Lappeenranta University of Technology
School of Business and Management
Strategic Finance and Business Analytics

MASTER'S THESIS

EVALUATION OF A NOVEL LOGISTICS SOLUTION FOR ROUNDWOOD IMPORT

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ABSTRACT

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Imports of Russian roundwood have a major role in fulfilling pulp mills' demand in Southeastern Finland. On this research feasibility of a novel logistics solution to transport this roundwood was studied. The novel logistics solution would utilize long train units, high capacity trucks (HCT), and terminal facilities at the Kouvola Rail-Road Terminal (RRT). Currently used direct railroad transports relying on short train units were used as a reference point. Costs on a whole supply chain level of these two were estimated. In addition to roundwood supply chain, synergy benefits on container backhauling from pulp mills to RRT for further train transports were studied.

Prior research on railroad transportation has proven that combining roundwood and intermodal container freight can enhance supply chain efficiency. Similarly, new concepts on railroad transportation of roundwood has been shown to enable significant cost savings.

Evaluation method used was cost-benefit -analysis (CBA), which takes in account both financial cash flows and economic external costs. This method is based on discounted cash flows (DCF), which in this research extends 33 years in the future. Profitability of the novel logistics solution was evaluated based on estimated cost savings in comparison to the currently used transportation solution.

Results indicate that the novel logistics solution is financially profitable (positive NPV) in the most likely scenario. Its external costs are higher than those of the currently used direct train transports, but not remarkably. However, payback period (PP) of this project is long. Due to uncertainty in multiple parameters and illiquidity of the terminal investment, this marks for a considerable downside risk. In contrast, the upside potential of this project is high. Results are particularly sensitive to terminal investment cost, wagon cycle times, volume of transported roundwood, and ruble-euro -exchange rate. The concept of novel logistics solution is general and can be applied also on locations other than those studied on this research.

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Venäläisen raakapuun tuonnilla on merkittävä rooli Kaakkois-Suomen sellutehtaiden raaka-ainetarpeen täyttämisessä. Tässä tutkimuksessa arvioitiin uuden logistiikka-ratkaisun soveltuvuutta näihin kuljetustarpeisiin. Tämä konsepti hyödyntäisi pitkiä junayksiköitä, High Capacity Transport -kuljetuksia (HCT) ja terminaalia Kouvola Rail-Road Terminal -alueella (RRT). Vertailukohtana oli nykyisin käytössä olevat rautatiekuljetukset lyhyillä junayksiköillä suoraan sellutehtaille. Kustannukset näille vaihtoehdoille arvioitiin koko toimitusketjun tasolla. Raakapuukuljetusten lisäksi tutkittiin konttien paluukuljetuksista RRT-alueelle saatavia synergiahyötyjä.

Aiempi tutkimus rautatiekuljetuksista on osoittanut, että raakapuun ja intermodaalikonttien kuljetusten yhdistämisellä voidaan parantaa toimitusketjujen tehokkuutta. Vastaavasti uusien konseptien on osoitettu mahdollistavan merkittäviä kustannussäästöjä raakapuun rautatiekuljetuksissa.

Arviointimetodina käytettiin kustannus-hyöty -analyysia (CBA), joka huomioi rahamääräisten kassavirtojen lisäksi myös kansantaloudelliset ulkoisvaikutukset. CBA perustuu diskontattujen kassavirtojen (DCF) menetelmään, joka tässä tutkimuksessa ulottuu 33 vuotta tulevaisuuteen. Uuden logistiikkaratkaisun kannattavuutta arvioitiin saavutettavilla kustannussäästöillä nykyiseen kuljetusratkaisuun verrattuna.

Analyysin tulokset osoittavat uuden logistiikkaratkaisun olevan kannattava pitkällä aikavälillä (positiivinen NPV). Sen negatiiviset ulkoisvaikutukset ovat suuremmat kuin nykyisin käytettävässä kuljetusratkaisussa, mutta eivät merkittävästi. Projektin takaisinmaksuaika (PP) on kuitenkin pitkä. Useiden parametriarvojen epävarmuudesta ja terminaali-investoinnin huonosta likviditeetistä johtuen sen riskitaso on merkittävä. Potentiaalia on kuitenkin myös odotettua parempaan kannattavuuteen. Tulokset ovat erityisen herkkiä muutoksille terminaalin investointikustannuksissa, vaunujen kiertoajoissa, kuljetettavan raakapuun määrässä ja rupla-euro -vaihtokurssissa. Uuden logistiikkaratkaisun konsepti on yleinen ja sitä voidaan hyödyntää myös muualla.

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ABBREVIATIONS

CAPM – Capital Asset Pricing Model

CBA – Cost-Benefit Analysis

DCF – Discounted Cash Flow

DPP – Discounted Payback Period, years

EU – European Union

FDR – Financial Discount Rate, %

FEU – Forty-foot Equivalent Unit -container

GDP - Gross Domestic Product

HCT – High Capacity Transport -truck

IRR – Internal Rate of Return, %

NPV – Net Present Value, €

PI – Profitability Index, ratio

PP – Payback Period, years

RRT – Kouvola Rail-Road Terminal

SCGE – Spatial Computable General Equilibrium

SDR – Social Discount Rate, %

TEN-T – Trans-European Transport Networks

Timber RRT – Timber section of the Kouvola Rail-Road Terminal

WACC – Weighted Average Cost of Capital, %

1 INTRODUCTION

On this chapter the basis for a research process described on this master's thesis is introduced. First, the background and setting for this research are presented. Second, objective for the research is announced and research questions are defined. Third, delimitations of the research are clarified. Last, structure for the rest of this thesis is briefly overviewed.

1.1 Background of the research

This research was carried out as a part of Metsäteho project "Terminal operations in energy efficient timber logistics" (Metsäteho, 2016a). Originally in Finnish: "Terminaalitoiminnot energiatehokkaassa puutavaralogistiikassa". Metsäteho Oy is a research and development company owned by the leading organizations in Finland's forestry industry (Metsäteho 2016b). Its goal is to carry out research and development on availability of timber, technology on timber harvesting and logistics as well as information flows and efficiency of operations on forestry industry in Finland (Metsäteho, 2016b). A third working package of the fore mentioned project concentrates on modelling and comparison of new timber terminal concepts and logistic networks (Metsäteho, 2016a). Subject of this research is a novel logistics solution, which relies on a possible timber section of the Kouvola Rail-Road Terminal (timber RRT) as a central hub to combine road and railroad transportation. The RRT as a whole is a regionally remarkable infrastructure project that was on its planning and development stage at the time this research was carried out. For this reason, significant uncertainty exists in many dimensions connected to this project, such as final layout and structure, governance model, construction costs, and customers to utilize the possibilities these completed terminal facilities would offer. According to the most recent information, the RRT is about to be developed, completed and remain under ownership of a public sector entity. The plan at this stage is to keep the terminal facilities open for competition, so that multiple private companies can operate on the area, would it be providing terminal services or in- and outbound logistics via rail or road.

On recent research, a need and demand for an additional railroad terminal located in Southeastern Finland was recognized (Metsäteho, 2016c). Railroads offer multiple benefits over road transportation on timber logistics, the most important being superior cost efficiency on extended distances (Metsäteho, 2016c&d). Well-functioning railroad connections are highly important especially in Southeastern Finland, as demand for timber on this region significantly exceeds local supply (Metsäteho, 2016c). On the framework of this research, Southeastern Finland accounts for the regions of Southern Karelia and Kymenlaakso, of which Kouvola is located on the latter one. Due to climate change caused difficulties, deteriorating forest road networks and a possible increase in biomass demand, the need for timber terminals in Finland are generally expected to rise in the near future (Metsäteho, 2016c&d).

Forestry industry is highly concentrated in Southeastern Finland. Because of this the demand for fiber timber is remarkably high both in Kymenlaakso and Southern Karelia (Natural Resources Institute Finland, 2016b). As the supply in local forests is by no means sufficient to fulfill this demand, roundwood has to be transported to the factories from a vast geographical area (Natural Resources Institute Finland, 2016a). On extended distances, railroad transport is economically superior to trucks. This advantage is most significant on Russian imports. The reason for this is the difference between maximum gross weight allowances on timber hauling trucks in Finland and Russia, the latter’s standard being remarkably lower (Saranen, 2009, 218). Hardwood fiber is by far the most important type of timber imported to Finland, Russia clearly the biggest source of imported roundwood, and the demand for hardwood fiber in Kymenlaakso greatly exceeds local demand (Natural Resources Institute Finland, 2016c). Due to these three facts, this research concentrates primarily on Russian hardwood fiber. UPM’s recent announcement to continue investments on pulp production expansion at Kymi mill further strengthens the relevance of this chosen point of view (UPM Pulp, 2016).

If constructed, the timber RRT would function as a receiving end terminal for roundwood transports via railroad. Today all major inbound timber terminals in Finland are located inside factory gates. Railroad terminals handling timber and not located next to a pulp mill or sawmill function as an outbound logistic link, in which timber is collected with truck transports to be further on sent with trains towards a factory. Due to this unique feature the timber RRT would possess, also the logistics solution studied on this research is a novel concept not yet put in practice anywhere else in Finland. This concept is introduced in the next Sub-Chapter.

1.2 Research setting

The primary interest on this research is to evaluate feasibility of the timber RRT investment opportunity and the novel logistics solution it would make possible to implement. Point of reference in here is the currently used means to transport roundwood from Russian border to a pulp mill. Therefore, the benefits from the novel logistics solution are measured by the cost savings it provides compared to the transportation solution currently used on roundwood imports. This currently used solution is direct railroad transports of Russian roundwood from the border to the factory. While this might seem to be the most straightforward solution, two factors leave room for considerable improvement on supply chain efficiency. First, terminal infrastructure at the factory limits the maximum length for a single train. This increases costs at the border due to the need to split longer Russian trains to two or even three units and on railroad transportation due to higher unit costs on freight compared to full length trains. Second, operations at the factory terminal and railroad transport cause the gate-to-gate lead times (from border to the factory and back again) on rented Russian stanchion wagons to be rather long. This means higher rent costs compared to more efficient operations and shorter wagon cycle times.

The underlying idea behind the novel logistics solution presented is to enhance efficiency on the whole roundwood supply chain beginning from Russian border, delivering the timber to a factory, and returning the empty wagons back to the border station. Therefore, the point of view on cost estimations of this alternative solution is on the entire supply chain. This allows estimating the benefits of the novel logistics solution as it is compared to the currently transportation solution used on roundwood imports.

In practice, multiple companies would be involved in operations of the novel logistics solution. Issues related to sharing the captured benefits between these companies is left outside of this research. The novel logistics solution for roundwood import is built around three major parts: 1) Considerably longer freight train units from the Russian border to the RRT and back; 2) Efficient terminal logistics at the RRT for both railroad wagons and roundwood; and 3) Transporting roundwood from the RRT to a factory via road on a purpose built High Capacity Transport -truck (HCT). A major forestry company has used a similar solution utilizing standard trucks in northern Sweden for 25 years (Forestry company 3, 2017).

Proposed logistics chain also provides a possibility for intermodal container backhauling from factory to RRT with the same HCT used for timber transportation. Synergy benefits arising from this possibility are taken into account in separate calculations. Just as with roundwood transports, the point of reference here is direct train transportation of containers to their destination at sea port. To enable these synergies in practice, the technological aspects must be paid attention before the investment in a purpose-built HCT is made. Prior research on railroad transportation has proven that combining timber and intermodal freight can enhance supply chain efficiency (Saranen, 2009). Similarly, new concepts on railroad transportation of timber has been shown to enable significant cost savings (Saranen & Hilmola, 2007).

Major drivers to achieve the desired cost savings with the novel logistics solution are shortened cycle times on rented stanchion wagons, lower unit costs on railroad transportation due to longer trains, efficient roundwood handling at the timber RRT with appropriate machinery, utilization of purpose built HCT on road transports, and synergy benefits on container backhauling from factory to the RRT.

Costs and benefits are evaluated from financial and economic perspectives. The latter takes in account external costs of congestion, accidents, air pollution, noise, and climate change. Utilized investment analysis method is Cost-Benefit Analysis (CBA), which is an adaptation of the widely used Discounted Cash Flow (DCF) method. Precision used in the calculation is annual. Analysis period covers 33 years, the first three representing construction of the required terminal infrastructure at the RRT. The remaining 30 years represent roundwood and container supply chains in operation. During this period, each year is assumed to be similar to each other in terms of parameter values used in analysis. While this might not be the case in practice, this choice was made to handle the uncertainty rising from the extended analysis period. All cost estimations are carried out in real terms and this is taken into account in the discount rates used.

1.3 Objectives of the research and research questions

There are two objectives for this research. First, to provide practical suggestions and decision-making support for the potential investors, terminal operators and customers on the expected benefits and profitability of the timber RRT. Second, to enhance knowledge on new timber terminal concepts and logistic networks within Metsäteho for further research and development purposes.

The main research problem of this paper is derived from the first objective of the research and it is to assess the feasibility of the proposed timber RRT investment. This is further broken down to two sub-problems in order to clarify the structure of the research process. These are the following:

- *What are the estimated investment and operating costs of the timber RRT and the novel logistics solution it enables?*
- *What are the benefits to be captured from this investment and alternative supply chain concept?*

1.4 Limitations of the research

The findings of this research are closely connected to the unique characteristics of the timber RRT investment project analyzed. For this reason, they might not suit to be generalized to cover other terminal projects. However, the novel logistics solution itself is a general concept and could thus be applied also on locations other than those studied on this research. There are four major factors to be considered, when comparing the results of this research with others studies or utilizing the proposed analysis model for valuation of other terminal projects.

First of these factors covers the ownership and finance structure of a terminal as well as its operation model. At the time this research was carried out, it was not yet clear how exactly these would be set. However, it was most likely that the timber RRT as a part of the wider RRT project would be built, financed and owned by a public sector entity. For this reason, both financial and wider economic effects of the terminal investment are included in the analysis. Here the benefits of potential financial savings due to more efficient operations and the corresponding external costs to environment and society are analyzed. If a terminal investment project is to be initiated by a private sector entity without possibility for public subsidies, a sole financial profitability of the project should be considered and external costs left out of the calculations. When it comes to the operation model of the timber RRT, the problem of uncertainty was solved by studying the entire roundwood and container supply chains as a single system. That is, the allocation of cost and benefits between individual companies is not studied on this research.

Second factor to consider is the location and transport connections of a terminal. The unique location of a terminal outlines to a high degree its potential to attract freight volumes and capture cost savings. A central location in relation to supply and demand of handled goods as well as connections to railroads and major roads in the region is crucial when considering establishing the kind of terminal studied on this research. Due to different cost structures and characteristics, the set of available transportation methods has a major influence on costs and benefits of a terminal investment. If a terminal does not have access to the transportation connections similar to the timber RRT project inspected here, the results of this research might not be comparable with it. For every individual terminal project connections to road, rail or waterway transportation should be assessed and possible limitations on each be considered. This includes the capacity to receive, forward, handle and warehouse cargo.

Third factor are the national legal restrictions on rail and road transportation. Regulations of train and truck characteristics in terms of maximum length or mass vary from country to country. These play a major role in the timber RRT case studied here. If the train lengths or truck masses were limited to lower levels, savings from the novel logistics solution studied in this research would be considerably different.

Fourth factor is the type of cargo a terminal is built for. If a terminal would be planned to store and handle cargo significantly different from roundwood, a differing set of investments and operational capabilities might be required. These differences can possibly have a major impact on expected costs and benefits. In general roundwood is transported in large quantities, has low value to weight -ratio and value-added services are rarely conducted on it before delivery to customer. Therefore, it shares common features with cargo classified as dry bulk or break bulk, although not considered to belong to neither of these two freight types.

The fore mentioned limitations on this research cover the results of analysis carried out. These results represent the particular case of timber RRT and the novel logistics solution around it. However, the model built to carry out this analysis is structured to be as general as possible. Therefore, the model can be easily adjusted to study a wide variety of different kind of cases or scenarios. One can change most parameter values such as distances, freight volume, train length, terminal investment cost, etc. Financial and economic costs and benefits are also computed separately before brought together, which enables a user of the analysis model to concentrate on either of the two. This feature of the model also provides a possibility of straightforward and easy sensitivity analysis.

1.5 Structure of the thesis

This paper is structured as follows: Chapters 2 and 3 introduce literature review on topics of infrastructure investments and investment analysis and criteria. Chapter 4 describes the research methodology utilized and conceptual framework of this research. Chapter 5 presents the research environment and data collected for required analysis. Chapter 6 discloses results of the analysis carried out. Chapter 7 discusses these results and Chapter 8 concludes. This structure is visualized in Figure 1 below.

CHAPTER	• CORE INFORMATION
1. Introduction	• Background, setting and objectives of the research • Research questions

2. Infrastructure investments	• Literature review
	  • Commonly accepted project assessment methods
	  • Unique characteristics of terminal investments

3. Investment analysis method and criteria	• Literature review
	  • Cost-Benefit Analysis – DCF method to accept inclusion of economic externalities in financial calculations
	  • Theoretical basis for the five investment criteria chosen

4. Research methodology and framework	• Justification for choosing the constructive approach • Data – means of collection, type, sources • Analysis model built and used for timber RRT assessment
5. Research environment and data	• Description of timber RRT in relation to the broader state of logistics in Kouvola area • Breakdown of data used on the analysis
6. Results	• Key results on base scenario analysis – financial & economical • Sensitivity analysis on the most crucial variables
7. Discussion	• Brief overview on relevance and importance of the results found in analysis • Interesting directions to extend the research and potential to utilize the constructed model elsewhere
8. Conclusions	• Review on the most important standpoints and results achieved on the research process

Figure 1. Structure of the thesis

2 INFRASTRUCTURE INVESTMENTS

This chapter is a literature review on the topic of infrastructure investments. It is structured as follows. First, the definition of the topic is clarified and its importance described. Second, methods to assess an infrastructure investment project are introduced and discussed.

2.1 Definition and importance

Definitions on infrastructure assets and widths of their framework vary. In its core infrastructure type investments are thought to account for assets that fall into two main categories: 1) transportation facilities, such as roads, railroads and ports, and 2) utilities networks including water and sewer lines, energy supply grids and communications systems (Gramlich, 1994, 1177; Kedaitiene, 2013, 61). Common characteristics for investments like these are long duration, illiquidity and high capital intensity (Grimsey & Lewis, 2002). As a part of transportation system, logistics terminals can be considered to fall under the first main category of infrastructure investments (Grimsey & Lewis, 2002). The timber RRT of interest on this research is a rather specialized investment project. Academic research on this particular topic is rather scarce, as majority of the papers published seem to be concentrated on assessing road and railroad projects. However, inland intermodal terminals, or dry ports, closely resemble timber terminals and quite recently research on them has been carried out (Panova & Hilmola, 2015; Liedtke & Murillo, 2012; Raicu et al., 2012). The main difference of timber and intermodal terminals is the nature of freight handled and stored. As on the first type the freight is bulk timber and on the second one it is standardized intermodal containers.

Economists seem to stand in line on the view that publicly funded infrastructure investment are closely linked to many significant factors of the economy on both local and national levels. Munnell (1992, 196-197) concludes on the topic on the following tone: “evidence suggests that, in addition to providing immediate economic stimulus, public infrastructure investment has a significant, positive effect on output and growth". Similarly, empirical research pointed out public sector infrastructure investment having a positive impact on private sector productivity and employment growth (Munnell & Cook, 1990, 25-26). Gramlich (1994, 1176) reminds that cuts on public investments on infrastructure in the United States in the late 1960s were soon followed by dramatic decrease on the productivity growth in the early 1970s, an obvious fact that was long ignored in the research community. This might be due to the exaggerated interest on oil crisis during the mentioned time period (Barsky & Killian, 2004, 1-2). On his research on the topic of the optimal rate of investment in infrastructure, Neill (1996, 527) pointed out a situation in which an increase in public investments on infrastructure was encouraged despite of the high level of uncertainty on the issue. All of these studies have been carried out in the United States and therefore can be biased towards the unique characteristics of the US economy. A recent research by Directorate-General for Economic and Financial Affairs outlines that in the long term investments in transport infrastructure and Gross Domestic Product (GDP) are positively correlated within the European Union (European Commission, 2014a, 23-24). This study found a unidirectional causal link between inland transport infrastructure investments and GDP, the first causing the latter. An important aspect of this relationship is the time dimension. Results show that positive effects from transportation infrastructure investments take time to fully materialize (European Commission, 2014a, 24). Due to the recent economic difficulties across the European Union, suggestions, plans and programs to increase infrastructure investments in the member states have indeed been carried out lately (European Investment Bank, 2015; European Investment Bank, 2016).

2.2 Infrastructure project assessment

Even though infrastructure is considered vital for a nation's economy, all the proposed projects can't nor should be executed. An investor, whether representing public or private sector institution, has a limited amount of funds to allocate and is looking for a positive and substantial enough return on the funds available for investments.

Therefore one needs an appropriate tool to assess whether an infrastructure project is feasible enough to be initiated or when comparing alternative investment projects, to determine ranking among these. A commonly used such tool is Cost-Benefit Analysis (CBA). Essentially CBA is an economic appraisal method based on Discounted Cash Flow (DCF) concept, first developed to offer decision-making support for public sector officials responsible on public investment projects (Prest & Turvey, 1965, 683-685). It seeks to capture all the relevant welfare effects of an investment and present them in monetary terms (European Commission, 2014b, 25). This means financial as well as originally non-monetary costs and benefits, the latter also referred as negative and positive externalities. Mackie, Worsley & Eliasson (2014, 6) reviewed government set policies and guidelines on seven developed western countries on when and how CBA should be applied on transport investments. They found out that practices on these countries are for the most part strikingly similar. In addition to concrete financial cash flows, the economic impact of the following factors are taken into consideration and valued in monetary terms: travel time savings, safety, travel time variability, crowding, fitness and health, carbon emissions, and wider economic impacts. Especially the last factor was recognized to be a disparate topic among the national standards reviewed. The reason for this is perhaps the fact that these issues are often, if not always, quite complex. Proposals to solve some of the most urgent problems on this area has been introduced by Bröcker, Korzhenevych & Shürmann (2010), and Calthrop, de Borger & Proost (2010), for example. These are discussed in more detail further on this chapter.

Although the underlying principle on every CBA remains the same independent of the project appraised, methods to estimate the relevant costs and benefits differ. The initial investment costs to complete an infrastructure project are often quite straightforward to estimate due to the fact that construction engineers specialized on this field can utilize their experience on vast portfolio of completed projects and practices on the infrastructure construction work are standardized to a high degree. The challenging part of an infrastructure investment appraisal is to model and forecast the transportation flows on a proposed project. This is highly important, because the net welfare effects on a CBA are evaluated by comparing the situation with the investment completed and without it, which is often the state at the time when the analysis is executed. A clarifying example of such comparison is presented by Saranen & Hilmola (2009, 463-465) on a set of alternative improvement possibilities on a specified length of railroad track on Finnish railroad network. The change in transport volumes, type (freight, private commuting, and public transportation passengers), mode (road, rail, waterway, and air) and time determine majority of the economic benefits and in some cases also part of the economic costs on an infrastructure investment. An example of such impact is that negative externalities caused by freight transport via road with trucks, such as noise, pollution and greenhouse gasses, can be significantly reduced by shifting the freight off the roads to railroads (Liedtke & Murrillo, 2012). Considering the valuation of non-monetary benefits and costs of an investment, all the relevant economic effects from the investment project need to be estimated first. When this is done, these measured effects can be assigned with a monetary value per unit and the CBA calculation be completed.

There are numerous alternative methods to carry out a CBA on infrastructure investments. On a broad level researchers seem to be divided into two groups here. The first one develops and utilizes models that lean on rather classical econometric methods such as general equilibrium formulas. Bröcker et al. (2010); Calthrop et al. (2010) and Verhoef, Koh & Shepherd (2010) have adopted this approach. The second group favors simulation applications to solve the same issues. De Palma, Proost & van der Loo (2010) and Saranen & Hilmola (2009) have carried out research on this manner. These two approaches should be seen complementary rather than competitive with each other. Which approach to adopt and method to use depends on the problem to be solved, the information available and researchers' expertise. As will be presented on the following two subchapters, methods based on both of these approaches can be successfully applied in practice.

