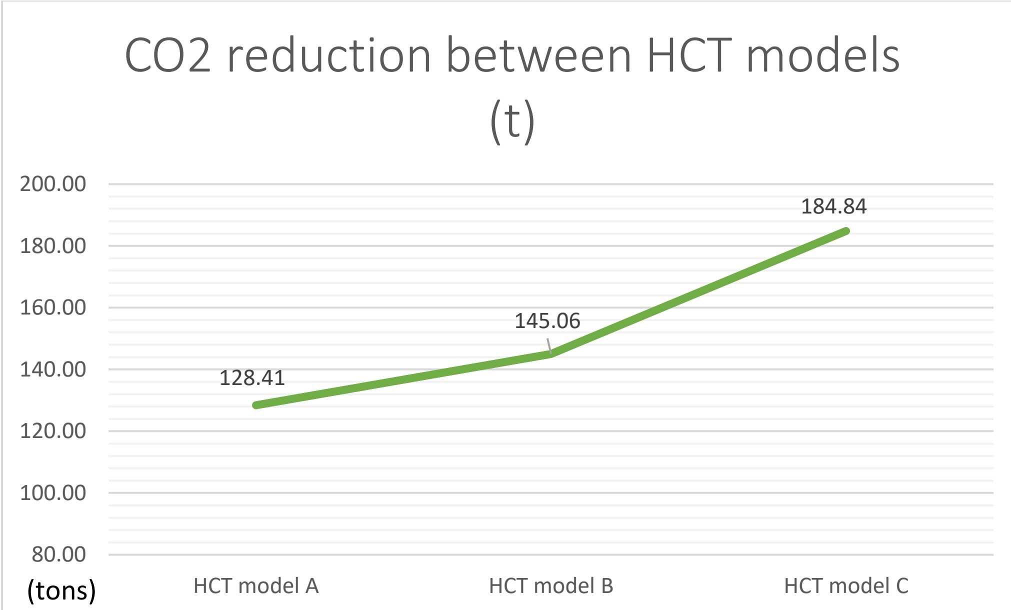


Figure 18. CO2 reduction amount between HCT models (tons)

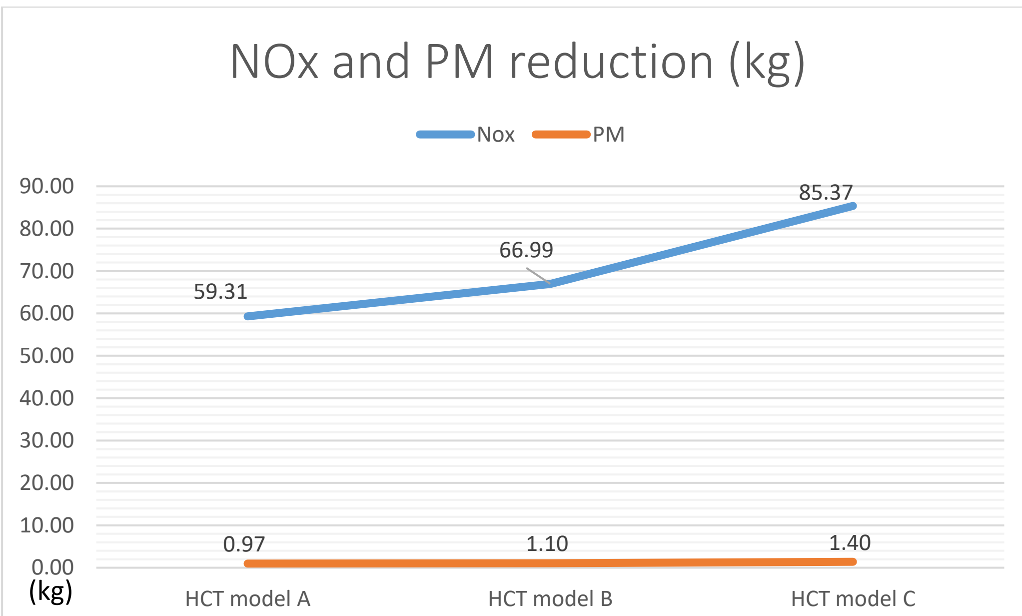


Figure 19. NOx and PM reduction amount between HCT models (kg)

6.4 Cost saving analysis

Table 14 showed financial savings summary under three categories: Operational cost (C_o), Salary cost saving (C_s) and Fuel spent saving (C_f).

Table 14. Operational cost saving - salary cost saving – Fuel spent saving of HCT models (€) in 1 year span.