2.2.1 Econometric methods

Bröcker et al. (2010) developed a Spatial Computable General Equilibrium (SCGE) model to better evaluate the effects infrastructure investments generate. They state that a standard CBA on infrastructure project appraisals is often biased for two reasons: 1) the underlying assumption on perfect markets is often violated due to: rigidities on labor markets, firms on the economy having differing degrees of monopoly power, some prices are regulated, and taxes and subsidies exist; 2) distribution of benefits is not covered, that is who and where the benefits will be reaped is not taken into account in the analysis. Rather than concentrating the analysis on the transport subsystem as is often done in the traditional CBA, the proposed SCGE model measures the utility increase in households which the investment project affects. This is done in a following manner. First, by creating a static general equilibrium model for a closed system that is a simplified presentation of the geographical area of interest. This system is divided into regions, each of which has production and household sectors in them and transportation network between each other. Second, calibrating this system with appropriate data representing the situation on each region. Third, running the model and comparing the outcomes of situations with and without the proposed infrastructure investment.

Applying the SCGE econometric tool for 22 Trans-European Transport Networks (TEN-T) projects to assess their overall social return and spatial distribution of benefits outside the immediate route of these railroad and road lengths, Bröcker et al. (2010, 807-809) found out that only 12 out of 22 of these major and European Union (EU) wide prioritized projects were expected to yield the social rate of return above 5%. This is the required minimum to be able to apply for EU subsidy finance, set by European Commission (2014b, 55). The spillovers were estimated to be rather high in some cases. This means that a major portion of the benefits a project yields are captured in regions that have not participated in financing the initial investment. Even though not taking into account all externalities on infrastructure projects, these findings provide valuable insight on the wider economic impacts of transport investments, prove that they can sometimes be considerably large, and that this fact might influence whether or not the project is initiated.

Also Calthrop et al. (2010) adopted a more traditional econometric approach as they developed a general equilibrium model for transport investment CBA. Just like Bröcker et al. (2010), Calthrop et al. (2010, 850) recognized a need to take into account the distortions on all markets in the economy, caused by taxes or external costs. More specifically, their model is developed to capture the distributional effects on net economic benefits of both the infrastructure investment itself and the way a project's financing is structured. The general equilibrium model proposed is based on five cornerstone factors on the economy: consumer utility, producer behavior, congestion, government budget restriction, and social welfare. These are defined in precise functions and the welfare effects of an infrastructure investment can be derived from these functions. Calthrop et al. (2010, 865) underline that indirect effects from an infrastructure investment can often be significant and thus should not be ignored on a CBA. On a numerical example the authors demonstrate this indirect effect on a rise in labor supply, but depending on the context of a project this can also be something else.

Verhoef et al. (2010) proposed a method to optimize capacities and tolls on a congested road network. This "long-run cost function" approach is designed to recognize the second-best alternative on capacity and toll levels on a given transportation network. The second-best setting tackles real problems consistently, whereas a first-best solution requires assumptions on perfect markets and toll differentiation to hold. This is rarely, if ever, the case when analyzing an existing or to-be-constructed road network. Just like Bröcker et al. (2010) and Calthrop et al. (2010), Verhoef et al. (2010) base their method on wide set of econometrics functions. However, simulation is utilized when applying the model in practice. This method was used to propose an optimized toll level on two separate road links on Edinburg's transportation network (Verhoef et al., 2010, 881-884).

The econometric approach for CBA can be considered theoretically sound and as shown above, possible to be applied in practice rather successfully. However, to function well enough and represent the reality to a high enough degree, methods based on this approach require highly sophisticated modelling and thus ask for specialized skills and understanding on economics and econometrics.

2.2.2 Simulation-based methods

De Palma et al. (2010, 834) have developed an instrument called MOLINO-II, which is a multi-purpose model that allows assessment of publicly financed investments and operators' strategic pricing behavior. This tool is based on modelling a simplified transport network and running a simulation on it with set parameters. It can deal with passenger and freight transport at the same time. MOLINO-II method provides an extension to a standard CBA by giving a verification or second opinion on the original project appraisal, and enabling analysts to study strategic pricing and possible interactions between projects nearby each other. The pricing dimension of this model is particularly useful, since nowadays basically all transportation can be priced and user pricing is becoming more common for infrastructure investments funding (de Palma et al., 2010, 835). A recent proposition by Anne Berner, minister of transport and communications, to transfer the whole Finnish transportation network of roads, railroads and waterways from government ownership under a separate company, and begin to collect tolls from every vehicle using these networks, is just one example of such development (Helsingin Sanomat, 2016).

MOLINO-II model was applied in practice to evaluate the Gdansk-Vienna corridor, one of the TEN-T priority projects, in ten scenarios with differing settings (de Palma et al., 2010, 845-846). The project itself was estimated to be worthwhile to execute with any combination of investment type (road only, railroad only, road and railroad) and pricing method (existing, marginal social cost, or maximum cost recovery). These findings are in line with Bröcker et al. (2010, 805-807) study, which also found this particular TEN-T project to be among those yielding high enough net welfare benefits to be initiated. The strengths of this method are, that it can be used for multiple purposes when assessing transport investments' profitability and requires a minimum amount of data compared to more complicated models. Comparing scenarios of alternative investment projects or different solutions on how to execute a single project provides valuable information for the decision-makers responsible of resource allocation.

Saranen & Hilmola (2009) adopted simulation as a tool to examine the role of freight transport in a railroad investment CBA. The principal idea is the same as de Palma et al. (2010) base their method on. The system of railroad network with its proposed links and stations was modelled separately for each five alternative investment scenarios inspected. This requires the model builder expertise and a clear vision on the overall situation on each case, as rail links with their limitations, stations, timetables and number of other important factors had to be included in the models correctly. The results of the study showed that even though the best alternative investment remained the same, ranking between the rest of the alternatives changed and cost-benefit -ratio for each alternative rose, when freight induced surplus was included in the CBA. This result underlines the notion that all relevant factors and their corresponding costs and benefits should be included into the CBA to fully capture the total welfare effects an investment is expected to yield.

These examples show that simulation, when applied correctly, can be used for infrastructure investment CBA. The strength of simulation-based methods lies in their relative simplicity and the fact that the modelling of system inspected can be done piece by piece. The situation around a proposed project can be modelled precisely enough to represent reality without a set of complicated functions the econometric approach requires. Software suitable for this purpose exist to ease the assessment task. De Palma et al. (2010, 843) utilized WinDev. Saranen & Hilmola (2009, 462) chose Quest.

2.3 Terminal investments

Research on the topic of timber terminals seems to be concentrated around energy wood, also known as forest fuel. Although of originally out of the same raw material, forest fuels and industrial roundwood are processed differently and eventually used for different purposes. For this reason requirements for terminal infrastructure and equipment on receiving, handling, storing and sending forward these two types of timber differ from each other. Regardless of this fact, findings of the following articles primarily concentrating on forest fuels can also be applied to industrial roundwood on the framework of terminals, when adjusted correctly.

Wolfsmayr & Rauch (2014) carried out an extensive literature review on the whole logistic system of a primary forest fuel supply chain. On the framework of energy wood logistics, terminals have two important functions (Wolfsmayr & Rauch, 2014, 212). First, they balance the seasonal fluctuation of power plants' demand for fuel and wood supply from the forests. Second, they enable the efficient change of transport mode by providing large buffer storage areas. This is a prerequisite for unloading high volumes of wood from train wagons or ships and storing it. An important notion Wolfsmayr & Rauch (2014, 213) point out is that terminal investment is a trade-off between additional costs on building and operating the terminal and decreasing costs on transport and chipping due to scale effects. This means that a terminal investment is feasible only when its cost decreasing effects on the whole supply chain level are greater than costs to construct appropriate terminal facilities and run the daily operations. A set of Swedish articles reviewed provide valuable insight on train terminals. Large train terminals used for both industrial roundwood and forest fuels are found to be more effective than smaller ones. High enough number of trains dispatched per week, utilization of maximum payload for each wagon, and fast and efficient loading are recognized as critical success factors for train terminals. It should also be noticed that the first transport of timber from forest to train terminal is always done with trucks due to woodlands accessibility issues, and that railroad transportation in general requires a long planning horizon.

Tahvanainen & Anttila (2011) analyzed supply chain costs on long distance transportation of energy wood in Finland. They conclude that on this framework train-based supply chains carry remarkable development potential and that terminals are an important part of these railroad dependent transportation solutions. Due to imbalance of supply and demand for energy wood between different regions in Finland, long distance transportation of this commodity is expected to increase. Results of this study reveal that railroad transportation of forest fuels can be a potential alternative to the truck transportation even in distances under 100 km. As trucks are the most cost effective transportation mode for short distances, railroads and waterways offer the most cost competitive and energy efficient means for transportation of forest fuels on longer distances. Similar to Wolfsmayr & Rauch (2014), Tahvanainen & Anttila (2011, 3373) recognize the importance of proper infrastructure on railroad terminals for handling and storing wood to reduce the overall logistics costs on the whole supply chain. Close integration with industrial roundwood logistics is also seen important to increase cost effectiveness. Another factor believed to lead on increased use of terminals in forest fuel supply chains, is securing power plants’ fuel supply during peak consumption and balance the fluctuations on timber flows from forest. In practice this is executed by keeping a buffer storage in terminal.

Kühmaier et al. (2016) compared costs of different terminal layouts for energy wood storage and processing. This research sheds some light on the most relevant costs for establishing and operating an energy wood terminal in terms of general categories and whether they could be considered variable or fixed. Evidence on this study suggests that infrastructure investments, labor costs, opportunity costs, and dry matter losses are main factors influencing economic efficiency of a terminal, measured in cost per cubic meter of energy wood stored (Kühmaier et al., 2016, 549-550). Annual turnover in terms of cubic meters and the number of storage turnovers per year heavily influence on which terminal layout could be considered the most cost-effective alternative. For small annual turnovers and few storage turnovers per year the best choice is small and simple storage yard with no specific infrastructure and only a gravel yard. However, as annual turnovers are greater and storage turnovers multiple per year, terminal with asphalt covering and permanent equipment for processing wood becomes more competitive. This is mainly due to the differing structures of variable and fixed costs on these alternatives (Kühmaier et al., 2016, 548). Results of this research reveal the potential for economics of scale in timber terminals in general, if demand for terminal services for energy wood or industry roundwood are on a high enough level.

Gronalt & Rauch (2007) propose a simple stepwise heuristic approach to design a regional forest fuel supply network. Although the perspective of this study is on a wider system than just on a single terminal, a rather similar concept can be applied to analyze one. First three steps of the total five can be used for this purpose: 1) Identify aggregate forest areas and other supply sources to determine the net available potential of forest fuel per region; 2) Calculate expected demand for forest fuel and forest fuel balance per region; and 3) Determine system cost elements (Gronalt & Rauch, 2007, 395). Steps 1 & 2 provide data for analysis on required transports of energy wood between regions in terms of volumes and distances. This information can be further utilized to determine which of the available transport modes is the most cost-effective and convenient for transports from a region with forest fuel surplus to another with deficit. System costs in forest fuel supply chain consist of transportation and terminal costs (Gronalt & Rauch, 2007, 398). The latter can be further divided into initial investment costs to build the terminal and the operational costs to run its daily operations. Taken the estimated forest fuel flows and cost parameters, feasibility of an individual terminal investment can be assessed by comparing two scenarios. One without - status quo - and another with the proposed terminal project.

3 INVESTMENT ANALYSIS METHOD AND CRITERIA

On this chapter the investment analysis method and criteria are discussed. A literature review on these topics is carried out in a following order. First, academic points of view are reviewed on the most suitable investment analysis method to evaluate the novel logistics solution. Second, the most widely accepted investment criteria are given a closer look, including the equations on how to compute them.

3.1 Investment analysis method

As briefly mentioned in the previous chapter, DCF is a well-known and widely used tool for investment analysis (Copiello, 2016, 195-197). It is used to assess the feasibility of an investment and multiple variants of techniques based on this core method exist, each designed for a specific purpose (Copiello, 2016, 195-197). The method chosen for this particular study is CBA, due to the fact that the timber RRT project crucial for the novel logistics solution is planned to be initiated by a public sector entity. European Commission recommends the use of CBA as an infrastructure investment appraisal method and provides concrete tools and guidelines on how to carry out these analysis on Guide to Cost-Benefit Analysis on Investment Projects: Economic appraisal tool for Cohesion Policy 2014-2020 (European Commission, 2014b). CBA method allows to take into account both tangible and direct as well as intangible and indirect benefits and costs associated with the planned investment project (Prest & Turvey, 1965, 684). On a more concrete level these costs and benefits can be viewed to be either financial or economic, the latter taking into account positive and negative externalities (European Commission, 2014b, 17-18). On a CBA framework all costs and benefits are denominated in the same currency unit and externalities are valued in monetary terms (European Commission, 2014b, 25). Financial costs and benefits of the novel logistics analyzed are to occur in Finland. Therefore both financial and economic costs and benefits from this investment are valued in euros, the official currency of European Economic and Monetary Union (Bank of Finland, 2016a).

According to Prest & Turvey (1965, 686) the general principles of CBA can be stated in four questions. These are the following:

1) Which costs and benefits are to be included?
2) How are they to be valued?
3) At what interest rate are they to be discounted?
4) What are the relevant constrains?

Detecting and valuing financial and tangible costs and benefits is often quite straightforward due to actual cash flows. However, the measurement and valuation of other economic benefits and costs, positive and negative externalities, can be a much more complicated issue. To measure the amount of units of an externality a displacing, or “before and after”, approach can be utilized (Moran & Sherrington, 2007, 2815-2816). With this rather simple method two scenarios, with and without the investment, are compared to estimate their difference in terms of positive and negative externalities. In case of the freight transportation these are connected to air and water pollution, greenhouse gasses, noise, congestion, accidents and land use (Demir et al., 2015, 97). Utilizing the same displacing principle on purely financial costs and benefits, also savings in travel time and vehicle operating costs can be measured (European Commission, 2014b, 88). Another problem connected to externalities, perhaps a more fundamental one, is how to value them in monetary terms. Essentially this means that a price tag needs to be placed on a phenomenon that often has no markets, is intangible and at least to a certain degree subjective. To solve this issue, public sector entities have delivered official, EU-level standardized guidelines including “price lists” on external costs (Maibach et al., 2008; DG MOVE, 2014; HEATCO, 2006).

The discount rate used in CBA, or in any type of DCF calculations, is a component that raises perhaps the most intensive discussion amongst researchers and academics. Copiello (2016, 197) points out two major schools of thought on the property investment valuation framework. The first one proposes the use of long-term Treasury bond yields as a basis for the discount rate used in analysis, whereas the second one prefers Weighted Average Cost of Capital (WACC), because it reflects the combined cost of all sources of funds to finance the project. Kishore (1996, 68) discourages using bond yields as discount rates for property type investment DCF analysis. He states that this approach produces outright flawed results due to the fact that property and bond returns are negatively correlated. To be accurate and trustworthy, WACC calculation requires both cost of debt and cost of equity to be estimated with a proper precision. The cost of debt on an investment project can be simply deducted from the required interest rate banks, other financial institutions or private investors require on debt financing on investments of a comparable risk (Copeland et al., 2005, 34). Companies listed on stock markets often use Capital Asset Pricing Model (CAPM) to estimate their cost of equity (Jagannathan et al., 2016, 1). This is, however, often not possible for non-listed private companies or public sector entities. There are models to compute cost of equity for private companies and broad studies on which factors in general are the most crucial when assessing discount rates for private equity placements (Abudy et al., 2016, 434-437; Chen et al., 2015, 49). It is questionable whether these can be used on investments projects where public sector is heavily involved, externalities are included in the DCF analysis, and managers might not be rewarded nor punished based on the success of their decision-making.

Despite of the heavy debate around discount rates, there seems to be somewhat clear consensus that discount rate should represent the risk or uncertainty connected to the investment project. The higher the risk or uncertainty, the higher the discount rate, and vice versa (Copeland et al., 2005, 34). The Economical appraisal tool for Cohesion policy provided by European Commission suggests to use a flat Social Discount Rate (SDR) of 5% for major projects in Cohesion countries and 3% for the other Member States as a benchmark and default rate for discounting in CBA computations (European Commission, 2014b, 55). Here a major project is considered to be a one that exceeds either 50 or 75 million euros in total costs, depending on the characteristics of the project (European Commission, 2014b, 15). Cohesion countries account for "EU Member States which have a GDP lower than 90% of the EU-27 average – Croatia not taken into account"; (European Commission, 2016a). This proposed approach does not allow any adjustments based on unique project or investment type specific risks.

Therefore using it might provide biased results favoring projects that in fact have a riskier profile and discounting unnecessarily heavy the net benefits of those with considerably lower risks.

Constrains to pay attention on while conducting a CBA are to a high degree connected to the unique features of each investment. These include issues related to physical characteristics of a project, laws and regulations, administration, uncertainty, probability distributions and budgeting (Prest & Turvey, 1965, 700-702).

CBA is suitable for various types of projects and it has been used extensively on logistics and transportation –type infrastructure projects. For example, Tangvitoontham & Chaiwat (2012) used CBA approach to evaluate economic feasibility of a domestic port project in Thailand. Similarly, Wang et al. (2014) utilized CBA on a commuter train improvement project assessment in Bangladesh. The CBA method is widely used in many countries, particularly in France, to support decision-making on investments related to transportation infrastructure (Damart & Roy, 2009). Norwegians have provided a CBA-based model for economic appraisal of aviation planning and operation (Bråthen et al., 2000).

3.2 Investment criteria

Using investment criteria as a basis for decision making has two primary purposes (Ross et al., 2008, 161; Copeland et al., 2005, 25). First, to assess if an investment project should be initiated. Second, to compare or rank alternative investments. Regarding timber RRT and the novel logistics solution, only the first purpose is of interest. This is because the novel logistics solution is valued as a stand-alone project and there are no alternative investments the timber RRT would be compared to. A range of methods exist to distinct whether an investment should be accepted or not. Some commonly used investment criteria are: Net Present Value (NPV), Payback Period (PP), Discounted Payback Period (DPP), average accounting return, Internal Rate of Return (IRR) and Profitability Index (PI) (Ross et al., 2008, 183). Pasqual et al.

(2013, 206) add net final value, benefit-cost ratio, equivalent annuity and average payback period to this list.

A strong consensus holds amongst academics that NPV is superior to other investment criteria (Ross et al., 2008, 163; Copeland et al., 2005, 29&34; Brealey et al., 2008, 115). However, also opposing points of views have been presented on this issue. Bhandari (2009) compared six commonly used investment criteria by checking which of the ten desirable characteristics for an ideal capital budgeting decision criterion each satisfies. These characteristics are simple to understand, easy to calculate, measure profitability, etc. The criteria inspected were NPV, IRR, PI, DPP, PP and modified internal rate of return. The results of this study shows that although none of these criteria meets all the desirable characteristics for an ideal investment criterion, both NPV and DPP fulfill seven out of ten of these. An important finding is that these two criteria “back-up each other” in a way that the characteristics one doesn’t meet, the other does. Only the ease to calculate seems to be a troubling issue in some cases for both of these criteria and this characteristic is only met by PP of all the criteria studied.

Pasqual et al. (2013) demonstrate that, although NPV is widely regarded as a superior investment criterion, there are several others that serve their purpose well when applied properly. The findings of this study show that the use of IRR, PI, DPP and four other criteria leads to the same investment decision as NPV and also enable proper ranking when choosing between two mutually exclusive projects, similarly to NPV. Some problems are connected to these criteria, which need to be taken into consideration. An example of such case is the possibility that a project can have multiple real IRRs. In order to be fully consistent with NPV, these alternative criteria needs to be adequately implemented and interpreted. These results stand in line with the empirical evidence, that practitioners on the finance departments broadly utilize multiple investment criteria (Ryan & Ryan, 2002, 359). According to this study, whereas NPV is the most commonly used by Fortune 1000 companies, IRR is almost as popular. Also PP, DPP and PI are quite often utilized.

Finance academia, textbooks and theory often seems to favor NPV as a one-shot solution to properly assess any possible investment project to come by. Vitolo & Cipparrone (2014, 431) propose that on the wider portfolio level this might not be appropriate for some companies. Their standpoint is that the choice of projects on company portfolio should be aligned with corporate strategy and industry in which a company competes. Taken this, information on which kind of portfolios the use of each investment criteria generates, can possibly be highly valuable for management. Results of Vitolo & Cipparrone's study propose the following: 1) NPV criterion generates portfolios with long term large and positive cash flow streams, and 2) IRR and PI criteria generate higher return on capital investment, which drives capital efficiency. Due to these differences, the use of NPV as a primary criteria is likely to foster growth for a company on a high growth industry, whereas IRR and PI are more likely to fit for companies on industries with slow growth, but large revenues (Vitolo & Cipparronne, 2014, 431).

Considering all the above, the superiority of NPV is perhaps not questioned per se, but rather the other investment criteria widely used in practice are proved to be valuable tools as well. Although NPV should for good reasons be used as the primary determinant when making investment decisions in most cases, other criteria can provide additional, supporting or complementary information for decision-makers. When multiple proper investment criteria exists, it would be outright foolish or naïve to rely on just one. After all, each investment criteria provides its own point-of-view on the project under analysis and thus makes the information available for management richer. Based on the findings of literature review five investment criteria were chosen for evaluating the novel logistics solution. These are NPV, IRR, PI, DPP, and PP. Each of them is discussed in more detail, and equations on how to compute them are provided on the Sub-Chapters below.

3.2.1 Net Present Value

In Net Present Value (NPV) method the difference between the sum of present values of a project's expected future cash flows and the initial cost of the project is calculated. The future cash flows are discounted to their present values using opportunity cost of capital, which represents the risk level of an investment. There are three reasons why NPV criteria is viewed to yield the most reliable and realistic valuation for an investment project: 1) NPV uses real cash flows instead of earnings, which are an artificial accounting construct; 2) NPV utilizes all the expected cash flows connected to an investment project, whereas some other methods ignore cash flows beyond a particular date – namely payback period and discounted payback period; and 3) NPV discounts the cash flows properly, taking in account the risk level of an investment and time value of money (Ross et al., 2008, 161-163). NPV can be computed according to the formula presented on Equation 1.

Equation 1. Net Present Value

$$NPV = \sum_{t=1}^{N} \frac{FCF_t}{(1+k)^t} - I_0 \qquad (1)$$

Here FCF_t is the free cash flow in time period *t*, I_0 is the initial cash outlay, *k* is company's WACC, and *N* is the number of years in the project (Copeland et al., 2005, 27). These symbols represent the same parameters also in the following equations, if not mentioned otherwise. As discussed earlier on, alternative discount rates can be used instead of WACC when computing NPV.

3.2.2 Internal Rate of Return

Internal Rate of Return (IRR) provides a single number combining all the net benefits of a project and is based solely on the cash flows the project is expected to yield (Ross et al., 2008, 169). Problems with IRR method are connected to valuing financing projects instead of investment projects, multiple rates of returns due to unconventional cash flows and comparing mutually exclusive projects (Ross et al., 2008, 171-175). As the project of interest in this research does not have any of these three attributes, IRR can be used reliably as an investment criteria. It supports NPV valuation by revealing the expected rate of return specific to the novel logistics solution. IRR can be derived utilizing formula by Copeland et al. (2005, 28) which is presented on Equation 2.

Equation 2. Internal Rate of Return

$$NPV = 0 = \sum_{t=1}^{N} \frac{FCF_t}{(1+IRR)^t} - I_0 \qquad (2)$$

3.2.3 Profitability Index

Profitability Index (PI) provides a ratio of expected future cash flows discounted to their present value and divided by the initial investment (Ross et al., 2008, 181). The major pitfalls of PI are connected to comparison of alternative investments in case they are mutually exclusive (Ross et al., 2008, 181-182). As the novel logistics solution is evaluated as a stand-alone project, these problems with the PI method can be neglected. For individual projects IP gives a same results as NPV in terms of whether to initiate the investment project or not. Instead of a currency based measure of NPV, PI returns a multiple of expected benefits with regards to expected costs, taking the time value of money into account. This provides a decision maker information in a form that is easily understandable and communicates project profitability perhaps even better than NPV.

The general concept of PI, by Ross et al. (2008, 181), is introduced as a formula in Equation 3, and a mathematical representation of this same formula is available on Equation 4.

Equation 3. Profitability Index, concept formula

$$PI = \frac{PV\ of\ cash\ flows\ subsequent\ to\ initial\ investment}{Initial\ investment} \tag{3}$$

Equation 4. Profitability Index, mathematical formula

$$PI = \frac{\sum_{t=1}^{N} \frac{FCF_t}{(1+k)^t}}{I_0} \tag{4}$$

3.2.4 Discounted Payback Period

In Discounted Payback Period (DPP) method the expected future cash flows are first discounted to their present values in a similar manner as with the NPV approach. After this a calculation is done to find out how long it takes these discounted cash flows to equal the initial investment. DPP is a variant of a more simple PP method, which does not take time value of money into account. Due to this reason it carries a major flaw common with the original version of this method. To make decisions based solely on DPP, a decision-maker has to define an arbitrary cutoff period to distinct acceptable projects from those that are to be rejected. As the DPP ignores all cash flows after this time and projects could have very different kind of cash flow structures, there is no single cutoff period that would lead to value maximizing results in all cases. (Ross et al., 2008, 164-166)

Even though the DPP has its downside, it can provide valuable information when incorporated with other investment criteria. As liquidity is important in many cases, investors are curious to know on which time frame a project is expected to break even and begin to produce net profits. DPP delivers this insight while taking into account the time value of money and therefore supports the analysis in which NPV is the core measure to rely on.

3.2.5 Payback period

Of all the commonly used investment criteria, Payback Period (PP) is perhaps the most simple to calculate and understand. Using this method, one simply compares the estimated future cash flows from a project against its required investment, and analyses how many years does it take until the nominal returns from the investment cover the initial cash input required (Brealey et al., 2007, 187). No discounting is required and the result is very clear to understand also for those who are not experts in finance. The payback rule states that a project should be accepted if its PP is below a specified cutoff period, and rejected if PP exceeds it (Brealey et al., 2007, 187). One can therefore see there lies two fundamental flaws in trusting solely on PP as a primary investment criteria. First, it does not appropriately recognize the time value of money (Brealey et al., 2007, 187). Second, it neglects all cash flows after a rather arbitrary cutoff period (Brealey et al., 2007, 187).

Regardless of the weakness of the PP method, it is widely applied even in major Fortune 1000 companies (Ryan & Ryan, 2002, 359). After all, in order to calculate PP one needs the same future cash flow estimations as with NPV and other investment criteria discussed earlier on. Once these have been completed, one might as well also calculate PP in addition to more theoretically sound measures. Due to its obvious flaws PP should not been used just by itself or as the most important criteria when evaluating an investment opportunity. However, it can provide valuable additional information to support or question the results on primary investment criteria.

3.2.6 Decision-making rules

Table 1 below concludes the decision-making rules for each of the five investment criteria used on this analysis on when to accept a project and when to reject it.

Table 1. Investment criteria decision-making rules

Investment criteria	**Accept project**	**Reject project**
NPV	> 0	< 0
IRR	> Discount rate	< Discount rate
PI	> 1	< 1
DPP	< Cutoff time	> Cutoff time
PP	< Cutoff time	> Cutoff time

(According to: Ross et al., 2008, 162; 164-166; 179; 181 & Brealey et al., 2007, 187)

4 RESEARCH METHODOLOGY AND FRAMEWORK

The methodology chosen and used on this research and the research framework on the novel logistics solution investment analysis is presented on this chapter. First, the general research methodology as well as data collection and analysis methods are introduced. Second, the framework and most important concepts of this research are clarified.

4.1 Research methodology

A constructive approach was adopted to carry out this research. This approach means managerial problem solving through construction of models, diagrams, plans, organizations or other tools. The main principle of constructive approach is to tackle real-world managerial problems with novel practical solutions that are based on existing theoretical knowledge and insight. Dividing the constructive approach research process into phases reveals the basic characteristics of this research method. Table 2 presents these phases in general terms and outlines on how they were followed on this particular research. (Kasanen, Lukka & Siitonen, 1993, 245-247)

Table 2. Phases of research process with constructive approach

Phase	General	Novel logistics solution research
1.	Find a practically relevant problem, which also has research potential.	Is the novel logistic solution profitable enough to initiate the required investments?
2.	Obtain a general and comprehensive understanding of the topic.	Literature review, expert interviews, and preliminary data analysis.
3.	Innovate, i.e., construct a solution idea.	Building the analysis model to evaluate financial and economic costs and benefits of the novel logistics solution.

4.	Demonstrate that the solution works.	Comparing the proposed solution against gathered information and expert insight.
5.	Show the theoretical connections and the research contribution of the solution concept.	Clarifying research’s connections to existing theory and defining the degree to which its results can be generalized.
6.	Examine the scope of applicability of the solution.	Assessing delimitations of the research.

(According to Kasanen et al., 1993, 246)

Constructive research can be categorized to belong in a group of applied studies, which share a common characteristics to produce new knowledge in the form of normative applications (Kasanen et al., 1993, 252). On the framework of this research, this means assessing appropriate methods and required data to find out, if the investments required to bring the novel logistics solution operational are profitable enough. Taken this, the primary interest of this research is to provide practical suggestions rather than building new theory. This research is a typical constructive research in a sense that it applies the case-method (Kasanen et al., 1993, 255). A thorough examination is given to a single case of proposed novel logistics solution relying on timber RRT to construct and fine tune a solution that best suits to find out the profitability of this unique project. Analysis model built to evaluate feasibility of the novel logistics solution is designed to be as general as possible. It can therefore be utilized not only to evaluate the particular case of interest on this research, but also in other locations where a similar operation model is possible. Majority of the parameters in the analysis model can be easily adjusted, which allows flexible study of different scenarios and sensitivity analysis.

4.1.1 Data collection

Data for this research was gathered from multiple sources. A rough division can be made to primary and secondary sources of data. The primary sources of data consist of interviews and first-hand observations as for the secondary sources include publications, databases, and internet sites and services. Both quantitative and qualitative data was collected. As CBA is the very core of this research, reliable quantitative data is first and foremost of importance. However, qualitative data was important in assessing the crucial parameters to study in the CBA and structuring an understanding on how the novel logistics solution would function in practice. Figure 2 below presents the division of data sources in a hierarchical order.

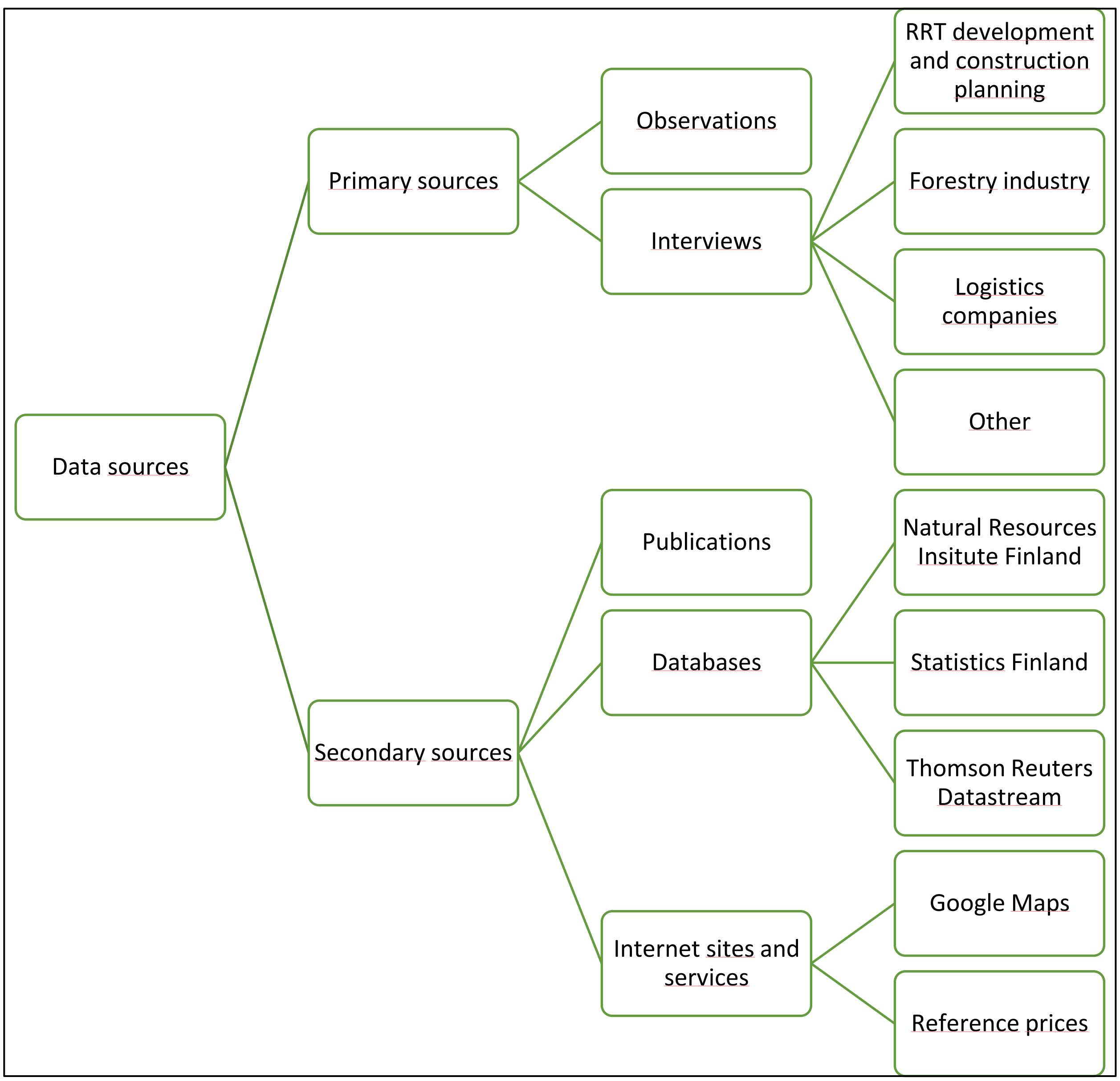

Figure 2. Data sources

When it comes to primary sources, interviews were of major importance. Firstly, interviewees' expertise was critical to build an overall understanding on the case examined. Secondly, a lot of information was gathered from these interviews that could not otherwise be accessed and proved to be crucial to define values for many of the key parameters in the analysis model. A total of eleven interviews were carried out on this research process. Interviews are divided in four categories based on the interviewees' organizations' expertise in relation to the timber RRT and the novel logistics solution for roundwood import. These are RRT development and construction planning, Forestry industry, Logistics companies, and Other, which do not fit in any of the other three classes. Eight of the interviewed specialists represented private or stock market listed companies. In addition to these, there were one of each of the following: municipality's research, development and innovation company, university, and municipally owned port company. Table 3 offers a complete list of the conducted interviews on this research. To guarantee the anonymity of the interviewed experts, labels describing their organization were used instead of actual names of these organizations. First hand observations play a smaller role and this data collection method was used basically just to estimate the efficient roundwood handling capacity of a material handler at the timber RRT.

Table 3. Conducted interviews

	Organization	**Field of expertise**	**Location / Type**	**Date**
RRT development and construction planning	Consultant company 1	Construction planning	Kouvola	10.5.2016
	Consultant company 2	Logistics consulting	Helsinki	21.6.2016
	Consultant company 3	Construction planning	Kouvola	5.8.2016
Forestry industry	Forestry company 1	Timber transportation	Phone	23.6.2016
	Forestry company 2	Timber transportation	Email	11.8.2016

	Forestry company 3	Terminal operations	Email	16.1.2017, 2.2.2017
Logistics companies	Logistics company 1	Railroad freight, Finland - Russia	Phone	20.6.2016
	Logistics company 2	Railroad freight, Finland - Russia	Phone	28.7.2016
Other experts	Other expert 1	Construction planning, Logistics	Kouvola	29.2.2016
	Other expert 2	Timber transportation	Kouvola	8.4.2016
	Other expert 3	Terminal operations	Lappeenranta	8.2.2017

Publications were used to build theoretical understanding on the research topic, but also to assess significant parts of the empirical side of the research. While theory section of this research is based on academic literature, reports and guidebooks were used as well. The latter were used to both structure major parts of the analysis model and collect multiple parameter values in it. This was the case especially with train and HCT transportation costs and external costs.

Three databases were used in this research. Of these the Natural Resource Institute Finland’s one and Thomson Reuters Datastream were most important. First one of these was used to gather data on preliminary analysis of roundwood flows to, from and inside Southeastern Finland, and the second one to assess financial information, the most important being ruble-euro -exchange rate. Multiple internet sites were used to capture reference prices for material handler, AdBlue, wagon rents etc. The distances between locations in the model – border station, RRT, pulp mills, and sea port – were measured utilizing Google Maps -service’s distance measurement tool. The same service was used also in round trip duration estimations on trucks travelling from the RRT to pulp mills and back.

4.1.2 Analysis method

Due to the nature of timber RRT's probable ownership and operating structure, CBA was chosen for the primary analysis method to find an answer for the research problem of assessing profitability of the novel logistics solution. Public sector involvement in infrastructure projects requires a wider point of view than a purely private investment does. In addition to financial costs and benefits, also economic aspects needs to be taken into consideration and the CBA method allows this to be done (Prest & Turvey, 1965, 684; European Commission, 2014b, 17-18). CBA is a variant of DCF, a family of methods that are widely accepted and applied in investment analysis, valuation and capital budgeting (Copiello, 2016, 195-197; Ross et al., 2008, 89-117). In CBA, the expected real financial cash flows and economic costs and benefits are estimated and discounted to represent their corresponding present values.

Five investment criteria were chosen to measure profitability of the novel logistics solution for roundwood import. These are NPV, IRR, PI, DPP and PP. The theoretical foundations and argumentations for these measures' suitability for this research, equations and decision-making rules for all of them are available in Sub-Chapter 3.2.

4.2 Research framework

Theoretical framework of this research is built on two major themes: infrastructure investments and investment analysis. To study the operational logic and profitability of the novel logistics solution for roundwood import, scope in these topics are directed to terminals and cost-benefit –analysis. The case of Kouvola RRT to which the novel logistics solution is centered around is unique in many senses. However, the analysis model to carry out this research was built to be a general representation of the proposed alternative supply chain for roundwood transportation. Road and railroad transportation represent a major share of the estimated costs in both currently used method for roundwood imports and the novel logistics solution. To further broaden the view on this direction, logistics are central considering terminals. Therefore, these two should be mentioned on the framework of this research, although not thoroughly investigated in theoretical sense. Research framework is visualized in Figure 3.

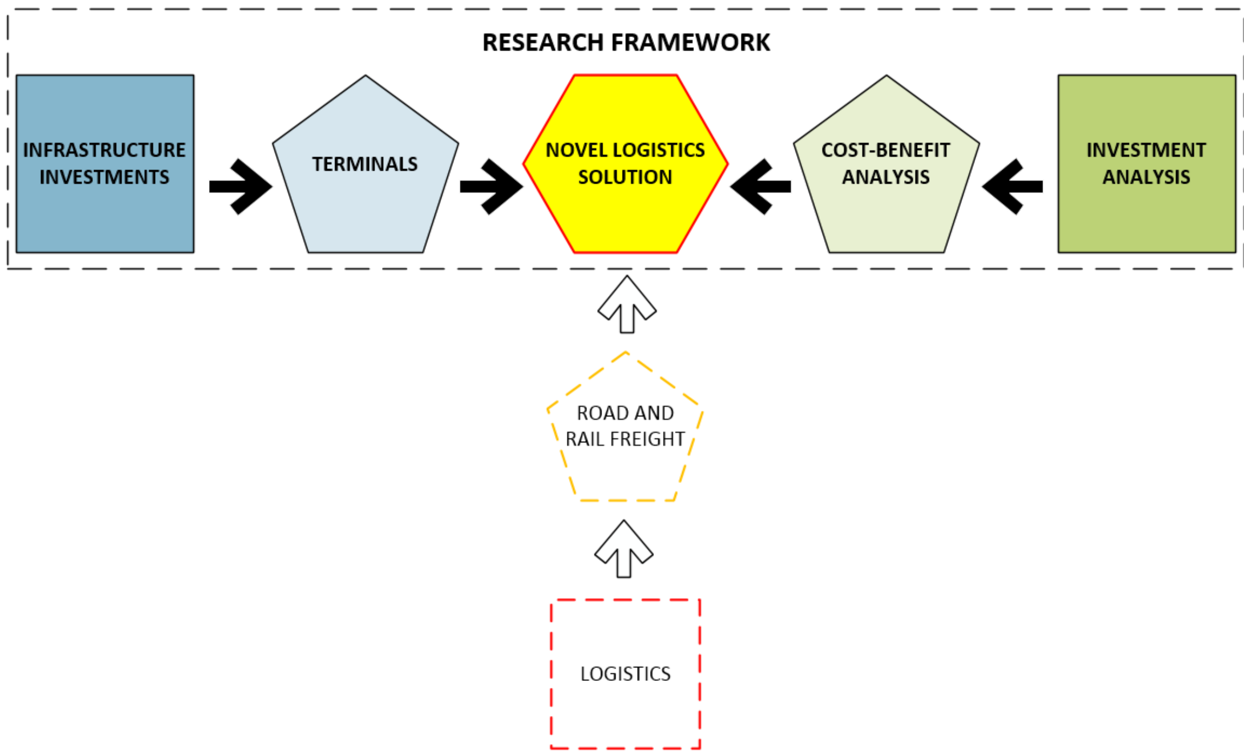

Figure 3. Research framework

4.2.1 Alternative logistics chains for roundwood imports

The investment analysis on timber RRT and novel logistics solution built around it is carried out by comparing the currently used solution for roundwood imports to the novel logistics solution. Both of these alternative logistics chains for roundwood imports are introduced in this Sub-Chapter.

The currently used solution for roundwood imports relies solely on direct train transports from the Russian border to pulp mills in Southeastern Finland. Due to limitations in terminal infrastructure at pulp mills, length for a single train unit is considerably limited. On Russian side of the border long train units are common on freight transports. Therefore, a single Russian train often needs to be split to two or sometimes even three separate train units at the Finnish-Russian border. This increases costs not only due to the train split operations themselves, but through higher costs per transported roundwood ton in shorter trains on Finnish railroads when compared to longer units. Often the stanchion wagons also need to be changed or handled between the border and pulp mill either before heading to a factory or after leaving one, causing yet additional costs. The wagon cycle times in currently used direct train transports are counted in several days, which leaves room for improvement. As the stanchion wagons used on import roundwood transports are mainly Russian, costs effect of extended wagon cycle times are very concrete – higher rental costs. On this research, the costs for roundwood transports on Russian side of the border are assumed to be identical for both of the compared logistics chains and therefore are not taken in consideration in any of the calculations. Figure 4 visualizes the currently used logistics chain for roundwood imports.

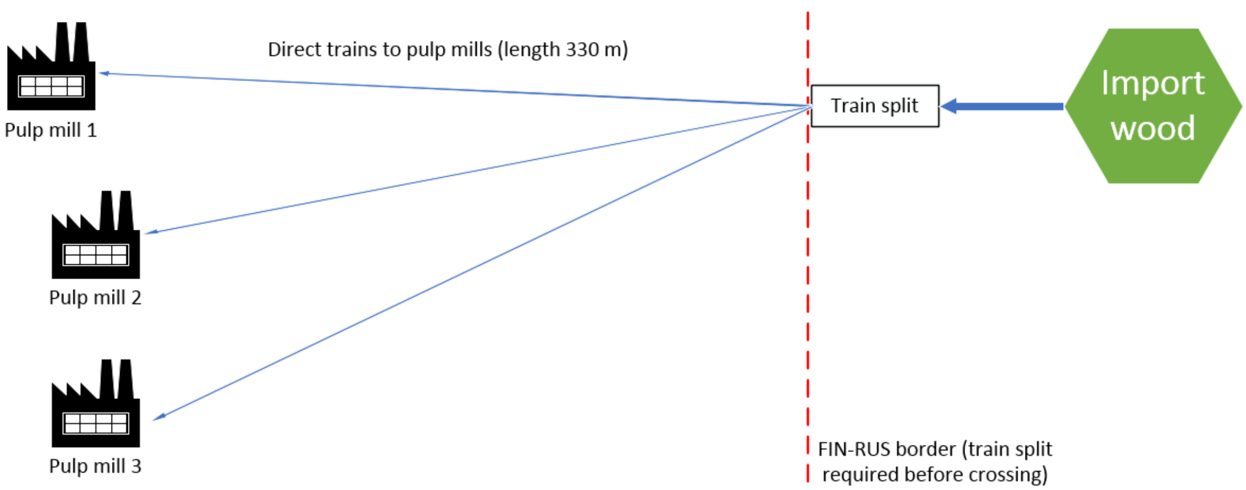

Figure 4. Import roundwood logistics chain, currently used solution

The novel logistics solution for roundwood imports presented here utilizes the possibilities Kouvola RRT provides. Although a separate section of the RRT, the timber terminal would benefit in three ways for being set up in close proximity to other terminal functions (mainly container terminal section). First, significant savings can be found on investment costs required to complete the timber terminal section in comparison to a similar separate terminal dedicated only for timber. Same infrastructure, first and foremost railroad and road connections, can be utilized for all freight types. Second, considerably longer trains can be accepted to and send forward from the RRT in comparison to pulp mills. Third, a possibility to utilize HCT on container backhauling from factory to RRT provides an option to capture synergy benefits through enhanced efficiency in container transportations outwards from pulp mills.

In the novel logistics solution full length trains are used to transport roundwood from the Russian border to the timber RRT. On the analysis model these full length trains are set to be double the length of those in the direct train transports currently used for roundwood imports (660 meters vs. 330 meters). No train splits are required at the border. At the timber RRT efficient material handler is used to empty the stanchion wagons of roundwood. From the RRT roundwood is transported on purpose-built HCT to pulp mills via road. This HCT -vehicle would have a considerably higher freight capacity compared to standard trucks used in roundwood transports, which yields savings on costs per transported ton of roundwood. Figure 5 visualizes main parts of the novel logistics solution.

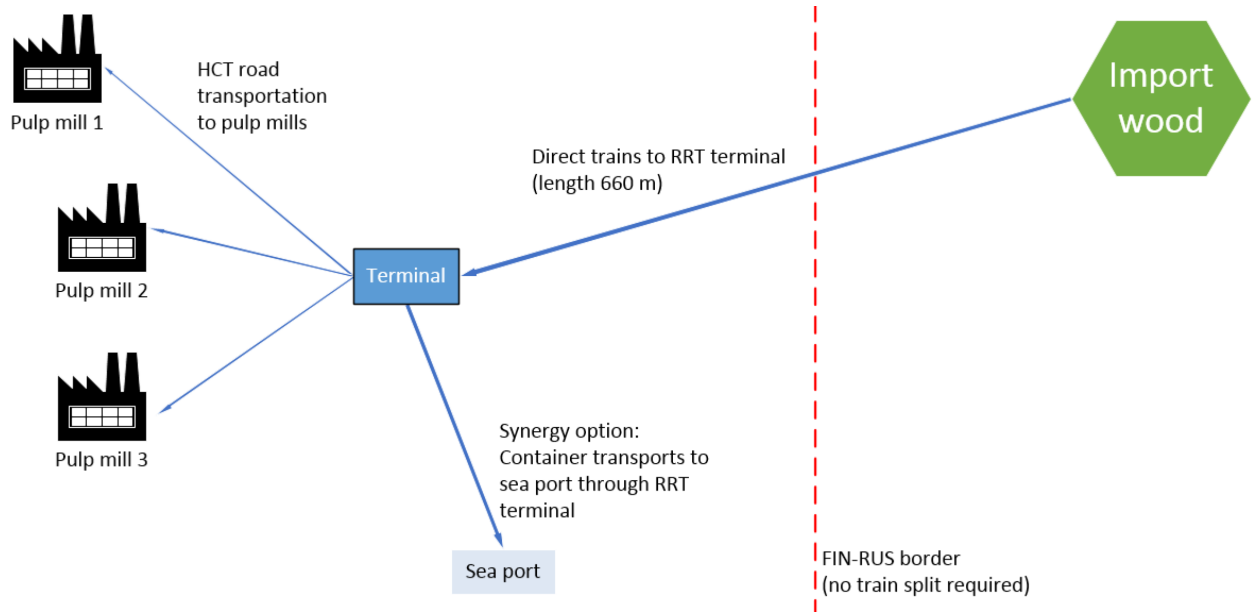

Figure 5. Import roundwood logistics chain, novel solution utilizing a terminal

Considering the synergy option for container backhauling from pulp mills to RRT on HCT, some technological aspects must be paid attention before the investment in HCT is made. To be able to carry out this task, such a vehicle should capable to transport both roundwood and containers, and the transition between the two freight types should be possible fast and easy. Concepts on trucks to adapt in this way to two types of freight already exist on research and development level. Pressure to further enhance the efficiency of logistics chains and cut costs is likely to bring such solutions on wider commercial use in the near future. However, an “off-the-shelf” -solution to a described technological issue does not yet exist.