C_o (€)	Kotka Port	Neuvoton	Iisvesi	**Total**
HCT model A	19329.84	-613.44	-14.88	18701.52
HCT model B	23650.48	377.28	91.76	24119.52
HCT model C	33912	2854.08	305.04	37071.12
C_s (€)	Kotka Port	Neuvoton	Iisvesi	**Total**
HCT model A	25344	1848	198	27390
HCT model B	28160	2552	264	30976
HCT model C	34848	4312	396	39556
C_f (€)	Kotka Port	Neuvoton	Iisvesi	**Total**
HCT model A	65082.1	4352.65	534.44	69970.17
HCT model B	72313.45	6010.76	713.92	79038.14
HCT model C	89487.89	10156.12	1070.89	100714.9

The negative results in the Neuvoton and Iisvesi column means the operational cost of HCT model A in some cases are higher than the traditional ones. Nonetheless, all of HCT models manage to make financial savings from kilometers reduction and time-saving results. The operational cost saving presents quite distinguished numbers among HCT models, while salary cost saving does not show too much difference between three types of vehicles. The salary saving costs are higher in all cases than the operational cost savings, but the fuel spent savings remain the largest.

To sum up, the sum of operational cost savings and salary cost savings and fuel spent savings will be the total cost savings of HCT implementation. As a result, HCT model A could potentially save around 116,000 euros per year while model B and C number is approximately 135,000 euros and 176,000 euros respectively (Figure 20).

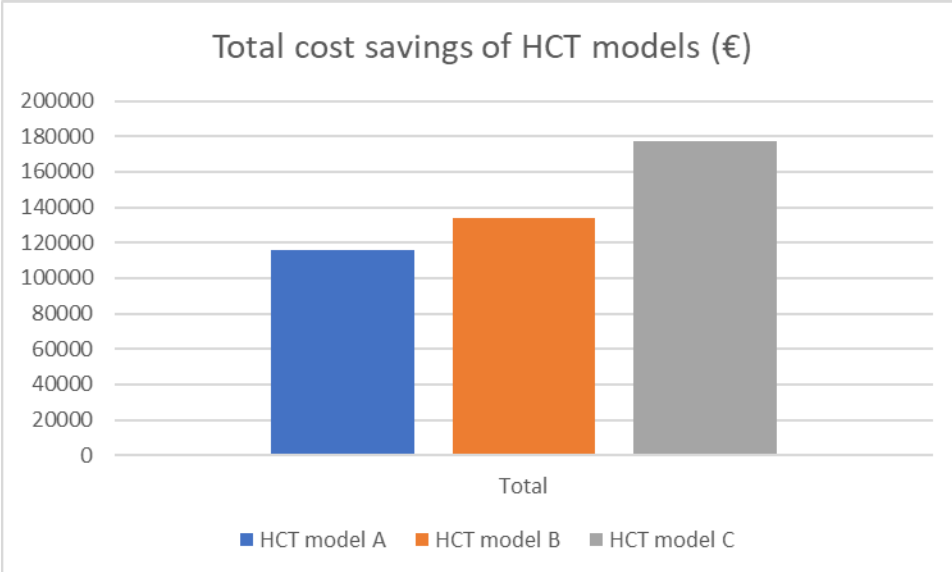


Figure 20. Total cost savings of HCT models A, B and C

7 DISCUSSION

The chapter discussed and analyzed final results and findings in different points of view: environmental performances improvement and potential economic boost from HCT models as well as assessments for different HCT model choices for different transport routes of the company case. During the analysis, differences that HCT models made will be mainly focused. In addition, limitations of the research and what the results mean for the future projects will be discussed.

7.1 About environmental performances

Environmental improvement is definitely the true objective of implementation of HCT vehicles in transport process. From the results, we could see big changes in number of emissions and fuel consumption. The positive thing is CO_2, one of the biggest problems of emission issues, seems to be greatly reduced in emissions if HCT models are applied.

The fact that about 0.07 megatons CO_2 were saved in Finland, 2015 thanks to HCT vehicles trials (Liimatainen and Nykänen, 2016) means that our HCT models could contribute quite a number to overall environmental performances in Finland.

According to European Automobile Manufacturers' Association (ACEA) (2019), high-capacity vehicles can reduce carbon emissions at the individual vehicle level in the range of 15 to 40 percent. In the case study, HCT models were estimated to be able to reach 40 to 60% of carbon emission reduction in total. With the number of vehicles used are 4-6 vehicles, the saving efficiency for each individual vehicle is also around 15%, which means the Misawa case could be a suitable scenario to apply for HCT vehicles with expected efficiency.

Although NO_x emission reduction showed less impressive numbers than with the case of CO_2, the efficiency in reducing NO_x from HCT models are quite good, with the ability to reduce 40 to 55 percent depends on the models. With the fact that implementation of EU legislation has reduced NOx from mobile sources by around 18% (from 2005-2010) and NO_x emission rom light duty vehicles have been on the rise (Borken-Kleefeld and Ntziachristos, 2012), implementation of HCT models in our case study could achieve great results.