4.2.2 Analysis model

The analysis model in this research is structured to measure savings the novel logistics solution would provide over the currently used transportation solution. It is built on Microsoft Excel 2013 -spreadsheet. Financial and economic costs were calculated on separate sheets after which the core results of each were collected on a CBA-sheet to bring the two together. This was done to have a clear picture not only of the full CBA, but also of its subparts. Sensitivity analysis tool on financial costs was constructed to study how results would change, if the most crucial parameters would not remain on expected levels in the long run. All the estimated cash flows are considered real rather than nominal, which allows to leave inflation out of the equation. This is taken into account on the discount rates used in the analysis.

Estimations were made on annual basis reaching 33 years forward, beginning from the point of time when terminal construction is launched. Terminal’s investment costs are allocated evenly on first three years, after which the actual operations begin and last for the remaining 30 years. Other required investments on material handler and HCT are set for years 3 and 17. Both of them are expected to serve for 15 years and have no salvage value after that. On a period the roundwood and container transportation operations are running, freight volumes and therefore also variable costs related to operations are set to be similar for each year. This and many other settings on the model can be quite easily changed or adjusted if a need arises for other future analysis requirements.

4.2.3 Base scenario

A base scenario was structured to set an appropriate standpoint for analysis on the novel logistics solution. That is, to have a representative case and analysis results, which could be clearly announced and to which alternative scenarios could be compared to. Furthermore, the base scenario is the starting point on the sensitivity analysis carried out in this research. Most likely parameter values, according to this research, were used in the base scenario. The most important of these are presented in Table 4. Many more were used in the analysis and all these are covered in Chapter 5. A conscious decision was made to assign all timber transports to and container transports from UPM Kymi pulp mill. This decision was done for two reasons. First, to keep the setting of the base scenario simple to understand and structure it to be a good reference point in terms of alternative scenarios and sensitivity analysis. Second, birch fiber is a crucial raw material especially for UPM Kymi and the on-going investment program at this pulp mill will remarkably increase its need for fiber timber, including birch. Results of the analysis on base scenario are presented both with and without the synergy benefits arising from container backhauling. These are provided for financial profitability, economic impact of externalities, and CBA combining these two.

Table 4. Most important parameter values in base scenario

Parameter	**Most likely value**
Terminal investment cost	4 300 000 €
Wagon cycle time, terminal	1.5 days
Timber wagon cycle time, UPM Kymi	5 days
Container wagon cycle time, UPM Kymi	4 days
Exchange rate	50 RUB/€
Roundwood volume, annual	300 000 tons
Container volume, annual	2 600 FEU

4.2.4 Crucial variables to assess for uncertainty in sensitivity analysis

As building of the analysis model progressed, multiple experiments were made with it to find the variables that have the most significant effect on profitability of the novel logistics solution. Primarily on the NPV measure. Four of such variables was found and chosen to be further studied in sensitivity analysis. These are: 1) Terminal investment cost; 2) Wagon cycle time in direct train transports of roundwood to pulp mill; 3) Total annually transported roundwood; and 4) ruble-euro -exchange rate (RUB/€). Also fifth remarkably important parameter was found – distances between the border crossing point, terminal, pulp mill, and sea port locations. As in the case studied these would not change, this aspect was not involved in the sensitivity analysis. However, this finding could prove to be valuable for those who would like to adjust the analysis model built in this research and use it to study similar terminal and supply chain solutions in other locations.

Sensitivity analysis was run for the base scenario both with the container backhauling synergies taken into consideration and without them. This was done independently for each variable (*ceteris paribus –principle*) in both directions – better and worse – from the most likely values used in analysis on base scenario. In addition to these sensitivity analyses, a couple of interesting scenarios were studied considering more efficient and thus affordable container handling at the RRT, and benefits arising from servicing multiple pulp mills to raise the roundwood volumes transported through the timber RRT.

5 RESEARCH ENVIRONMENT AND DATA

This chapter describes the research environment around the timber RRT and presents the data gathered to complete investment analysis on the novel logistics solution. Although not covered in detail on this research, the general characteristics of the Kouvola RRT infrastructure development project are crucial to understand timber RRT's role as a part of a larger logistics site. The data collected for this research covers information on roundwood supply, demand and imports in Finland, terminal investment and operating costs, roundwood transportation costs on train, HCT, and regular truck, wagon cycle times and rents, container transportation and handling costs, economic costs of externalities, as well as some other factors crucial to complete the investment analysis.

5.1 Kouvola RRT and timber terminal section

The timber RRT is to be executed as a part of a larger logistics center development project called Kouvola RRT. At the time this research was carried out, this project was on its planning phase and many details and practicalities connected to it were still an open question. However, Kouvola Innovation and city of Kouvola have already put considerable effort and dedication on this project. Its first stage development is estimated to cost approximately 3.4 million euros (European Commission, 2016b). Kouvola is located alongside the core TEN-T in Finland and is an important crossroads especially for railroad, but also for road transports on an EU-level (Finnish Transport Agency, 2016). In fact, on top priority TEN-T the railroad terminal at Kouvola is considered to be the only one in whole of Finland classified this high in importance. Due to this reason, European Commission has allocated 1.7 million euros of funding for Kouvola RRT planning phase to cover half of its total costs (European Commission, 2016b).

Logistic services are already an important economic driver in Kouvola and just recently Kouvola was ranked as a number one logistics center in the Nordic countries (Kouvola

Innovation, 2016). The new Kouvola RRT development project is about to be a significant extension on the existing logistics infrastructure on the region. This project stands on two cornerstones: railroad connection and intermodal containers. Considering railroad freight, Kouvola stands on a crucial crossroads between east and west in Finland. A high proportion of trade between Finland and Russia, if transported via railroad, moves through Kouvola. On the very core of the RRT project are intermodal container logistics. Convenient and cost-effective logistics services together with a central geographical location are the competitive advantages this terminal is seen to have in the future from intermodal container freight perspective. The focus is most likely to be on international railroad transports both from and to east – Russia and beyond all the way to western China. A point worthwhile to mention is Kouvola RRT's planned capability to load and unload extra-long trains – a maximum of 1 100 meters – on a single rail, which is rare in Finland. This marks a significant potential for costs savings on train transports due to higher efficiency on terminal and on railroad routes to and from there.

The timber section of Kouvola RRT was originally thought to be designated for bulk cargo. This means that in addition to timber, also coal, pulp, chemicals or other forms of dry or break bulk could be stored and handled on this area. The requirements on terminal characteristics on different bulk materials vary and so does the costs to set up and operate a terminal. A central idea and goal in Kouvola RRT is to seek for benefits of scale. Therefore the high initial investments costs must be justified by significantly lower unit costs in terminal operations and enhanced efficiency of road and railroad transports in the long run. This requires a high enough volume of freight in the RRT for the project to be profitable. There are two reasons why the analysis on this research was based on the bulk section of Kouvola RRT to be primarily dedicated for timber. First, forestry industry in Kymenlaakso uses far more timber than is available on the region. For this reason high volumes of roundwood needs to be transported to Kymenlaakso from elsewhere in Finland and abroad. Second, due to roundwood's requirements on terminal for its handling and storing, the associated costs for terminal set up are lower than for many other types of bulk freight.

5.2 Timber supply and demand

Forests cover 75 % of Finland’s land area, which is the highest proportion in Europe (Metsäyhdistys, 2016a). On a vast majority of this area, wood grows sufficiently fast to provide steady harvest levels and raw material supply for country’s forestry industry (Metsäyhdistys, 2016b). Nine percent of these forests are classified as natural reserves and harvest on these areas are strictly limited, whereas on another four percent conservation rules allow woods to be cut to some degree (Metsäyhdistys, 2015). Due to Finland’s northern location softwood species dominate the stock of wood in the nation as pine (mänty) accounts for 50 % and spruce (kuusi) for 30 % of the total volume in standing forests (Metsäyhdistys, 2016c). Hardwood species (lehtipuu) cover the remaining 20 % and most of this is birch (koivu) (Metsäyhdistys, 2016c). Since mid-1970s the trend of harvest levels has been rising in Finland (Metsäyhdistys, 2016d). However, the forest growth has been greater every year for the same time period and this remains to be the case today (Metsäyhdistys, 2016d). According to expert estimates, the annual timber harvest levels in Finland could be significantly increased without endangering ecological sustainability or long-term raw material supply for local forestry industry (Metsäteollisuus, 2015a).

Forestry industry has a long history in Finland, dating back to tar production in 16th century (Metsäteollisuus, 2013). Wood is by far the most abundant natural resource in Finland and being renewable, it has offered a natural competitive advantage for companies specialized in refining it. Today Finnish forestry companies UPM and Stora Enso are international powerhouses and among the largest on their industry on a global scale (Metsäteollisuus, 2016). For decades forestry industry in Finland has been based mainly on two cornerstones – mechanical and chemical refining of raw timber (Metsäteollisuus, 2013). The first offering saw mill products and the second producing pulp and pulp-based products, mainly paper and cardboard. In recent years, significant investments have been made on R&D and production sites to seize business opportunities outside these two traditional fields. An example of such venture is biofuel production based on residues from pulp production processes (UPM, 2016a). Forestry industry is an important part of Finnish economy. It employs 42 000 people directly and remarkably more on the whole logistical value chain from harvests in the forest to transports of roundwood to factories and end products abroad (Metsäteollisuus, 2015b). In 2015 forestry was the largest exporting industry in Finland accounting for 22 % of total exports (Kauppalehti, 2016). Faith on forestry industry's success on the long run seems strong, as multiple major investment projects have already been launched and many potential ones are already far on planning or financing phase. Metsä Group's Äänekoski bioproduct mill is currently under construction and holds a record for being the largest single forestry industry investment in the history of Finland with a 1.2 billion euro price tag (Metsä Group, 2016a; Metsä Group, 2016b). Having just completed a 160 million euro investment program in Kymi mill to expand annual pulp production capacity by 170 000 tons, UPM announced a 98 million euro investment program to add yet another 170 000 tons to this number in just a few years' time (UPM Pulp, 2016). Other promising projects on which investment analysis or planning phase is currently on the way are Finnpulp's softwood pulp mill in Kuopio and Kaidi biorefinery in Kemijärvi (Finnpulp, 2016; Kaidi, 2016).

5.2.1 National level

Finnish Natural Resources Institute reports industrial roundwood supply and demand by two industrial end purposes - logs for sawmills and fiber for pulp production - and three species – pine, spruce and hardwood, of which birch is the most common. These statistics are available on annual level and the reporting unit is thousands of cubic meters (1000 m^3). On domestic statistics both harvests and demand are given by 15 geographical regions. On imports the roundwood supply is reported by country of origin.

Domestic harvests in Finland remained on a rather stable level between 50 and 60 million m^3 since year 2000 (Natural Resources Institute Finland, 2016a & 2017a). However, in 2009 the harvests were on a remarkably lower level than before or after. A quite obvious explanation for this major variation would be the financial crisis that originated from subprime lending in United States and escalated after the fall of Lehman Brothers investment bank. In general, this event seems to account for a rather clear structural break on most statistics on Finnish industrial roundwood on both supply and demand sides. A rapid decline in 2009 was adjusted by significant recovery on a following year and the trend since has been a conservative growth. Visualization of these statistics is presented on Figure 6.

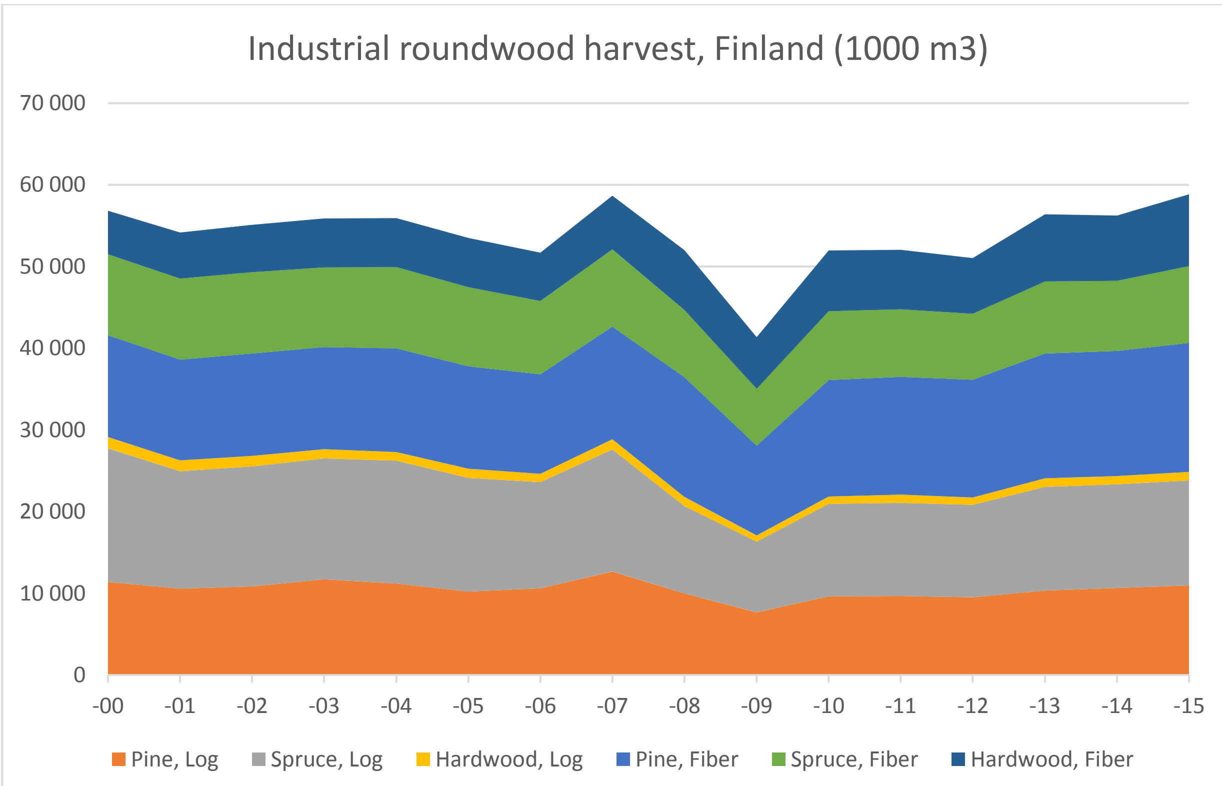

Figure 6. Industrial roundwood harvest in Finland, 2000-2015, 1000 m^3

From year 2000 to 2008 the annual demand for roundwood in whole of Finland remained around 70 million m^3 (Natural Resources Institute Finland, 2016b & 2017b). Hitting the bottom of less than 50 million m^3 in 2009, this number has stabilized around 60 million m^3 annually since 2010. Comparing these statistics to domestic harvests in Finland one can clearly notice that regardless of the major drop in roundwood demand, local supply alone is not enough to meet forestry industry demand in Finland. To close this gap, significant amount of roundwood imports are needed every year to provide enough raw material for Finnish pulp and saw mills. Figure 7 presents industrial roundwood demand in Finland broken down to six timber classes.

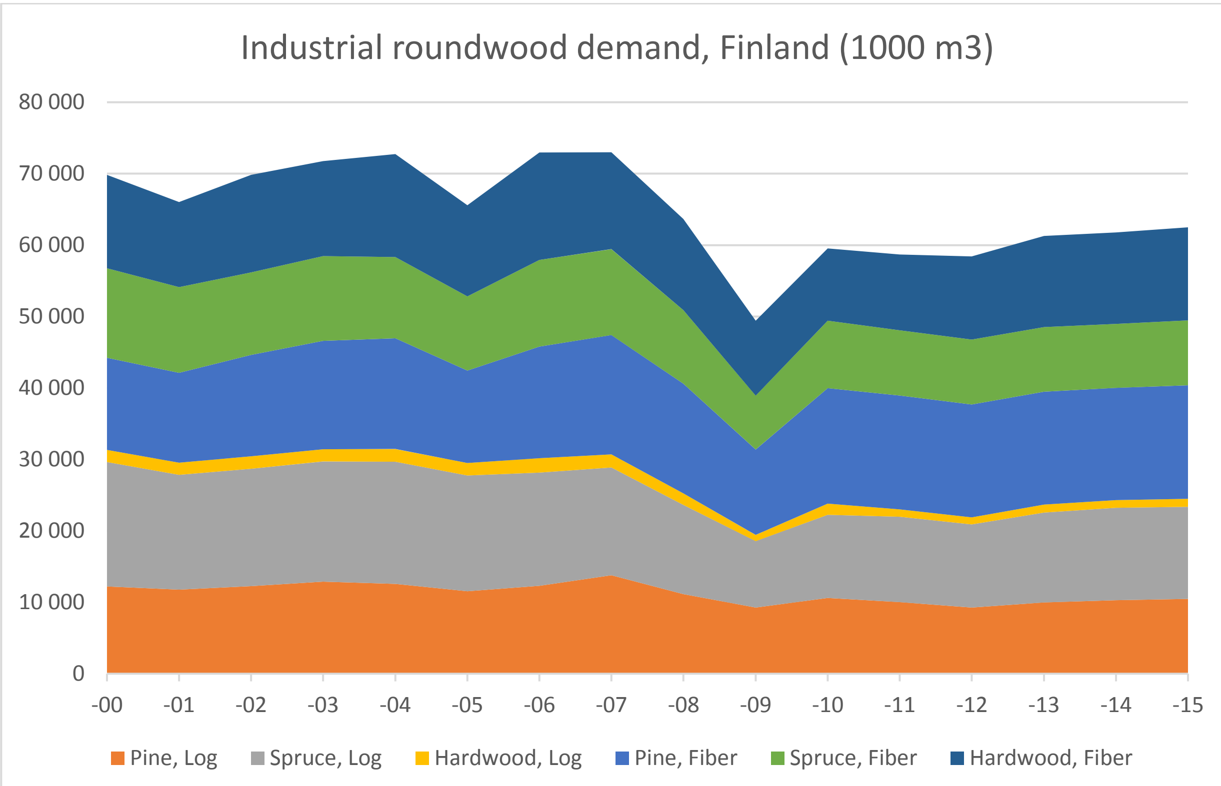

Figure 7. Industrial roundwood demand in Finland, 2000-2015, 1000 m^3

For decades Finland has been a net importer for roundwood (Rämö et al. 2002, 13). From late 1970s onwards volumes of imported roundwood grew slowly but steadily. In yearly 1990s these numbers grew remarkably. Domestic harvests were not able to keep up with the rising demand new investments in production capacity caused (Metsäteollisuus, 2014). The combination of global financial crisis and digitalization led to decline in paper demand in western development nations (Metsäteollisuus, 2015c). Finnish companies on forestry industry have answered to this change in markets by heavily cutting their paper production capacity (for example: YLE, 2012a; YLE, 2012b). Regardless of this, the annual volumes on roundwood imports have been around 6 million m^3 in recent years (Natural Resources Institute Finland, 2016c). Russia is without a question Finland's biggest source for imported roundwood, followed by Estonia and Latvia. When it comes to timber classes, birch fiber dominates the import statistics. Since 2010 birch fiber have covered more than 2/3 of the total roundwood imported to Finland. Figure 8 visualizes statistics on roundwood imports to Finland for years 2005-2015.

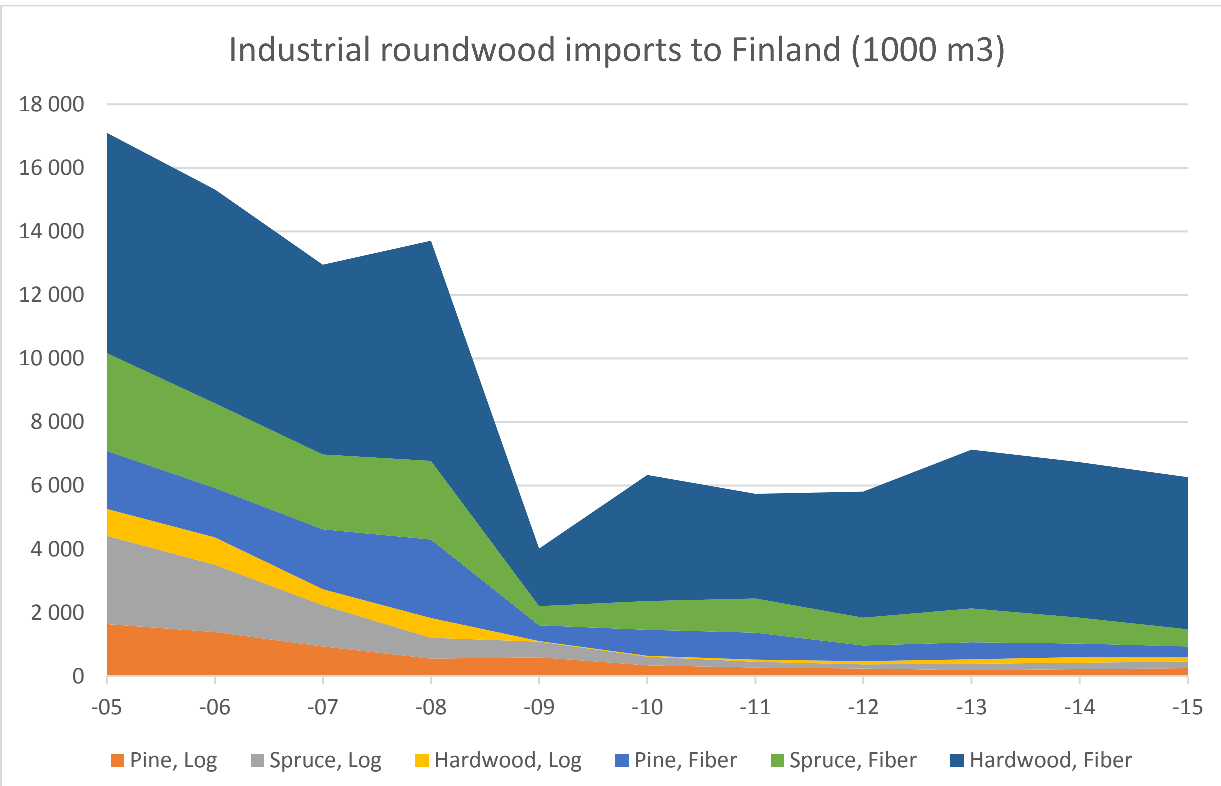

Figure 8. Industrial roundwood imports to Finland, 2005-2015, 1000 m^3

5.2.2 Southeastern Finland

Industrial roundwood harvests in Southeastern Finland have followed the national trends when it comes to changes in total volumes and timber class proportions (Natural Resources Institute Finland, 2016a & 2017a). Time series on these developments are presented on Figure 9. Same could be stated on the demand side. From this perspective Southeastern Finland is unique and strikingly different from every other forestry region in the nation. Even though covering a rather small geographic area, Kymenlaakso and Southern Karelia together cover more than fourth of the total national demand for industrial roundwood (Natural Resources Institute Finland, 2016b & 2017b). Multiple major pulp and saw mills are located on these regions and especially the demand for fiber timber is great. Statistics on industrial roundwood demand in Southeastern Finland are presented in Figure 10.

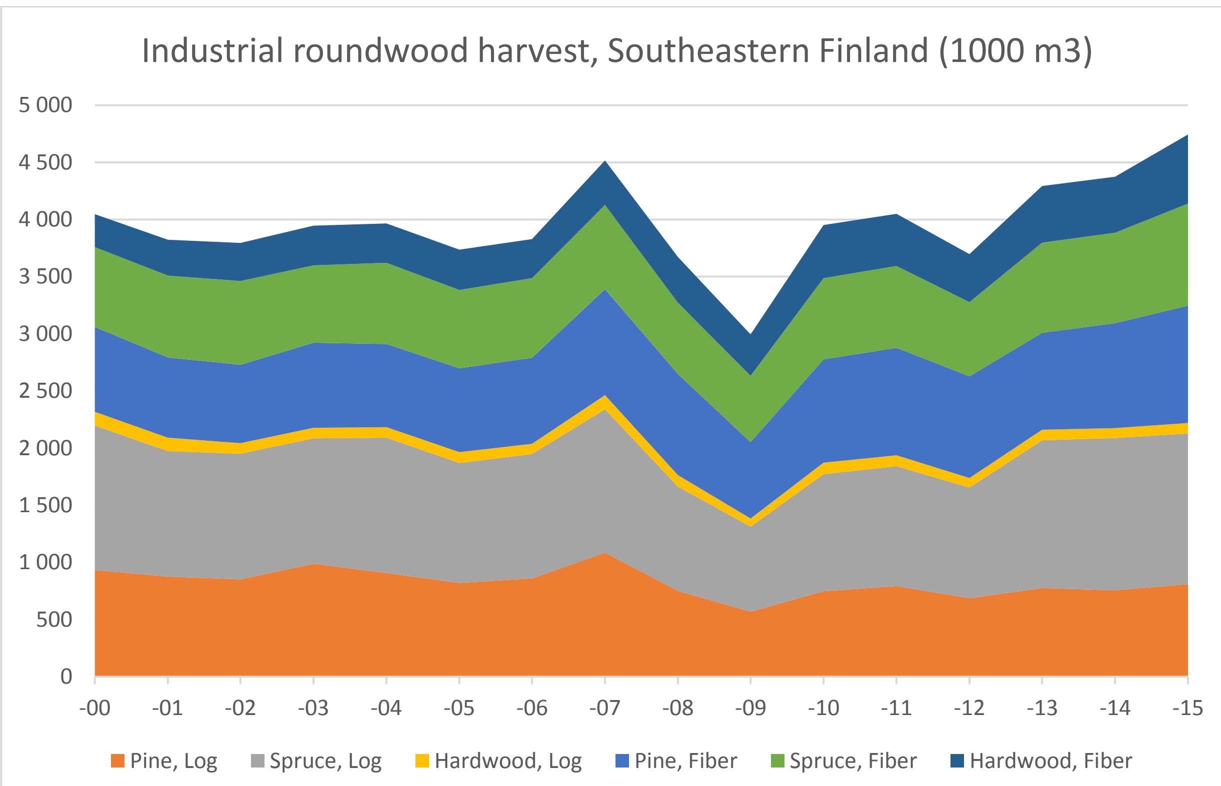

Figure 9. Industrial roundwood harvest in Southeastern Finland, 2000-2015, 1000 m^3

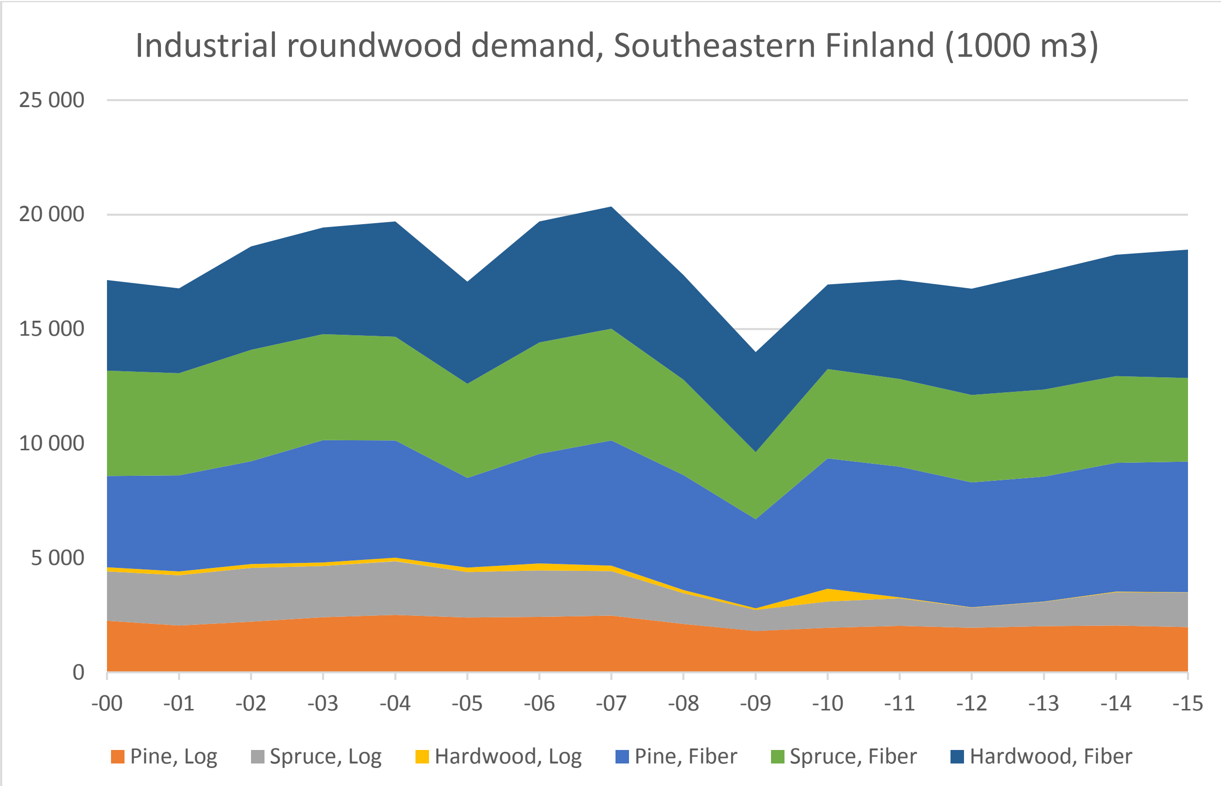

Figure 10. Industrial roundwood demand in Southeastern Finland, 2000-2015, 1000 m^3

To differentiate between timber flows to Kymenlaakso and Southern Karelia, expert estimate for year 2020 was used. This scenario, in which annual timber imports are assumed to rise for three million cubic meters on a national level, includes information on estimated demand and supply on both of these regions separately (Venäläinen, 2016). Table 5 communicates these estimates for Kymenlaakso, and Table 6 for Southern Karelia.

Table 5. Timber supply and demand estimate 2020, Kymenlaakso, 1000 m^3/year

	Log			Fiber			Total
	Pine	**Spruce**	**Hardwood**	**Pine**	**Spruce**	**Hardwood**	
Supply	349	542	38	440	535	230	1 951
Demand	20	680	0	1 800	1 999	2 096	6 596

Table 6. Timber supply and demand estimate 2020, Southern Karelia, 1000 m^3/year

	Log			**Fiber**			**Total**
	Pine	**Spruce**	**Hardwood**	**Pine**	**Spruce**	**Hardwood**	
Supply	454	587	43	524	360	283	2 251
Demand	2 039	370	0	4 050	1 799	5 320	13 579

5.3 Terminal investment and operating costs

Costs directly connected to the terminal functions on the novel logistics solution can be broken down on three major categories: investments in terminal infrastructure, terminal operating costs, and material handler investment and operating costs. The nature of these three categories is very different. The investment to enable roundwood handling and storage at the timber RRT needs to be completed before any operations can take place. These costs are basically all fixed once the investment decision has been made and need to be covered before any of the potential savings can be realized. Terminal operating costs need to be covered every year, as they include lot rent and payments required to keep the terminal facilities operational. Material handler costs cover investment and operating costs to purchase, operate and upkeep an appropriate machine required to efficiently handle roundwood at the terminal.

5.3.1 Initial investment on infrastructure

Terminal investment costs represent the one-time, up-front costs to complete infrastructure at the timber RRT and prepare this area for roundwood handling operations. On a practical level all these costs are caused by planning, construction, and supervision of the construction process. Estimation on total cost of the required investments to bring the timber RRT operational are divided in two categories. First one of these covers costs to complete the common infrastructure at the RRT, which are allocated to the timber section. Second one covers costs that are specific to the timber terminal section of RRT. Interview on Consultant company 1 (2016) was used as a basis when estimating the terminal investment costs. This company carried out the first preliminary investment cost estimation on the whole RRT. However, at that time the layout structure of the RRT was very different from the one today, including more rails and switches. In these estimations the section suitable for roundwood handling and storage was considerably larger than the one considered to be sufficient for the novel logistics solution of interest on this research. Regardless of these differences, Consultant company 1 (2016) representative provided valuable information in form of unit costs on required infrastructure. By using these unit costs the estimation on overall investment costs could be scaled down to match the current layout plan of the RRT and its timber section. Consultant company 2 (2016) provided insight on comparable roundwood terminals elsewhere in Finland, pointed out practical technological requirements for a roundwood terminal, and emphasized the importance of competitive pricing on terminal services. Consultant company 3 (2016) is responsible for planning the RRT entity as it stands today. Its representative expert approved the investment cost estimations represented here to be the best estimation based on the information available when the research was carried out. However, he pointed out that precise estimations on RRT infrastructure investment costs have not yet been made and may very well vary a lot from those presented here.

The RRT infrastructure construction costs allocated to the timber section are estimated to be approximately 2 211 000 € in total. This covers rails, switches, roads, fencing, buildings, and planning, supervision and permits. Rails and roads are the most important cost driver, as together they cover 70 % out of these costs.

Construction costs specific to the timber terminal section of the RRT are estimated to be approximately 2 072 840 € in total. This covers gravel field, transport and protection of land masses, ditches, runoff and waste water sewers, water and electricity connections, lights, and planning, supervision and permits. Gravel field is the most important cost driver here, as it covers as much as 72 % out of these costs. Gravel is sufficient pavement for handling and short term storage of roundwood. Using asphalt as a pavement material would be favored over gravel due to multiple reasons, but is remarkably more expensive. To keep the already remarkably high infrastructure investment costs on sustainable levels, gravel was chose for a pavement material on the entire terminal field instead of partial or complete asphalt covering.

The estimated total cost to complete the timber RRT is approximately 4 283 840 €. This investment would provide a 3.3 hectares (33 000 m^2) terminal field with gravel pavement and appropriate road and railroad connections to operate roundwood logistics as presented in the novel logistics solution. Time to complete such a terminal is assumed to take three years in total. On DCF calculations terminal investment cost is set to 4.3 million €. This is divided evenly on the first three years of the analysis period. Appendix 1 presents cost breakdown on infrastructure investments required to complete the timber RRT.

5.3.2 Operating costs

Operating costs at the timber RRT are estimated on an annual level and can be divided on two categories: lot rent and costs due to terminal maintenance, services and utilities. The land on which the whole RRT is to be built in Kullasvaara area is owned (or will be owned) by city of Kouvola. In early 2016 Kouvola city government made a decision to value the lots in this area to 20 €/m^2 (Kouvola, 2016). Annual lot rent for all the lots dedicated for industrial and business use is 5 % of the value of a lot plus adjustment for inflation (Kouvola, 2016). As calculations on this research are carried out in real terms, inflation is neglected here. Taken these standpoints, the annual rent for lots at the RRT is 1 €/m^2. For the timber section annual lot rent is therefore 33 000 €. An assumption was made, that Kouvola city government would not change the valuation of this lot nor the rent rate on industrial and business lots in general.

Terminal maintenance, services and utilities costs are estimated to be 21 000 € on annual basis. This covers rail and switch maintenance, snow plowing, security services, electricity, and water. Estimation of these costs is based on interview with Consultant company 1 (2016). They are presented in detail on Table 7. The overall annual operating costs of the timber section of RRT are 54 000 € in total. In DCF calculations the lot rent is set to be paid for every year of the analysis, whereas terminal maintenance, services and utilities costs start to run as the roundwood handling operations begin.

Table 7. Annual operating costs of timber RRT

Rail and switch maintenance	10 000 €
Snow plowing	2 000 €
Security services	6 000 €
Electricity	2 000 €
Water	1 000 €
TOTAL	**21 000 €**

5.3.3 Material handler

Material handler is needed at the timber RRT to lift roundwood on or off between train wagons, HCT and terminal field. Five cost types on material handler are recognized: investment, diesel, AdBlue, salary and other. These are presented briefly below. Appendix 2 discloses more precise information on material handler related costs.

Investment cost for an appropriate material handler ready for operations at the timber RRT is estimated to be approximately 100 000 € in total (MachineryZone, 2016; RealParts, 2016a&b). Material handler is expected serve for 15 years, after which it would be scrapped without salvage value, and similar machine is purchased in order to continue the roundwood handling operations at the terminal.

Diesel and AdBlue costs are variable and determined based on the annual roundwood volume handled at the terminal. Material handler diesel consumption is estimated to be 18 liters/hour, and AdBlue consumption 5 % of this, 0.9 liters/hour (Hakonen, 2013, 37; Kurki, 2013, 27). Handling capacity of a material handler was estimated to be 540 tons of roundwood per hour (Atlas, 2016).

Salary costs were set variable based on annual material handler operating hours. Assuming handling capacity of a material handler to be fixed, salary costs are determined by the annual roundwood volumes handled at the RRT. An assumption was made here, that employees at the RRT would operate the material handler only when needed and could otherwise carry out other tasks at the terminal area. Hourly wage for operating the material handler is set to 14.90 € (AKT, 2014, 9). On DCF calculations indirect wage costs and requirements for maintenance and breaks are taken in account.

Other costs cover maintenance, insurance, and management. These are assumed to remain fixed, and are estimated to be 7 913 €/year in total (adjusted from: Hakonen, 2013, 37; Kurki, 2013).

5.4 Transportation costs

Data on two modes of roundwood transport was gathered for this research. Train represents railroad transports of roundwood from Russian border directly to pulp mills on the currently used solution or to timber RRT on the novel logistics solution. Majority of these costs hold also on container transports when they are carried out on trains. These container transportation costs are presented in detail on Sub-Chapter 5.6. Switching transport mode from rails to road at timber RRT and hauling roundwood to pulp mills with a High Capacity Transport (HCT) -truck represents supply chain in the novel logistics solution. Insight on regular truck costs is included on the analysis mainly to underline the potential for increased efficiency on road transports that new HCT -class vehicles have. In addition to cost data, models on how each transport mode’s total costs are thought to be determined are briefly described.

5.4.1 Train

Finnish Transport Agency’s report on railroad traffic cost models were used as a basis for determining train transport costs on roundwood. Both data on costs and structure of cost modelling on train transports of roundwood were gathered from this document. In this research train transport costs are broken down to six cost types. Table 8 presents time based costs, distance based costs, and railroad payments and fuel taxes. Cost for changing and handling wagons on a rail yard is 19 €/wagon. Locomotive change costs at the border is 146 €/change. General costs account for 15% out of all the rest five types of costs. General costs cover management, planning, marketing and sales, real estate upkeep as well as insurance. All costs are denominated on year 2012 cost levels. (Iikkanen, 2013, 37-39)

Table 8. Railroad transportation costs, electric locomotives and wagons

	Time based costs, €/h	**Distance based costs, €/km**	**Payments and taxes, €/km**
Locomotive, 1st	235	1.39	0.15
Locomotive, 2nd & 3rd	122	1.39	0.15
Wagon	2.05	0.10	0.10

In the currently used method for roundwood import from Russia, train transports are utilized for the whole route from border crossing point at Vainikkala to pulp mill. In the novel logistics solution all roundwood is transported via rail from Vainikkala to RRT regardless of its final destination. Average train speed was assumed to be 65 km/h, with two exceptions. On direct train transports to UPM Kymi and Stora Enso Anjala the average train speed was assumed to be 40 km/h on a route between Kouvola rail yard and pulp mill. This facility is located very close to the RRT. Therefore the distance between RRT and the two fore mentioned pulp mills is used as a proxy on these slower train transports.

Railroad infrastructure at the pulp mills limits the maximum size for a single train unit. On this research train unit size on direct train transports of roundwood to pulp mills is set to 22 wagons. Length of such a train unit is approximately 330 meters and one locomotive is powerful enough to pull it. On the novel logistics solution length of a train unit is not an issue and on this research the train unit size heading to RRT was set to 44 wagons. This stretches the length of these longer trains to approximately 660 meters. Due to roundwood being heavy cargo, two locomotives are required to effectively pull such a train unit (Iikkanen, 2013, 26). Table 9 presents the most important differences on train transports of roundwood between the currently used direct transports and the novel logistics solution.

Doubling the number of wagons per train unit halves the amount of trains that are needed for roundwood transports of the same magnitude. Longer train units would thus release railroad capacity in terms of time slots granted for train units willing to move on a certain route. Financial benefits of this effect when choosing the novel logistics solution are not calculated on this research. As most of the train transports modelled on this research are carried through the route between Luumäki and Kouvola, this aspect of the novel logistics solution could be particularly interesting to some parties. This is because the fore mentioned rail stretch is the most heavily used in Finland in terms of freight volumes (Finnish Transport Agency, 2015, 29). Taking in account that also passenger travel takes place on this route, it could be possible that time slots available for freight trains become scarce. This is likely especially in a case where both passenger and freight transports increase.

An assumption was made when constructing the model that on direct train transports every train heading to pulp mill would need to stop at Kouvola rail yard once and stock the wagons there. This could occur either before roundwood shipment to the pulp mill or afterwards when the wagons are empty. Such assumption is quite well in line with Iikkanen's (2013, 36) remark that each wagon would require a total of four change and handling operations on its one way trip from point of origin to destination, which would mark for one stop in between. On the analysis model four change and handling operations are assigned for each wagon when utilizing the current direct train transport solution: arriving to Kouvola rail yard, departing from Kouvola rail yard, arriving to the pulp mill and departing from the pulp mill. This means extended wagon cycle times in comparison to the novel logistic solution combining train and HCT transports of roundwood from Russian border to pulp mills. On the current transportation solution three additional change and handling operations are required in comparison to the novel logistics solution.

Table 9. Main differences of train transports on two alternative logistics solutions

	A) Direct train transports	**B) Novel logistics solution**
Wagon change and handling times	4	1
Wagons / train unit	22	44
Locomotives / train unit	1	2
Train unit length, meters	330	660
Train units / year	207	103

Considering the fore mentioned parameters on train transports fixed, total annual cost for the current solution relying on direct train transports is determined by three variables: volume of annually transported roundwood, wagon rent, and wagon cycle time. Data on wagon characteristics, rents and cycle times is presented on Sub-Chapter 5.5.

5.4.2 High Capacity Transport -truck

HCT is a term used for trucks that exceed the legal maximum measurements on weight, length or both. In Finland this accounts for vehicles that are heavier than 76 tons on gross weight or longer than 25.25 meters. In late 2013 a change in legislation opened logistic service providers a possibility to apply for a permission to operate such vehicles. Finnish Transport Safety Agency considers each application case by case and granted licenses are vehicle and route specific. The primary driver for the change in legislation was to enable research and development in practice. Therefore, every license is linked to a research project on which vehicle supplier, logistic operator and customers participate in. This research concentrates on topics of potential savings, emission reduction, road safety, suitable HCT routes and heavier trucks' effect on road paving and bridges. In July 2016 four HCT vehicles dedicated for roundwood transports had been granted an operating license and couple of applications were under Transport

Safety Agency investigation. (Metsäteho, 2016e; Finnish Transport Safety Agency, 2017)

Basis for modelling HCT costs was taken from Kurki's master's thesis on which trucks limited to maximum of 60 tons gross weight were closely examined (Kurki, 2013, Appendix 2). Some adjustments were made on the original model, the most important of which is leaving depreciation out of HCT costs. This was done because the analysis is of DCF type, which relies on real cash flows instead of accounting measures. Data on indirect salary costs, AdBlue consumption, efficient driver working time and tire purchasing price, wear and repair cost were used as presented (Kurki, 2013, 27; Appendix 2). Costs due to maintenance, insurance, government vehicle taxes and payments, management and upkeep were adjusted upwards for HCT. This adjustment was done based on relation between HCT and regular truck purchasing prices. Immanen's (2009) approach on estimating fuel consumption, presented on formula 5 below, was chosen to be used on HCT cost analysis similarly as it was utilized on Kurki's research. Initial investment cost for the HCT truck is without tires. Tire costs are calculated in the analysis model based on distance driven, which is a slight violation to the DCF method. This choice was done to simplify the cost modelling on the analysis. As costs are counted on annual level and tires are not a major cost driver, this approach could be considered to be accurate enough to represent reality. All costs are considered without value added tax on Kurki's research as they are on this one as well.

Equation 5. Freight truck fuel consumption estimation formula

$$Fuel\ consumption\ (l/100km) = \frac{Gross\ weight\ (tonnes)}{2+20} \tag{5}$$

On Finnish Ministry of Economic Affairs and Employment's (2015, 40) research three HCT vehicles were used as a basis for cost calculations and analysis. Characteristics between these vehicles varied on the purchasing price from 285 000 € to 335 000 € and on the maximum net freight capacity from 61 to 68 tons. The one with a 335 000 €

price and 66 tons net freight capacity was chosen for a basis on the analysis on this research.

To correctly estimate the salary costs of HCT drivers, duration on a roundtrip from RRT to pulp mill and back were compiled. This was done separately for all four pulp mills included on this research. Time to load the roundwood on HCT at the RRT is same for all destinations, 15 minutes. Unloading of roundwood at the pulp mill was estimated to take slightly longer, 20 minutes. This is difference is due to the factor, that probability of having to queue at the pulp mill before unloading is greater than a corresponding waiting time for roundwood loading at the RRT. Total distance for roundtrips between RRT and pulp mills were measured with Google Maps route recommendation service (locations: Google Maps, 2017a&c-f). Average speed between the locations was expected to vary due to differences in distance and routing. Total time for a roundtrip was first calculated in minutes and then transformed to hours due to hourly wage measure in driver salaries. Rounding precision of 0.05 hours was used here. Table 10 presents these computations.

Table 10. Roundtrip durations on roundwood transports, RRT – pulp mill – RRT

(minutes, if not mentioned otherwise)	**UPM Kymi**	**Stora Enso Anjala**	**UPM Kaukas**	**Metsä Group Äänekoski**
Loading roundwood (RRT)	15	15	15	15
Unloading roundwood (pulp mill)	20	20	20	20
Round trip (RRT-pulp mill-RRT)	41	48	161	436
One way trip, km	*17*	*24*	*87*	*236*
Average speed, km/h	*50*	*60*	*65*	*65*
Required breaks per round trip	0	0	30	60
TOTAL, minutes	**76**	**83**	**226**	**531**
TOTAL, hours	*1.25*	*1.40*	*3.75*	*8.85*

Driver salaries on the analysis are based on the common agreement between labor and employer unions. The base wage for a driver operating full scale truck rises together with work experience. A simple average on three experience classes for drivers with more than four years behind the wheel is 14.36 €/hour from 1.12.2015 onwards (AKT, 2014, 9). Drivers with less experience were not considered as operating a HCT vehicle requires an employee with enough work experience and driving skills to ensure safety on road. Bonuses relevant to this analysis are: evening bonus for driving between 18:00 and 22:00 – 15% of the base wage, and bonus for operating a vehicle that requires special skills from the driver – 5% of the base wage (AKT, 2014, 11). Assuming that HCT operating time between RRT and pulp mills would be 06:00 - 22:00 daily and freight hauling would be divided equally between this period, evening bonus would have to be paid for every fourth hour. This would set the average driver wage without special skills bonus to 14.90 €/hour. Special skills bonus on a driver operating HCT vehicle was set to 1 €/hour, which slightly exceeds minimum union contract level. This assumption was made because HCT vehicles are at this stage essentially prototypes and thus require clean records, sufficient driving skills and significant dedication from employees operating them.