PM emission efficiency from HCT models showed negligible results in comparison to other two pollutants. It is partly because that, the majority of PM emissions is caused by non-exhaust sources (tire and brake wear, road abrasion), by mechanical parts rather than combustion process (Borken-Kleefeld and Ntziachristos, 2012). Hence, using HCT models will not play significant role in PM emission reduction. On the contrary, bigger vehicles could lead to increase in PM emission.

The results also show that environmental impacts in logistics transport have a heavy connection with distances covered by vehicles. For example, our Kotka port route which witnesses biggest impacts on environment of all three routes, has the longest haulage distance as well as biggest gaps between company’s vehicles distance travelled and HCT models ‘distanced travelled. In other words, the concept of HCT transport which focuses on increase load capacity and reduce distances is an effective tool for environmental performances improvement.

7.2 About financial cost savings

The results see a promising scenario for making profits by installing the HCT system in the transportation of Misawa company. It is true that if the company wants to adopt the new system, external costs will be created. However, with a cost savings range from 115,000 euros to 175,000 euros per year, those costs probably will be replenished in a period of one or two years. With the obvious positive environmental impacts, HCT system is an absolute bargain and a true further step into green logistics and sustainability.

Of the cost savings, salary cost savings, in this case, dominate the operational cost saving. Potentially the savings could go even higher if the whole transport system involves in more vehicles with more drivers. HCT transport system means cost savings profits but also means decline in job opportunities for truck drivers. On the other hand, HCT permits the consolidation of freight in fewer vehicles, thus offering a technical solution to the lack of truck drivers and easing the current and projected driver shortage (ACEA, 2019). Those issues are more in a big picture but appears to be marginal in the company case.

We saw some negative values in financial performances from HCT models. If the maintenance or operational cost is higher with HCT vehicles, it is unwise to apply them into system without researching first, because the profits might not cover enough for increase in operational cost and maintenance prices. Luckily, our HCT cases, although witnesses some negative values, they are still well covered by cost savings profits. The operational cost is a tricky part, because HCT vehicles with heavier weights and more axles and tires also could result in increase of operational and maintenance cost (Liimatainen and Nykänen, 2016).

The fuel spent savings, however, occupy the largest proportion of all three types of savings, with over double the figures of both the other two types. Fuel usage is an important factor in both economic and environmental. Therefore, a strong case in fuel spent savings generally means not only being profitable in economic aspects but also showing potential for an environmentally-friendly system.

7.3 About HCT models

We could see obviously that the first two models share quite similar results. It is understandable because both models have similar figures: both have gross weight of 74 tons and the load capacity is only 4 tons difference. However, model B seems to be a preferable choice, not only has slightly higher positive impacts on environmental performances, but also does not contain any negative numbers in financial analysis like model A does.

Model C (90 tons with load capacity of 66 tons) seems to be a great choice, even the best with its biggest impacts on both environmental and economic aspects. However, it is not really an optimized system to gain the best results and best possible sustainable framework of transport. For instance, the Iisvesi route seems to have too little figures to be implemented with heavy vehicles like model C.

In long haul transports, the dimensions of the dimensions and payload of vehicle are more important than the maximum weight of trucks. It is also possible to increase the potential payload by reducing the own weight of the truck by using lightweight materials (Galos et al., 2015). Afterall, the main concept of HCT is to increase the payload to improve the efficiency.

To sum up, choice of vehicles should be strongly based on individual scenario of the transport process: the distance of transport destinations, amount of goods needed to be transferred, road conditions etc. Misawa company should be encouraged to apply for more experiences on HCT vehicles trials, potentially to have a mixed and combination of different HCT models in their transportation process, in order to maximize the efficiency and positive impacts on environment.

7.4 About the transport routes

As it is mentioned above, different transport routes need different vehicles and system to be able to operate efficiently. For Misawa, their focus should be on

Kotka port route and Neuvoton route. The Iivesi route should be of secondary priority, considering its low figures in the graph results.

Specifically, the Kotka route could gain benefits best by model C, while model A and B are also proper options. The Neuvoton route should be considered between model B and model C. Mixed options of different models on a route should be considered as well.

7.5 Limitation of the study

The topic was chosen because of my interest in green logistics and supply chain management. HCT vehicles happens to be one of popular topics that related to logistics and environment. In addition, Finland is a country that famous for producing and exporting woods and timbers, which involve in road transportation and vehicles. All things were aligned quite nicely to create for me an opportunity to do research and write about the topic. However, limitations of my own skills as well as limitations of the research study were also discovered during the process.