Fuel costs account for a remarkable portion of total costs on truck based logistic chains. Basically all trucks today, including HCT, run on diesel. Data on diesel prices and brief analysis on probable forthcoming developments are represented together with crude oil on Sub-Chapter 5.8.2 further on. Modern trucks require a liquid called AdBlue to be used for the engine to function properly. AdBlue consumption is approximately 5% out diesel consumption (Kurki, 2013, 27). Prices for AdBlue liter vary quite a lot depending on volume purchased and container on which it is delivered. A thousand liter container of AdBlue without VAT and collateral costs around 333 € (Infraline, 2016). This sets the AdBlue price to 0.33 €/liter, which is used on this analysis. Technical life of a HCT vehicle was set to 15 years. This parameter represents the real depreciation period of such vehicle after which it needs to be replaced and no residual value accounting or cash flow wise is expected. A brief look at an online market place for used Finnish trucks reveals that multiple trucks from year 2000 and well over a million kilometers on the odometer are for sale, but for a rather low price (Nettikone, 2016). This result is pretty much in line with the assumption made on the technical life of a HCT vehicle. Full list and breakdown on HCT cost parameters is presented on Appendix 3.

5.4.3 Regular truck

For comparison purposes a regular truck not requiring a special license was included into the analysis. This was done primarily to find out to which degree the HCT transports are more efficient than standard ones. Cost modelling and adjustments on some cost parameters were done similarly to a HCT vehicle. These are described in detail on the previous Sub-Chapter 5.4.2. Other differences between HCT and regular truck are maximum net weight for roundwood freight, number of tires on truck and trailer, no need for a HCT bonus for the driver of a regular truck and vehicle purchase price. For a new regular truck with a maximum gross weight of 76 tons the purchase price was assumed to be 275 000 €. On the Finnish Ministry of Economic Affairs and Employment's (2015, 40) research document the price difference between trucks with maximum gross weight of 60 tons and 76 tons is 35 000 €. Kurki (2013, Appendix 2) reports a new 60 ton truck to cost 240 000 €. Price for a 76 ton truck on the Finnish Ministry of Economic Affairs and Employment's publication was not used directly because it included a crane for lifting timber. This kind of device is needed when collecting roundwood from forest sites and terminals, but not on the novel logistic solution between timber RRT and pulp mills analyzed on this research. For this reason the described indirect method was used to find a correct investment cost on a regular truck to transport roundwood. Appendix 4 lists the cost components on regular truck transports.

5.5 Wagon characteristics, rents and cycle times

Train wagons used for roundwood transportation are of major importance for the analysis on this research. They are a significant cost driver on train transportation total costs in both of the compared supply chain solutions. Especially these wagons' daily rental cost and cycle times are among the most crucial parameters to distinct whether the novel logistic solution could be considered a feasible alternative to the currently used direct train transports of imported Russian roundwood.

5.5.1 Dimensions and other basic characteristics

Although dimensions, capacity and other basic characteristics between different stanchion wagons used for railroad transportation of roundwood might slightly vary, in general they are rather similar with each other. On this research Nurminen Logistics' (2016) stanchion wagon model 13-3121 was used as a representative wagon in terms of dimensions and capacity. Table 11 presents these measures in detail. Most railroad routes in Finland are built to withstand a maximum axle mass of 22.5 tons and the maximum train length of 750 meters (Kiuru et al., 2015, 27-30). On the framework of this research the route between Vainikkala rail yard on the Russian border and Kouvola is most important. On this route the maximum axle mass is set to 25 tons and maximum train length to 1100 meters. However, the short stretch between Kouvola rail yard and UPM Kymi mill does not share these enhanced characteristics. The maximum freight stanchion wagons could be loaded with is determined either by the loading capacity and weight of the wagon itself or the maximum allowed axle mass on the route the wagons is to be transported on. As these wagons have four axles, their maximum gross weight is limited to 90 tons on a route with a 22.5 tons maximum axle mass and to 100 tons on a route with a 25 tons maximum axle mass. Considering these limitations, the loading capacity of the representative Nurminen Logistics' stanchion wagon is volume wise approximately 107 cubic meters of roundwood, and weight wise either 70 tons on railroads with 25 tons axle mass allowed or 66.3 tons on ones with the standard maximum of 22.5 tons axle mass.

Table 11. Nurminen Logistics' Stanchion Wagon 13-3121, basic characteristics

Parameter	Unit	Measure
Length	meters	14.62
Weight	tons	23.70
Loading capacity	tons	70
Loading length	meters	13
Loading width at the bottom of stanchions	meters	2.57
Loading width at the upper part of stanchions	meters	2.95
Stanchion height	meters	2.99
Cargo type	-	round timber

5.5.2 Daily rents

Roundwood imported to Finland from Russia is mainly transported via railroads utilizing Russian stanchion wagons designed for this purpose. These wagons are rented from companies specialized in operating and managing them. Rent is paid on daily basis on the time they are used. As the organizations renting these wagons are mostly Russian and primarily operate on Russian soil, the rents are denominated in rubles. Data on wagon rents were gathered from five sources, four of which are in Russian. Outside help was used to find the relevant information from these sites and translate it. This data is presented on Table 12. As there were only few sources on wagons dedicated to roundwood, data also on general platform-type wagons was collected. Most of this data was quite recent, but some of it reached back to year 2000. The range on wagon rents collected was wide, from 380 to 1200 rubles per day.

Table 12. Russian wagon rents, RUB/day

	Wagon type	**Date**	**Rent (RUB/day)**	**Source**
1	Timber	2016	380	Закон прост (2016)
2	General	2014	978	Морские вести России (2014)
3	General	2015	1050	Морские вести России (2014)
4	General	2014	650-850	Морские вести России (2014)
5	General	2016	850	ЭРВК (2016)
6	Timber	2000 - 2010	1000 - 1200	Promgruz (2011)
7	General	2011	800 - 1000	Promgruz (2011)
8	General	2015	600 - 1000	Brunswick Rail (2015)
	Adjusted average		**907**	

For the base scenario analysis on this research, a single number for daily wagon rent was computed. On this calculation the first observation, 380 RUB/day, was left out as it was remarkably out of line from the other rent data points collected. A simple average was computed on the rest seven data points listed on Table 12. In case the data point was an interval, its minimum and maximum were considered as individual data points on computing the adjusted average. The result of this brief analysis is 907 RUB/day rent for a timber wagon. This is almost exactly the same as an expert estimate on this parameter, 900 RUB/day (Logistics company 1, 2016). On the DCF analysis ruble denominated wagon rents are translated to euros on the exchange rate found appropriate. Sub-Chapter 5.8.1 covers this exchange rate in more detail.

5.5.3 Cycle times

Wagon cycle times are very important parameter when potential savings from the novel logistics solution are analyzed. Increased efficiency in railroad and terminal logistics is one of the cornerstones to capture cost savings in comparison to currently used means of transportation. Rent needs to be paid for every day a wagon is tied in the operations on the supply chain, so the longer the cycle time, the higher the rental costs. In this case the all the wagon cycle times considered are “gate-to-gate”. This means that the cycle time covers a wagon’s entire round trip, beginning from point A, transport to its destination at point B, and back again to point A. For stanchion wagons this cycle begins from Russian border at Vainikkala in full roundwood load, continues with transport to pulp mill or RRT where the roundwood is lifted off, and ends when the empty wagons are transported back to the Russian border. For container wagons the rationale is the same, the difference being that the cycle begins from a pulp mill or RRT with the container loaded on the wagon, which is transported to and dropped off at the harbor in Mussalo, Kotka.

Wagon cycle times at the pulp mills are based on expert interviews of company representatives, who work close to logistics functions of these factories (Forestry company 1, 2016; Forestry company 2, 2016). Estimates for wagon cycle times vary by pulp mill, ranging from only two days (minimum at UPM Kaukas) to six days (maximum at UPM Kymi). Situation at Stora Enso Anjala is very similar to that of UPM Kymi, and therefore this same estimate was used for Metsä Group Äänekoski. The shorter cycle time at UPM Kaukas is very likely due to this pulp mill’s close proximity to Russian border in Southern Karelia, whereas Stora Enso Anjala and UPM Kymi are both located further away in Kymenlaakso. Although there is still some room for improvement in supply chains of Russian roundwood when it comes to wagon cycle times, the situation has been a lot worse in not-so-distant past. In 2012-2013 wagon cycle times were drastically longer than today, extending to around 14 days on average and as much as 21 days at worst (Logistics company 2, 2016). These numbers are for the route Vainikkala (Russian border) – Kouvola rail yard – Vainikkala, so transport from Kouvola rail yard to a pulp mill and back is not even included. Primary reason for these extended wagon cycle times were changes in ownership of Russian wagons from public to private, which caused major challenges for Finnish rail freight operator VR. Today the situation with Russian wagons is remarkably better, and seems to be somewhat stable.

At the RRT cycle time for all the wagons, both for roundwood and container transportation, was assumed to be 1.5 days. This is considerably shorter than that of the railroad transports heading directly to pulp mills. There are two major reasons for this difference. First, the RRT and its possible timber section will be planned and built to meet the needs of today's and tomorrow's logistics in both railroad and road transports. There are no limiting factors in terms of existing infrastructure or scarce space, and therefore the entire project can be executed in the most effective way when it comes to layout and connections. This is not the case at pulp mills, which have stand for decades on locations between waterway(s) and nearby town. Space in these locations is often very limited, and infrastructure covering roads and railroads have been built in multiple phases over extended period of time. As transportation technology has improved, these facilities are often not the most optimal to grasp all the benefits from these improvements. Second, logistics is the very heart and soul of the RRT when it comes to its business model. This means that efficient operations to, at, and from the RRT are its top priority. For pulp mill's profitability in- and outbound logistics are only one part among many processes and operations its management needs to plan and control. Balancing between multiple goals to achieve the best results, pulp mill management can't pay all attention to roundwood or container logistics only. Furthermore, sometimes to reach other more highly prioritized goals, in- and outbound logistics of some of the raw materials or end products at the pulp mill might have to be set in a suboptimal manner.

As the RRT has not yet been built nor therefore been in operation, the 1.5 day wagon cycle time at the RRT is rather "a sophisticated guess" than result of any empirical study. It should also be noted, that efficient operations at the terminal are only one determinant in the wagon cycle time. Required actions at the border and railroad transports therefore play an important role. As the RRT can accept full length Russian trains, there is no more need for splitting or combining the trains at the border, which is the case on direct train transports of roundwood to pulp mills. Recently railroad freight to and from Russia was opened for competition and are thus no longer under legislative monopoly (Finlex, 2016b). In practice these transports are still dictated by government owned railroad operator VR. Some new railroad freight operators have already begun to serve their customers (Fenniarail, 2017). It is likely that pressure from competition will increase flexibility and efficiency for railroad freight in Finland in general, and perhaps also bring its pricing down to some extent. Due to the reasons stated above, the substantially shorter wagon cycle time at the RRT is seen justified.

Cycle time for the container wagons at the pulp mills was estimated to be four days on average. This estimate is based on stanchion wagon cycle times, but takes into consideration the differences between these two supply chains. Three factors were considered when determining that the cycle time of container wagons is slightly shorter than that of the stanchion wagons. First, pulp mill management has financial incentive to prioritize outbound container transports over incoming timber transports when there are limitations in railroad capacity. Whether packed with paper or pulp, containers leaving the factory are considerably more valuable than incoming raw materials. As cash flow from customers is dependent on product deliveries, containers should leave the pulp mills as soon as possible or at least “rather sooner than later”. The combined rent of container and a wagon to carry it is also remarkably higher than that of the Russian stanchion wagon. Second, to three of the four pulp mills considered in this research (excluding UPM Kaukas) Russian roundwood must be transported through the railroad length between Luumäki and Kouvola. This is the most heavily utilized railroad connection in Finland, which means that time slots to use it are rather limited (Finnish Transport Agency, 2015, 29). Traffic at the railroad connection between Kouvola and Kotka is also rather busy. However, it is more likely that a train between Kouvola and Russian border needs to wait for an appropriate time slot longer than a train between Kouvola and Kotka. Third, container logistics at the receiving end at Kotka harbor are very efficient as it is the most important container port in Finland and thus needs to be able to handle large number of containers fast when necessary (Finnish Port Association, 2017).

Table 13 presents the wagon cycle times used on the analysis of this research. These figures represent averages and in practice the cycle times vary due to numerous reason. This is taken into consideration in sensitivity analysis, as stanchion wagon cycle time at pulp mills is one of the four critical parameters studied on it.

Table 13. Wagon cycle times by destination

Destination	**Gate-to-gate cycle time**
Terminal, all wagons	1.5 days
UPM Kymi, stanchion wagons	5 days
Stora Enso Anjala, stanchion wagons	5 days
Metsä Group Äänekoski, stanchion wagons	5 days
UPM Kaukas, stanchion wagons	3 days
Pulp mills, container wagons	4 days

5.6 Container transportation and handling costs – backhauling synergy potential

Kouvola RRT's primary purpose is to provide enhanced intermodal container logistics. This provides an opportunity to find synergy benefits by combining roundwood and intermodal transports. On this research a possibility to backhaul containers from pulp mill to RRT with the same HCT used to transport roundwood was studied. This operation model would significantly increase the efficiency of HCT transports. As the roundwood transports are directed only one way, from RRT to pulp mill, and they are expected to drive only on a route between these two locations, half of the operating time the HCT would be driven empty without freight. The end product of pulp mills, whether pulp or paper, must be packed in intermodal containers in order to ship it abroad to a final customer. This could be done at the factory or at the export port, where the end product is transported to using either train wagons designed specifically for this task or a freight truck. For the HCT to be able to transport both roundwood and containers, its technological aspects need to be paid attention before the investment in such a vehicle is made. Transition between the two freight types should be quick, easy, and technologically as simple as possible to allow efficient supply chains in both directions. Concepts that enable combining timber transports with other freight types exist already in research and development -phase (ExTe, 2017a&b; Metsähallitus, 2017). Pressure to enhance efficiency of logistics is likely to bring these concepts to wider use in the near future and encourage further investments in research and development of such solutions.

In the analysis of synergy benefits arising from container backhauling, approach similar to that of imported roundwood was used. The currently used method is compared to a novel logistics solution, and savings potential from adopting an alternative supply chain was studied. Direct train transports of containers from pulp mill to port in Kotka was used as a reference point representing the currently utilized method. Three major cost drivers were recognized and measured on container backhauling supply chain. These are train transportation costs, HCT transportation costs, and costs specific to container rent and handling.

Parameters determining total cost for railroad transport of containers are mostly the same as with roundwood transports. Cost for time and distance based train transport, wagon change and handling cost, taxes and other payments, and overhead costs are exactly the same as those covered in Sub-Chapter 5.4.1. As these transports are carried out entirely within Finnish borders, Finnish wagons must be used instead of Russian ones. Rent for a Finnish platform wagon suitable for container transport is expected to be 22 €/day. This somewhat higher than a daily rent for a comparable Russian platform wagon due to lack of competition and monopolistic pricing of VR. Trustworthy quotes on wagon rents for railroad transports inside Finland are difficult to obtain, which is the reason an expert estimate was chosen as a standpoint here. For direct train transports of containers the train size was set to be the same as with the roundwood import trains heading to pulp mills, 22 wagons capable to transport a same amount of Forty-foot Equivalent Unit (FEU) containers. Length of such train would be approximately 330 meters. On the train transports leaving from RRT the train size was assumed to be slightly greater than a comparable one on timber imports. Therefore the full length train for container transports is set to be 50 wagons, and thus 50 FEU containers. Such train stretches up to approximately 750 meters. RRT is to be a major hub for container logistics. It can therefore accept, handle and send forward significant amount of containers on daily basis. Longer train units can be utilized also in these transports. While terminal infrastructure at the receiving end could set limits to maximum train length in some destinations, this is not an issue at Mussalo port in Kotka. All railroad transports of containers were assumed to be carried out with electric locomotives.

On HCT transports of containers from pulp mill to RRT, only costs additional to those already caused by roundwood transports were considered. Therefore only three types of costs were paid attention here. These are diesel, AdBlue, and salary costs. Due to transporting containers on the way back to RRT, HCT's total weight is heavier than without freight. This causes a corresponding increase in diesel and AdBlue consumption. To simplify the calculation in the analysis model it was assumed that the containers transported on HCT would weigh as much as a full load of roundwood. The purpose-built HCT was assumed to be able to haul two FEU containers at the same time, similarly to vehicles already in operation today (Finnish Transport Safety Agency, 2017). Increase in salary costs is due to increased operating hours of drivers. Lifting the container on and off the HCT requires some time to be completed, and for this time a driver has to wait until the task is finished. Total handling time for loading or unloading the container was estimated to be 15 minutes. Lifting a container directly from HCT to a train wagon yields some savings. Operating in this manner, only one lift is required to prepare the container on a train and be ready to ship forward. This is however, not always possible due to the mismatching timetables of HCT, container reachstacker, and wagon logistics at the RRT. On this research the degree of direct container lifts is assumed to be 25%. This means that 75% of the containers backhauled from pulp mills to RRT needs to be lifted twice. First when lifted off the HCT, and second when lifted on a wagon in a train heading to Kotka harbor.

Number of containers transported with the novel logistics solution was set to 2 600 FEU in a year. This means that roughly every third time the HCT leaves a pulp mill, it backhauls two containers to the RRT. Would this alternative supply chain be found to provide savings and be otherwise an appropriate solution in practice, the volume of backhauled containers could easily be increased substantially. Cost for handling a container was set to be 35 €/lift in the base scenario (Henttu & Multaharju, 2011, 51). Container rent is estimated to be 7.50 €/day (Finncontainers, 2016; OV Lahtinen, 2016). Table 14 presents the most important parameters in analysis of container backhauling synergies.

Table 14. Container supply chain, most important parameters

Parameter	**Value**
Number of transported containers, annual	2 600 FEU
Container wagon rent	22 €/day
Container rent (FEU)	7.50 €/day
Container handling cost, loading/unloading	35 €/lift
Container handling time, loading/unloading	15 minutes

5.7 Economic costs of externalities

European Commission (2014) guidelines were used on estimating the external costs for the novel logistics solution and direct train transports to pulp mills. These were then compared to each other similarly as with the financial costs and benefits. Five types of external costs were considered: congestion, accidents, air pollution, noise and climate change. Primary measure used in estimation was vehicle kilometers (vkm). On railroad transports tonkilometers (tkm) were used instead in congestion, air pollution and climate change estimations. Considering the novel logistics solution, annual diesel consumption estimates of HCT and material handler were used to come up with an appropriate measure on climate change cost instead of vkm. Values used on this analysis were drawn from two handbooks providing guidance and data on estimation of external costs on transportation sector (Maibach et al., 2008; DG MOVE, 2014).

From external cost tables at Maibach et al. (2008) and DG MOVE (2014), articulated heavy goods vehicle (HGV) was chosen to represent trucks used on road transportation of roundwood. Mass class of 50-60 tons was used on HCT, because this was the heaviest one listed. For Russian standard trucks this gross mass class was 34-40 tons.

All trucks were assumed to meet the EURO IV -emission standards. Whenever an environment type had to be considered while choosing the appropriate external cost values, a rural or non-urban was chosen due to the fact, that majority of the roads and railroads included in the model exist on countryside. Similarly day was used as a point of time and thin as a type of traffic to represent the realistic circumstances most roundwood freight is likely to be transported on. Table 15 presents the parameter values used on the external cost analysis for diesel and electric freight trains and Table 16 the same measures for HCT and Russian standard trucks.

Table 15. External costs on freight transport via railroad, in monetary terms

	Freight train, Diesel	**Freight train, Electric**
Congestion	0.2 €/1000 tkm	0.2 €/1000 tkm
Accidents	0.2 €/1000 vkm	0.2 €/1000 vkm
Air pollution	0.0060 €/tkm	0.0008 €/tkm
Noise	57.8 €/1000 vkm	57.8 €/1000 vkm
Climate change	0.0026 €/tkm	0.0008 €/tkm

Table 16. External costs on freight transport via road, in monetary terms

	HCT	**Russian standard truck**
Congestion	0.168 €/vkm	0.168 €/vkm
Accidents	0.005 €/vkm	0.005 €/vkm
Air pollution	0.095 €/vkm	0.069 €/vkm
Noise	1.5 €/1000 vkm	1.5 €/1000 vkm
Climate change	0.081 €/vkm	0.081 €/vkm

On climate change costs representing primarily CO_2-emissions, a conversion factor was required to have an appropriate value also on electric freight train. LIPASTO (2009) statistics on Finnish railroad transports report an average CO_2-emission of 7.2 grams/tkm on electric freight train and 24.0 grams/tkm on a diesel one. Based on this data, climate change costs of an electric freight train were assumed to be 30% of those caused by a comparable diesel train. Climate change cost for a diesel used in trucks and material handler is 0.243 €/liter. This includes the external costs caused by emissions of CO_2, CH_2 and N_2O.

5.8 Other crucial factors

On this subchapter four topics crucial to carry out the DCF calculations to compare the novel logistics solution and direct train transports are presented. These are ruble-euro exchange rate, prices of diesel and crude oil, discount rates used in the analysis and cost of capital, and transportation distances.

5.8.1 Ruble-euro exchange rate

Majority of the costs on both the novel logistic solution and direct train transports of roundwood are denominated in euros and for their part exchange rate does not have to be considered. When importing roundwood from Russia via railroad the wagons used are mostly owned by Russian companies. Therefore the rents on these wagons are denominated on Russian rubles. This is also the case for the roundwood itself purchased from Russia. When comparing the current mode of roundwood transports from Russia – direct train transport from the border to pulp mills with a stop on the rail yard in between – and the novel logistics solution combining train and HCT transportation, wagon rents are a major cost driver on both. The purchasing price of Russian roundwood affects calculations on the savings potential indirectly through cost of capital tied on stocked roundwood and is not as significant a parameter as the wagon rents are.

Monthly data on ruble-euro exchange rate from January 2000 to July 2016 was retrieved from Thomson Reuters Datastream service (2016a). Figure 11 represents the developments on this data set. Since year 2000 the general trend of ruble against euro has been subtle but clear depreciation. The effect of financial crisis can be seen also on this statistics as a fast and sharp decline hit ruble value in the beginning of year

2009. After this the ruble-euro exchange rate remained in a rather stable levels for approximately four years. In the summer of 2014 two major events hit Russian economy. Unexpected fall on crude oil prices and strict western sanctions due to Russian's involvement on crisis in Ukraine combined had a dramatic effect on ruble value (Bloomberg 2014). In just few months it depreciated for more than 60% against euro. Since then ruble's value against euro has remained on low levels compared to years before 2014 and the volatility has been remarkably high.

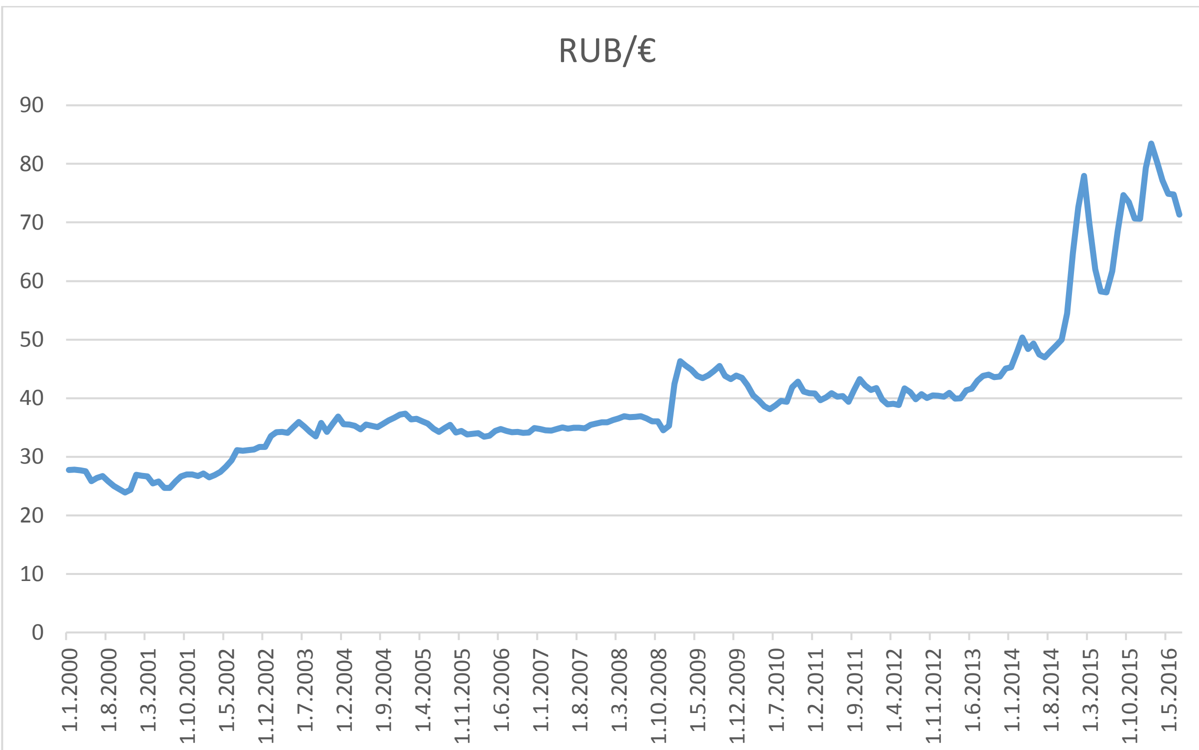

Figure 11. Russian ruble to euro -exchange rate, 1.1.2000 – 1.7.2016

Basic descriptive analysis reveals that although ruble's value hit the bottom of 83.47 RUB/€ in early 2016, on a longer term Russian currency has been remarkably stronger against euro. For this reason the analysis time frame should be stretched back beyond the fierce depreciation period that begun in 2014. As the financial crisis marks for a clear structural break also here, a medium term look from January 2010 till July 2016 gives perhaps a better idea on the situation on this issue than looking back all the way to year 2000. It is worthwhile to notice that on this interval the ruble-euro exchange rate has been just under 50 RUB/€ on average. Table 17 presents the results on this analysis.

Table 17. Ruble-euro -exchange rate time series, descriptive statistics

RUB/€	**2000-2016**	**2010-2016**
Average	40.06	49.71
MAX	83.47	83.47
MIN	23.89	38.15

Forecasting exchange rates decades forward is extremely difficult, if not impossible. However, on ruble's case this might be more straightforward than on many other currencies. Habib & Kalamova (2007, 28) came to a conclusion on their research that ruble can be considered an "oil currency", as its real effective exchange rate has a positive long-run relationship with real oil price. Taken this, the future developments on global crude oil market prices will most likely strongly influence ruble's value against major currencies, including euro. If the oil price is going up, ruble is about to appreciate and vice versa. The economic sanctions on Russian trade are a result of complex political tensions between multiple actors. Although not likely to last for decades, it is difficult to estimate when these sanctions will be eased or predict upcoming events that could either lead to further restrictions or have a positive influence on foreign trade in Russia.

5.8.2 Finnish diesel and global crude oil prices

On this subchapter data on prices of diesel in Finland and crude oil on a global scale is presented. Also a brief analysis of probable or possible future developments on these two is discussed.

Diesel

Data on diesel consumer prices in Finland from January 2000 to May 2016 was gathered from Statistics Finland public database (2016). These prices include VAT and they were adjusted to represent the price levels without it. The general value added tax rate in Finland was 22 % until 30.6.2010, 23 % between 1.7.2010 and 31.12.2012, and 24 % from the beginning of year 2013 (Vero 2010; Vero 2013). In addition to VAT, refining tax, also known as fuel tax, is included to the diesel price at the time it is purchased. This tax is essentially a combination of different taxes and tax-like payments to the government, all of which are volume or weight based (Petroleum & Biofuels Association Finland, 2016). As these taxes are not deductible for companies like VAT, they were left included on the time series data studied. Figure 12 visualizes the developments on VAT 0 % diesel consumer price in Finland from January 2000 to May 2016.

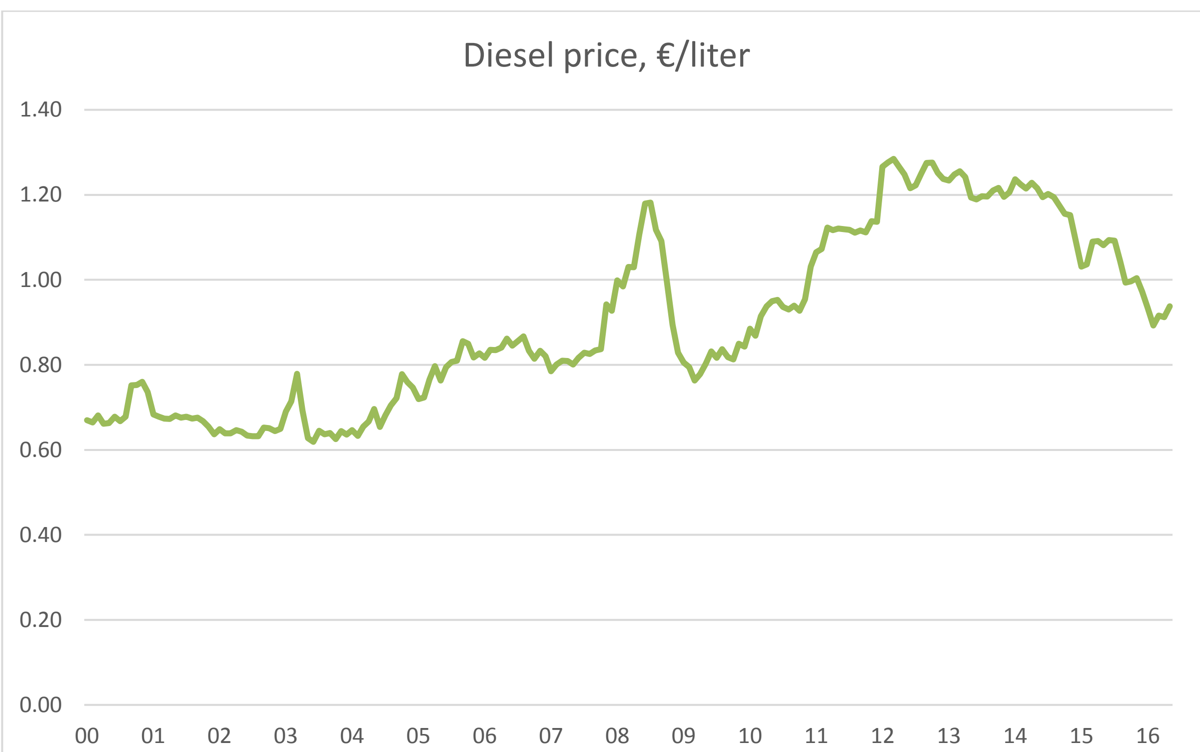

Figure 12. Diesel consumer price in Finland, €/liter (VAT 0 %), 1/2000 – 5/2016

In the long run, domestic diesel price seems to follow pretty much the same path as global crude oil of which corresponding time series is presented on Figure 13. However, the volatility does not seem to be as fierce. This is probably due to the volume based fuel tax in Finland, which is politically determined. From January 1st, 2017 onwards the fuel tax for diesel is approximately 0.53 €/liter (Finlex, 2016a). This remains fixed until a political decision is made to change it. In a situation where this tax component accounts for more than a half of VAT-free diesel price, diesel price is “hedged” against the volatility in crude oil market price (as noticed by Hilmola, 2015). On the time frame from the beginning of year 2010 to May 2016 the diesel prices were on relatively low levels after the financial crisis from where they steadily rose to around 1.20 €/liter in mid-2012. After remaining on this level for a couple of years the global changes on crude oil prices lead to remarkable decline also on Finnish diesel prices and for the first half of year 2016 it has been under 1.00 €/liter without VAT. Basic descriptive statistics on diesel consumer prices in Finland are listed on Table 18 below.

Table 18. Finnish diesel consumer price time series, descriptive statistics

€/liter (VAT 0%)	**2000-2016**	**2010-2016**
Average	0.90	1.11
MAX	1.28	1.28
MIN	0.62	0.87

The general direction on diesel prices in Finland is dictated by changes on global crude oil markets. This has been the case in the past and will also be so in the future on a high degree of certainty. Prospects on the crude oil price levels for the coming years and decades are further discussed on below on the next section of this subchapter. As global markets represent a high uncertainty to where they will move next, so does the politicians on Finnish government. The pressure for politicians to raise fuel taxes comes from two directions. This tax is already a remarkable source of income on the government budget and due to the extended hardships on Finnish economy it was slightly raised in early 2015 (Petroleum & Biofuels Association Finland, 2016). If the economic stagnation continues for long, similar upward adjustments on fuel taxation could be seen more in not so distant future. Another factor possibly leading to raises on fuel taxation is EU demands to cut emissions. Just recently European Commission published its proposal on required emission cuts (YLE, 2016). On this proposal, Finland is demanded to remarkably cut greenhouse emission on the timeframe from 2021 to 2030. As this goal is set on emissions of which rights are not traded on markets, traffic is the single most significant source of emissions. To be able to meet these strict demands from EU side, it is likely that fuel taxes will be raised in order to reach lower levels of diesel and gasoline consumption.

Crude oil

Monthly spot prices for Brent crude oil nominated in US dollars per barrel, free on board (FOB) were gathered from Thomson Reuters Datastream service (2016b). The time frame on this data is the same as with ruble-euro exchange rate, from January 2000 to July 2016. During this period the oil markets have been extremely volatile. The steady growth in oil prices from the beginning of millennia ended in early 2007 as a fast boom lead to bust just one and a half years later due to financial crisis. After this the crude oil prices recovered and seemed to reach a steady state around 110 dollars/barrel from early 2011 to mid-2014. Suddenly the prices dropped to less than a half in just a half years' time and have remained on low levels to date. Figure 13 visualizes these developments. Numerous reason are behind the rapid drop in crude oil prices and the fact that barrel's cost has been less than 50 dollars for almost a year, the most important being massive oversupply on global markets (Thomson Reuters, 2015).

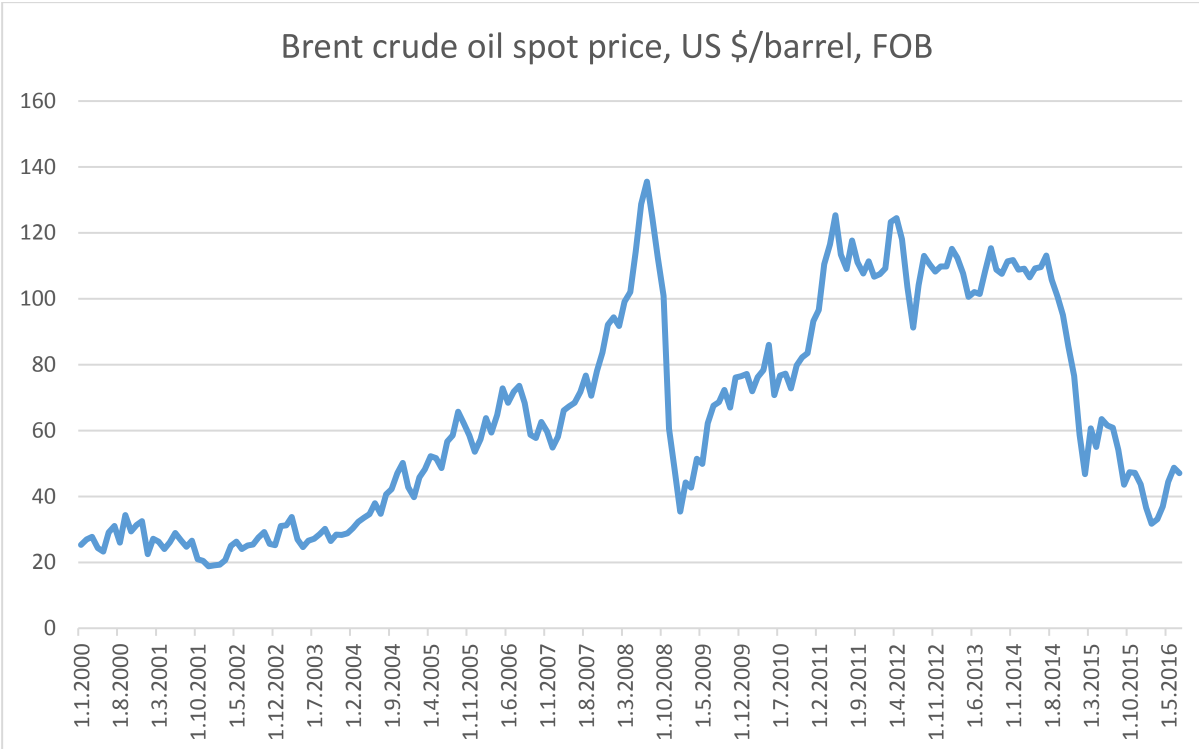

Figure 13. Brent crude oil spot price, US dollar/barrel, 1.1.2000 – 1.7.2016

A basic descriptive analysis on Brent crude oil spot prices reveals that extremes are very far from each other and due to high volatility long term averages are perhaps not a reasonable mean on attempt to create trustworthy forecasts far on the future. These statistics are presented on Table 19. A noteworthy remark must be made on correlation between ruble value and crude oil prices. Although not remarkably strong on time period 2000-2016, data after financial crisis from 2010 to 2016 suggests RUB/€ exchange rate to have a semi-strong relationship with Brent spot price. The correlation coefficient between these two is -0.54. This result supports prior, more in-depth, studies such as Habib & Kalamova’s (2007) that suggest Russian currency to have close ties with global oil prices. In practice this means that as the oil prices have risen, ruble has appreciated against euro and vice versa.

Table 19. Brent crude oil spot price time series, descriptive statistics

US $/barrel	**2000-2016**	**2010-2016**
Average	65.07	88.97
MAX	135.54	125.36
MIN	18.80	31.75

Taken the volatile history of crude oil and multiple major but unpredictable shifts in its price, forecasting the price levels on this commodity is nothing but easy. Long term estimates on crude oil were gathered from three organizations: U.S. Energy Information Administration (2016), World Bank (2016) and IMF (2016). The prices on this data are nominal US dollars and frequency is annual. All these time series are gathered together on Figure 14. Even though U.S. Energy Information Administration's forecast differs slightly from strikingly similar estimations by World Bank and IMF, the general view seems to be the same. From now on crude oil prices will rise slowly, but steadily. If adjusted for inflation, the real price forecasts would be remarkably lower. Stretching farthest in the future, U.S. Energy Information Administration's forecast predicts crude oil price per barrel to exceed 100$ in 2022, 150$ in 2031 and 200$ in 2037. Considering the growing global demand on energy and diminishing oil reserves, this would seem like a plausible long term scenario. As the short and medium term fluctuations in oil prices have so far been high in multiple occasions, it is more likely than not that events in the future will have similar effects. Countless number of possible economic or political developments might have such impacts on the markets.

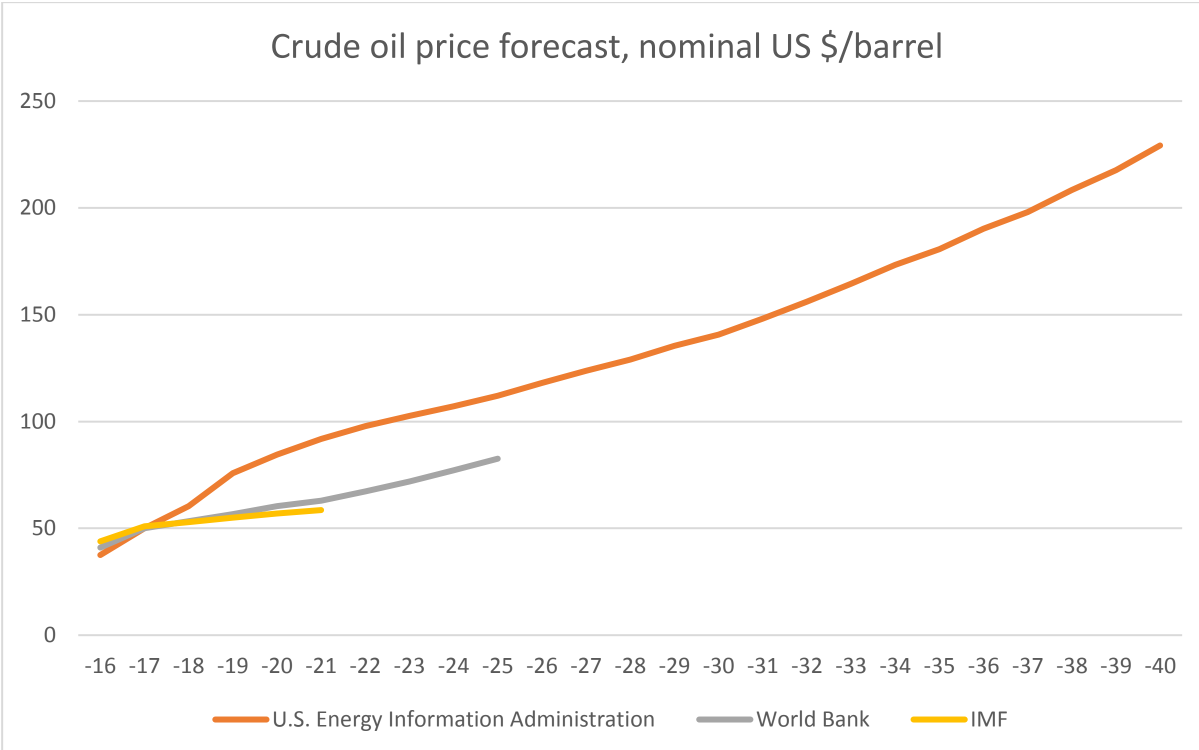

Figure 14. Crude oil price forecasts, nominal US dollar/barrel, 2016 – 2040

5.8.3 Discount rates and cost of capital

Two discount rates were used in the DCF calculations to analuze the novel logistics solution on this research. This approach was adopted due to the European Commission (2014b) recommendation to use separate Financial Discount Rate (FDR), and Social Discount Rate (SDR). FDR is used when discounting truly occurring cash flows of cost and benefits, in this case the cost saving potential of switching to the novel logistics solution from the currently used method of transportation relying on direct, but short train units. SDR on the other hand, is used to measure the social impact of investments, or its economic costs and benefits. Here no actual cash flows occur in terms of payments to one direction or other, but the external effects of an investments are given a monetary value to study their overall economic impact on society. In this particular case the SDR is used for discounting estimated external costs from congestion, accidents, air pollution, noise and climate change, caused by use of train, HCT, Russian standard truck, and material handler. Financial discount rate used on this research is 4 % p.a. in real terms (European Commission, 2014b, 42). Correspondingly, social discount rate is set to 5 % p.a., also in real terms (European Commission, 2014b, 55).

Cost of capital employed in roundwood was calculated by multiplying three factors: expected rolling stock, value of imported roundwood, and cost of capital. On the novel solution also average stock at the terminal field was considered. The average rolling stock is dependent on wagon cycle times as well as the roundwood volume transported through the terminal on an annual level. Average stocking time for roundwood at the RRT was assumed to be four days. Increased efficiency on the roundwood supply chain is in the very core of the novel logistics solution, and this approach encourages to keep the storage levels comparably low and not to gather unnecessary large stocks at the terminal field. Furthermore, value from using the timber section of the RRT as a back-up safety storage for a pulp mill is outside of the scope of this research. Value for the imported Russian birch fiber was assumed to be 36 €/ton (Natural Resources Institute Finland, 2016c).

For cost of capital, estimation on UPM WACC was used. Fair value of equity was collected from Nasdaq (2016) in July 2016. Fair value of debt is based on information collected from UPM Annual Report 2015 (UPM, 2016b). Here the total interest-bearing liabilities were considered. Estimation on cost of debt is based on interest and other financial expenses reported for year 2015 in this same document. For cost of equity CAPM approach was used. Beta for UPM was estimated to be 1.24 on a three year period 7/2014 – 7/2016 (Yahoo Finance, 2016a & 2016b). Market risk premium for the reference index OMXH25 for the same time frame was 7.4 % p.a. (Yahoo Finance, 2016b). Interest rate for a ten year Finnish government bond was used as a risk free rate. This was 0.5 % in July 2016 (Bank of Finland, 2016b). Corporate tax in Finland is 20 % (Finlex, 2013). Based on these parameter values in the WACC calculation, UPM's cost of capital was estimated to 7.6 % p.a. in July 2016. Table 20 presents the components used in these WACC calculations. Due to the reason that cost of capital is not a remarkably important parameter in the profitability analysis on novel logistics solution, WACC and CAPM methods are not covered or discussed in more detail on this thesis.

Table 20. Cost of capital estimation on UPM

Components of WACC	**July 2016**	**Source**
Equity	8 951 m€	Nasdaq, 2016
Debt	3 066 m€	UPM, 2016b
Total assets	12 017 m€	
Cost of equity	9.0 %	
Cost of debt	4.3 %	UPM, 2016b
Corporate tax	20 %	Finlex, 2013
Beta	1.24	Yahoo Finance, 2016a & 2016b
Risk free rate	0.5 %	Bank of Finland, 2016b
Market risk premium	7.4 %	Yahoo Finance, 2016b
WACC	**7.6 %**	

5.8.4 Transportation distances

Seven locations of interest were included in the analysis model to study the novel logistics solution. These are Kouvola RRT, Vainikkala border station, Kotka port in Mussalo (under Port of HaminaKotka ownership), and four pulp mills. Pulp mills included in this research are UPM Kymi, Stora Enso Anjala, Metsä Group Äänekoski, and UPM Kaukas. Geographical locations for each of these can be found with Google Maps (2017a-g).

Distances of routes between RRT and each of the other six locations were measured utilizing two functions on the Google Maps service, route finder and distance measure tool. Distances on these routes are very similar via road and railroad in all cases except one, Metsä Group Äänekoski. Table 21 presents these distances. In the case of Metsä Group Äänekoski the distance to RRT in this table is via road. The route via railroad to

Metsä Group Äänekoski is measured directly from Vainikkala border station, due to the difference in road and railroad connections between these two locations. Also the distance on route between UPM Kaukas and Vainikkala via railroad is measured in this manner. This particular pulp mill is located rather near the border crossing point and thus direct trains transports there would not go through RRT in Kouvola, but straight from Vainikkala. Distances via railroad on these two routes mentioned were aggregated from a map provided by Finnish Transport Agency (2015, 15) and they are also presented on Table 21.

Table 21. Distances between locations in modelled supply chains

Kouvola RRT to, via road/rail	
Vainikkala (Russian border)	91 km
UPM Kymi	17 km
Stora Enso Anjala	24 km
Metsä Group Äänekoski	236 km
UPM Kaukas	87 km
Kotka port	57 km
Vainikkala (Russian border) to, via rail	
Metsä Group Äänekoski	402 km
UPM Kaukas	64 km

6 RESULTS

In this chapter the results of this research are presented. First, estimation on future timber flows to Kymenlaakso region are discussed. Development on these transports from outside the region are a major driver to determine the potential of annual roundwood volumes to be transported through the timber RRT. Second, feasibility of the novel logistics solution for roundwood imports introduced on this research is revealed. This issue was analyzed from multiple points of view. In addition to financial profitability of the novel logistics solution, also its wider social and economic effects were studied. Furthermore, sensitivity analysis on this investment opportunity was carried out and alternative scenarios were used to reveal its full potential.

6.1 Timber flows to Kymenlaakso region

There is a remarkable imbalance between roundwood supply and demand in Kymenlaakso for all three classes of fiber timber. This has been the case for long time due to the high concentration of pulp mills in the region. Forecast for 2020 expect this imbalance to grow even greater due to supply staying somewhat at the same levels as in 2015, but demand rising to remarkable degree (Venäläinen, 2016; Natural Resources Institute Finland, 2017a&b). This difference is most striking for hardwood fiber. Its regional deficit in Kymenlaakso was greatest of all six timber classes considered on this research already in 2015, and it is expected to be even greater in 2020. This is clearly visualized in Figure 15.

The difference between regional supply and demand needs to be filled with transports from other regions or imports. Southern Karelia is a neighboring region to Kymenlaakso, and the imbalance for fiber timber supply and demand is even greater there. This leads to a situation in which some fiber timber must be transported to pulp mills in these regions from extended distances. As both of these regions are located very close to Russian border, from where fiber timber supply is generous, also imports are used in order to meet the required raw material flows to pulp mills. In case of hardwood fiber there also seems to be a lack of supply on a national level in Finland, which further underlines the importance of imports. Approximately two thirds out of the total six million plus cubic meters of timber imported to Finland is hardwood fiber, and most of it is from Russia (Natural Resources Institute Finland, 2016c). These standpoints steer the interest of this research towards hardwood fiber.