One of the drawbacks from the research is the limits in the sample size, which is somewhat important during a case study. There were only three samples to be researched, which could limit the reliability of the results. However, it is not really critical because although there are numerous types of HCT vehicles, the gross weight limit, which is an important factor of HCT, only appears in limited versions (basically HCT vehicles include 64 tons, 74 tons, 76 tons, 90 tons and 104 tons). Hence, although the sample size might be small, it is understandable.

During the data collection process, there were some obstacles. Firstly, there were some delays from the interviewees, which lead to delayed results. Secondly, there were a lot of difficulties in information gathering about HCT models figures. Fortunately, the author managed to receive handouts and guidelines of vehicles from vehicle manufacturing companies.

During the calculation process, it is obvious that we have to make some assumptions and emulations about the case study apply to new HCT models.

The author had to assume that new vehicles also use the same type of fuels, with the same number of vehicles that the company currently using. It is not always ideal when you have to make assumption in a research study. However, it had to be done because the company has never used HCT vehicles before, only traditional ones.

Overall, there are still some flaws in the thesis study. However, the author believe that the thesis presented a suitable framework and methods of research for this particular topic and the thesis question has been answered presented in a professional, reliable and credible way.

7.6 Further suggestions for research studies

There is a lack of research on how green logistics is used in practice in the logistics industry in Finland. The author hopes the thesis will give a clear explanation and a clear insight for future related research.

The thesis contract also stated that this thesis could help potential movement in business and corporate of Misawa Homes of Finland Ltd. HCT certainly is a potentially beneficial answers to the company stakeholders who are seeking to improve profits while still holding on three pillars of operation: creating spaces that foster children's character development, creating communities in which customers build assets and protecting the global environment.

Lastly, a future study could focus on fuel types and efficiency since it is as important factor as payload capacity and emission performances in transportation. A research on impacts of renewable fuels with interrelation with HCT vehicles would be very useful. The results should be a further step of this thesis’s results, and equally useful for logistics entrepreneurs. The results of this thesis alone bring a view of a promising future of green and sustainable logistics.

8 CONCLUSION

HCT vehicles, undoubtedly, deliver significant changes on aspects of sustainability and green logistics: environmental, economic and social prior to traditional vehicles. The concept is simple, but the results shows drastic differences. It is truly a solution to guide towards innovative and sustainable logistics system.

Environment emissions and fuel consumption, as always, are biggest factors while considering sustainable and green transportation. HCT models showed that it could fit well into Misawa transport system with strong positive impacts on environment and quite efficient energy and fuel usage overall.

The HCT 90 tons with the payload capacity of 66 tons seems to be the best scenario for the case study company. The other two options are also considerably potential. However, it is still far from the best possible system for transportation in this case. A lot more of factors needed to be discussed additionally such as safety reason, durability or road conditions. Nonetheless, it is worthy for the company to try trials for HCT systems, considering all benefits and positive environmental impacts that the system can bring. In the long-term, it can no doubt bring back profit from all the cost savings from operation, fuel spent or salary cost capital.

All in all, HCT is inevitably a well-known and effective solution for a better transportation. However, it is still needed to be analyzed, to have more trials and research to be able to reach an efficient and sustainable transport system, not only in Misawa company case, but also in a bigger picture scenario. Without doubt, it is the right direction to go from traditional vehicles to HCT ones, considering all advantages and future profits despite potential initial costs.

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APPENDIX 1
Interview Questions (Misawa)

1. What is the amount of wood production from your sawmill in Mikkeli last year (or last 6 months)?

2. Where is the destination that your products from the sawmill mainly transported to (by road only)?

3. How long is the distance from your sawmill to that final transportation destination?

4. What is the amount of wood being transported to the destination from last year (or last 6 months)?

5. Do your company organize the transport process internally (by yourself) or do you work with other transport/logistics company (if yes, could you tell me the name of the company)

6. How many transports does your company use (in each transport route)? Or How many are provided by the transport company?

7. How much does one vehicle weight? (in tons)

8. How many wheels (or axles) of one vehicle?

9. What is the size and dimension of each type of vehicles?

10. What is the maximum load capacity of wood that one truck can carry? (in kg or tons)

11. What kinds of fuel do your trucks use (gasoline, petroleum, biodiesel or others)? If possible, could you name of the specific fuel that vehicles used?

12. When the trucks return, do they run empty? How many empty-running trips can you estimate?

13. What is the average salary of a driver per hour?

14. What is the operational/maintenance cost of each types of vehicles?

APPENDIX 2 Interview Questions (Logistics and Truck companies)

1. Do your company use/produce High-capacity vehicles (HCT)?
2. If yes, how many types of HCT do you have? (categorize by grossweight)
3. What is the load capacity of each types?
4. How many wheels (or axles) of one type?
5. What is the size and dimension of each type of vehicles?
6. What is the cost of one HCT truck?
7. What are operational/maintenance cost of each type of vehicles