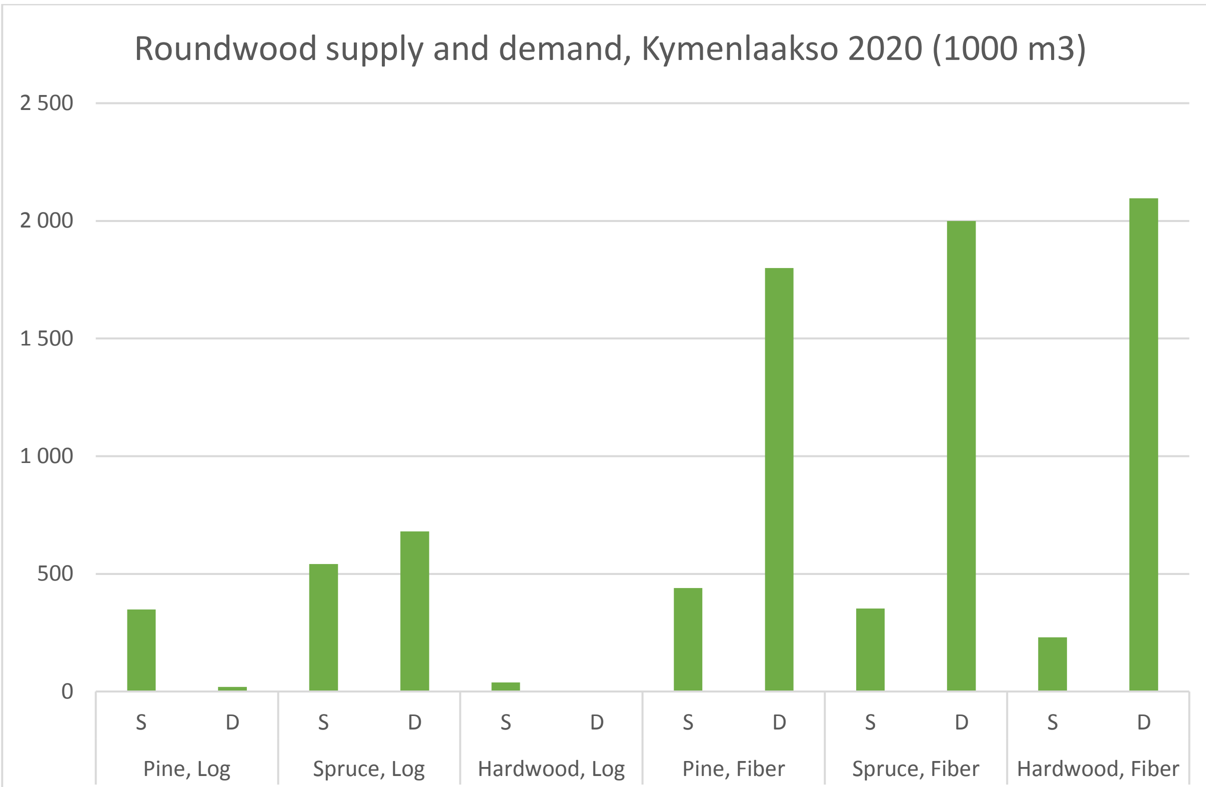

Figure 15. Roundwood supply and demand, Kymenlaakso 2020, 1000 m^3

Demand for hardwood fiber in Kymenlaakso was approximately 1.7 million m^3 in 2015 and it is expected to rise to around 2.1 million m^3 in 2020 (Venäläinen, 2016; Natural Resources Institute Finland, 2017b). On the same time frame regional supply of hardwood fiber is expected to decline slightly. This causes the regional imbalance for hardwood fiber in Kymenlaakso to grow from approximately 1.5 million m^3 in 2015, to 1.9 million m^3 in 2020 (Venäläinen, 2016; Natural Resources Institute Finland, 2017a&b). Using precise numbers, this accounts for 403 000 m^3, or 27.5 % rise in regional deficit. All this adds on the transports already carried out on roundwood freight towards pulp mills in Kymenlaakso. Due to the shortage of hardwood fiber supply in Finland, majority of this rise in demand is likely to be fulfilled with Russian imports.

6.1.1 Estimate on future roundwood flows through Kouvola RRT

The volume of roundwood flows transported through the timber RRT utilizing the novel logistics solution is highly dependent on major forestry companies operating pulp mills in northern Kymenlaakso, namely UPM and Stora Enso. Their dedication to seek long term savings through this new supply chain concept is crucial to accrue enough roundwood volume, which to a high degree determines if this operation model could become profitable in the long run.

National statistics on roundwood are stored in cubic meters, whereas tons were used in the DCF calculations of this research due to the maximum weight limits on HCT and stanchion wagons. Timber weight in relation to its volume can vary a lot depending on roundwood's size, moisture degree, and class (pine, spruce, hardwood). In general timber is lighter than a ton per cubic meter, but precise measures used by forestry industry or other organizations are often classified information. Here a weight/volume -conversion rate of 0.9 tons per cubic meter of roundwood was used.

On a base scenario of this research annual volume of roundwood transported through the timber RRT was set to 300 000 tons. This would account for approximately 17.5 % of the total hardwood fiber transports to Kymenlaakso, or 82.7 % of the expected rise on these transports between 2015 and 2020. Although the primary interest on this research is on hardwood fiber imports from Russia, there are no practical limitations to use the timber RRT also for pine or spruce fiber imports. Considering these standpoints, the 300 000 tons annual roundwood volume transported utilizing the novel logistics solution is in realistic proportion and could well be served, would the timber section at the RRT be constructed and other necessary investments made.

6.2 Feasibility of the novel logistics solution for roundwood imports

Results of feasibility analysis on the novel logistics solution studied on this research are presented on this subchapter from six perspectives. First, estimated annual savings to be captured from adopting the novel logistics solution are presented. Second, the overall long term profitability on the whole supply chain with its required investments is revealed. Third, economic impact of the project in terms of external costs are presented. Fourth, a CBA combining the results of financial profitability analysis and estimated economic impact of external costs is discussed. Fifth, sensitivity analysis on financial profitability of the project is presented. Last, some alternative scenarios varying from the base scenario are used to reveal the magnitude of potential cost savings capable to be captured with the novel logistics solution.

6.2.1 Comparison of annual costs between the alternative supply chains

To clearly illustrate the differences between currently used methods of transportation and the novel logistics solution, comparison of annual costs of these two are presented here. This is done separately for roundwood and container supply chains on a regular year of operations after the required investments in terminal infrastructure, HCT, and material handler have been carried out. Figures here represent the case in base scenario, where all transports are to or from UPM Kymi pulp mill. Table 22 presents cost breakdown of roundwood transports to pulp mill, and Table 23 container transport costs to Kotka port. The cost classes in both of these tables present major cost classes. For Other train transport costs, HCT transports, Terminal, and Material handler the figures are compiled of multiple minor cost classes. On Other train transport costs these are time and distance dependent train transport costs, taxes and other payments, overhead costs, and cost of capital employed in timber. On HCT transport these are diesel costs, AdBlue costs, tyre costs, salary costs, and other costs, which cover maintenance, insurance, and management. In case of container transports, only costs additional to idle drive back to RRT are considered for HCT transport costs. On Terminal these are land rent and maintenance, services, and utilities costs. On Material handler these are diesel costs, AdBlue costs, salary costs, and other costs, which cover insurance, maintenance, and management.

Roundwood

Table 22 clearly illustrates the savings potential the novel logistics solution possess to enhance the efficiency of import roundwood supply chain to pulp mill. Annually it is estimated to capture a total savings of 336 974 € when compared against the currently used transportation method relying on short train units heading directly to pulp mill. This means approximately a 23 % saving when choosing the novel logistics solution.

Table 22. Annual cost comparison, roundwood transports to pulp mill

	A) Direct train transport	**B) Novel logistics solution**
Wagon rents	409 091 €	122 727 €
Wagon change and handling	345 455 €	86 364 €
Locomotive change	60 124 €	45 093 €
Other train transport costs	629 902 €	437 713 €
HCT transport	-	307 718 €
Terminal	-	54 000 €
Material handler	-	53 983 €
TOTAL	**1 444 572 €**	**1 107 598 €**

Taking a closer look at where these savings could be captured from, one can find the increased efficiency on railroad transports to be the main driver. More precisely, this is due to two improvements on roundwood supply chain the RRT enables to implement. First, features of the RRT makes possible a significant increase in efficiency of wagon logistics. This leads to shorter wagon cycle times and drastically decreases the need to change and handle the wagons around in the railroad terminal. These improvements lead to lower costs in wagon rents, and wagon change and handing. Second, possibility to accept longer train units at the RRT increases the efficiency of transports via railroad. When there is no longer a need to split the Russian trains at the border to shorter train units, changing locomotives at the border accumulate less costs in comparison to the currently used method of roundwood transports. Utilizing longer train units also means lower transportation costs per tonkilometer on freight, thus leading to savings in overall train transport costs.

As the novel logistics solution utilizes terminal and road transports, three costs classes additional to the currently used method have to be taken in consideration. These costs from HCT transports, Terminal and Material handler account for a significant proportion of the total costs when choosing the novel logistics solution. However, keeping these functions efficient, and considering the increase in efficiency of railroad transports to the RRT, this alternative concept is able to provide significant savings on an annual level when compared to the currently used solution.

Containers

The opportunity to backhaul containers from pulp mill to RRT utilizing the same HCT as for roundwood transports offers potential for some savings on total costs for the whole supply chain. When compared to direct train transports from pulp mill to Kotka port, the novel logistics solution offers annual savings of 75 407 € on container transports. This accounts for 10.2 % saving from the currently used method of container transports for export. Breakdown of this cost comparison is presented on Table 23.

Table 23. Annual cost comparison, container transports to port

	A) Direct train transport	**B) Novel logistics solution**
Wagon rents	228 800 €	85 800 €
Container rents	78 000 €	29 250 €
Wagon change and handling	197 600 €	197 600 €
Other train transport costs	235 799 €	146 891 €
HCT transport	-	46 001 €
Container handling	-	159 250 €
TOTAL	**740 199 €**	**664 792 €**

Savings potential from container backhauling is not as remarkable as it is for roundwood transports, but the key drivers that determine these synergy benefits are the same for both of these supply chains. Utilizing the novel logistics solution for container transports increases the efficiency of wagon and container logistics, thus leading to shorter cycle times and lower rent costs on both. Possibility to use longer trains for container transports leaving the RRT also yields savings on Other train transportation costs. On the novel logistics solution containers need to be lifted off the HCT and on a train. Often this lift needs to be done twice, as the container is set on terminal field to wait for the right train to be ready at the RRT. This container handling adds substantial costs on a novel logistics solution that are not present for the currently used direct train transports of containers.

A notion must be made that no attention in these calculations have been paid to the investments a novel logistics solution requires before its operations could be run. HCT and material handler must be purchased, and terminal infrastructure for the RRT and its timber section built before this is possible. Especially the construction costs of RRT are remarkable when compared to the estimation on annual savings when switching to the novel logistics solution. This is the case whether the synergy benefits of container backhauling are considered or not. To grasp an understanding if these investments are worthwhile in the first place, a long term point of view must be taken. Whether the savings potential presented here is great enough to justify the required investments is discussed in the next subchapter, where results of the DCF calculations in financial terms are presented.

6.2.2 Financial profitability

Results of analysis on the base scenario suggest that the novel logistics solution studied is financially profitable in the long run. This is the case with and without the estimated synergy benefits taken into account. Table 24 presents the key results of the analysis on base scenario by investment criteria in cases both with and without the synergy benefits that could be captured on container backhauling.

Table 24. Financial profitability analysis, key results on base scenario

	With synergies	Without synergies
NPV	1 769 953 €	564 384 €
IRR	6.7 %	4.9 %
PI	1.4	1.1
DPP	20	27
PP	14	18

Although the degree of estimated savings captured by container backhauling is not as significant as with the timber transports, these synergies play a major role in determining the profitability of this investment possibility. The NPV for the solution studied more than triples when synergies are considered. Also IRR is considerably better with synergies. However, PI is not by any means great for either cases. Payback periods, whether discounted or not, are long even when synergies are taken in account.

The fact that majority of the investments have to be made before the novel logistics solution can be operated, and the benefits accumulate over a long period of time, significantly increases the risk of this project. Many parameter values used in this analysis are likely to fluctuate, which could lead to smaller annual savings than estimated here. In a situation where the required investments are made and the novel logistics solution is operational, divestments could turn out to be difficult. Would in such a case the environmental factors around RRT and roundwood transports turn unfavorable for the novel logistics solution, HCT and material handler could rather easily be used in other locations or sold. This might not be the case for by far the most important investment, terminal infrastructure. Roundwood terminal is a very specific asset for which markets are rather scarce. This terminal could of course be used for other freight classes, but this would most likely require some additional investments. Thus divestment on the terminal infrastructure itself could turn out to be a major issue, would it ever be necessary.

Considering the long payback time on investments required for the novel logistics solution, synergies with container transports play a major role on controlling this projects risk level. Although the estimated backhauling synergies are not as remarkable as the savings on roundwood transports, they are additional benefits in terms that no investments are required to capture them. With these synergies the novel logistics solution is profitable also in situations where some of the critical environmental factors turn out to be less favorable for the project than expected. This topic is discussed in more detail in Sub-Chapter 6.2.5 that cover sensitivity analysis on financial profitability.

6.2.3 Economic and social impact

Five different external costs were studied on this research: congestion, accidents, air pollution, noise, and climate change. Analysis on base scenario shows that the novel logistics solution would accrue somewhat higher external costs from roundwood transports than the currently used solution relying on direct trains to pulp mills. The currently used supply chain possess lower external costs on three of the five cost types considered. Overall external costs of the novel logistics solution are 46.5 % greater than those of the direct train transports. For both of these alternatives congestion, air pollution, and climate change cause majority of external costs, whereas accidents and noise are less important. Considering container transportation, external costs are remarkably lower than those of roundwood imports. Here the novel logistics solution causes less external costs in total than direct train transports from pulp mill to Kotka port. This is due to use of longer train units in the novel logistics solution, and the fact that container backhaul to RRT with HCT causes very little additional external costs in comparison to idle drive back. Taking in account both roundwood and container transports analyzed on this research, external costs caused by novel logistics solution would exceed those of direct train transports by 26 236 € on annual basis. Table 25 presents a breakdown of these costs. Furthermore, Table 26 lays out estimations on three major emission types (CO_2, CH_4, N_2O) for each alternative transport solution.

An alternative point of view can be taken on when studying external costs on roundwood transportation. If the combined train and HCT transports are not compared to utilization of direct trains as in financial analysis, but rather to Russian standard trucks, the results are strikingly different to those described above. Due to the fact that these trucks have a much lower allowance on maximum mass and all the transports from the border onwards are driven on road, external costs for this method of roundwood transportation are significantly higher than those of the novel logistics solution. On annual level this difference is 833 467 €. In case of Russian trucks congestion is clearly the most significant cost class, as it causes more than half of the total external costs. These cost estimations are also available on Table 25. Financial costs on roundwood transports with Russian trucks were not estimated as this alternative is not desired to be taken in use as long as other cost effective means exist. However, with Russian roundwood imports likely to be on a rise and capacity to accept railroad transports at some pulp factories is limited, this scenario is possible to occur, if the novel logistics solution is not utilized.

Table 25. External costs of alternative transport solutions, annual level

€	Roundwood			Containers	
	Novel logistics solution	Direct train	Russian trucks	Novel logistics solution	Direct train
Congestion	31 377	6 480	485 132	593	770
Accidents	776	9	14 464	1	3
Air pollution	36 522	39 180	199 607	2 502	7 381
Noise	1 319	2 580	4 339	343	1 011
Climate change	44 512	29 913	234 321	2 246	6 628
TOTAL	114 506	78 161	937 864	5 685	15 793

Table 26. Emissions of alternative transport solutions, annual level

	Roundwood			Containers	
	Novel logistics solution	Direct train	Russian trucks	Novel logistics solution	Direct train
CO_2, tons	451	276	2 570	41	28
CH_4, kg	13	3	135	1	0
N_2O, kg	13	3	135	1	0

When the analysis timeframe is extended from annual level to cover the whole 33 year period, discounted values should be used. Comparing the novel logistics solution to direct trains, the NPV of monetarily measured external costs is -365 812 €. When the reference point is Russian standard trucks, external cost NPV is 11 621 254 € for the advantage of the novel logistics solution. On this case it was assumed, that direct train transportation of containers would be utilized on a solution relying on Russian trucks on roundwood imports. Comparing these two very different outcomes, it is clear that the reference point has a great impact on whether the novel logistics solution is recognized to cause positive or negative impact on society and environment if initiated.

6.2.4 Cost-Benefit Analysis – combining financial profitability and social impact

Combining the results of financial and economic costs analyses would still support the conclusion to take the novel logistics solution in use. However, greater external costs on the novel logistics solution when compared to direct train transports brings the NPV combining financial and economic factors down to 1 404 142 €. This takes in account both roundwood and container supply chains studied. Measured in this way, the NPV on a CBA would remain positive for this project also when the synergy benefits from container backhauling are not considered.

Conclusions from results of CBA on the novel logistics solution are twofold. On one hand, this project has positive NPVs whether measured only from financial perspective or taking in account also the external costs. This would propose that the solution as a whole is worthwhile to investment in and could thus attract private companies to participate in running its operations as modelled in this research. However, the corresponding PPs on the whole project are very long. As values on many of the parameters included in this analysis are subject to change, this marks for a considerable risk especially when the terminal infrastructure is considered. On the other hand, the project having positive financial NPV is likely to be an issue if EU financing is applied for. In general this funding is not available on projects that have a positive NPV solely from financial standpoint (European Commission, 2014b, 28). Here the Russian standard trucks as an alternative mean to import roundwood could become an important factor. It could be argued, that the novel logistics solution is able to ensure these economically inefficient road transports are not used when roundwood import volumes rise. As the novel logistics solution has long financial PP, EU financing would be necessary to initiate the investments required on making this supply chain operational. This funding could therefore prevent the remarkable rise in external costs, which the use of additional Russian standard trucks would otherwise cause.

6.2.5 Sensitivity analysis

Sensitivity analysis was carried out on four of the most important variables in the model in terms of profitability. These are terminal investment cost, wagon cycle time on direct train transports (gate-to-gate), total volume of annually transported timber, and RUB/€ -exchange rate. For each variable, its estimated value was altered for better and worse to find out the effect this has on the novel logistics solution's NPV. This was done for one variable at a time as the other crucial variables remained constant and had same values as in base scenario analysis (all transports to/from UPM Kymi, annually transported roundwood volume 300 000 tons). Increments used were: 1 000 000 € – terminal investment cost; one day – wagon cycle time; 50 000 tons – annual timber volumes; and 10 RUB/€ – RUB/€ -exchange rate. Situations with and without synergies were analyzed separately. Table 27 presents the results of sensitivity analysis with synergies, and Table 28 without them.

Table 27. Results of sensitivity analysis on base scenario, with synergies

Terminal investment cost (€)	3 300 000	**4 300 000**	5 300 000	6 300 000	7 300 000
NPV	2 731 985	1 769 953	807 922	-154 110	-1 116 141
Gate-to-gate, UPM Kymi (days)	3	4	**5**	6	7
NPV	-882 128	443 913	1 769 953	3 095 994	4 422 035
Total transported timber (tons)	200 000	250 000	**300 000**	350 000	400 000
NPV	-544 090	612 932	1 769 953	1 914 622	3 071 644
				(2 HCT vehicles)	
Exhange rate (RUB/€)	40	**50**	60	70	80
NPV	2 887 546	1 769 953	1 024 892	492 705	93 565

Synergies taken into account, profitability of the novel logistics solution is rather sensitive for changes in all of the four crucial variables studied. This goes both ways, towards negative and positive directions. As in the base scenario NPV is positive and thus suggests to take the novel logistics solution in use, interest of a potential investor is most likely to be more on the negative side of the risk. Turns out, that the novel logistics solution can take somewhat remarkable downward hits in all of the four variables, before the NPV of a base scenario turns negative. However, if more than one of these variables would take a remarkable turn for worse from the values expected, it could very well bring the NPV negative. Considering the upside, if wagon cycle times at the pulp mill turn out to be longer than expected, this would have a significant positive impact on the overall profitability of the novel logistics solution.

Table 28. Results of sensitivity analysis on base scenario, without synergies

Terminal investment cost (€)	3 300 000	**4 300 000**	5 300 000	6 300 000	7 300 000
NPV	1 526 416	564 384	-397 647	-1 359 679	-2 321 711
Gate-to-gate, UPM Kymi (days)	3	4	**5**	6	7
NPV	-2 087 697	-761 657	564 384	1 890 425	3 216 465
Total transported timber (tons)	200 000	250 000	**300 000**	350 000	400 000
NPV	-1 749 659	-592 638	564 384	709 053	1 866 075
				(2 HCT vehicles)	
Exhange rate (RUB/€)	40	**50**	60	70	80
NPV	1 681 977	564 384	-180 678	-712 865	-1 112 005

Without synergies the novel logistic solution is a lot more risky to end up being unprofitable in the long run. Although also in this case the NPV is positive on base scenario with most likely values on critical variables, the situation turns around if any of these is worse than expected. If any of the studied variables turn out to be one increment less beneficial for the novel logistics solution, the NPV is negative. This underlines the importance of synergy benefits the RRT can provide.

While carrying out the sensitivity analysis and multiple alternative scenarios, it was found out that also a fifth factor has remarkable effect on the NPV of the project. This is the distance between a pulp mill and the timber RRT. Based on the experiments run on the model, the novel logistics solution is applicable on transports heading to pulp mills relatively close to the terminal. In case of the timber RRT, this means UPM Kymi (17 km) and Stora Enso Anjala (24 km). On transports with destinations further away direct train was found out to be more cost efficient. The novel solution utilization on roundwood transports to Metsä Group Äänekoski (236 km) and UPM Kaukas (87 km) were not found to have a positive NPV no matter how favorable the variable values were set.

6.2.6 Alternative scenarios

In addition to base scenario and sensitivity analysis, some other alternative scenarios were paid attention. Table 29 presents results of the financial profitability analysis in terms of NPV with alternative destinations for roundwood. Parameters values used in the base scenario were kept otherwise unchanged here. Results of this analysis on Stora Enso Anjala are very similar to those in the base scenario, where the destination is UPM Kymi. Also in this case the novel logistics solution is a profitable investment both with and without synergy benefits taken in account. For Metsä Group Äänekoski and UPM Kaukas the NPVs are highly negative even with the container backhauling synergies. The striking difference between these two pulp mills and those where the novel logistics solution seems feasible is distance, which is already discussed in the previous subchapter.

Table 29. Financial profitability analysis results, alternative destinations

NPV	**With synergies**	**Without synergies**
Stora Enso Anjala	1 798 207 €	334 510 €
Metsä Group Äänekoski	- 18 890 488 €	- 28 171 767 €
UPM Kaukas	- 14 618 795 €	- 18 405 641 €

Two additional alternative scenarios were studied to demonstrate the upside potential the novel logistics solution holds. For both of these, synergies were taken into account while calculating investment criteria. First one of these has higher volumes of roundwood transported through the RRT due to two destinations instead of just one in the base scenario. With 50 % of the roundwood transports heading to UPM Kymi and another 50 % to Stora Enso Anjala, and 500 000 tons of rounwood a year, financial NPV for the novel logistics solution is 6 335 542 €. This is more than three and a half times greater compared to the financial NPV of the base scenario with synergies. The second alternative scenario holds other values equal, but has a lower cost of 20 €/lift on container handling instead of the 35 €/lift in the base scenario. The financial NPV on this scenario is 2 861 097 €. This clearly reveals the significance of synergy benefits for the novel logistics solution's profitability, as NPV almost doubles by just assuming lower cost on container handling at the RRT. Such development is realistic, if the container terminal at the RRT expands rapidly. In such a case, higher volumes of containers handled at the site are likely to bring down the unit cost for a single lift.

Costs on road transports of interest in this research were also estimated for a regular truck according to Finnish regulations (total maximum mass of 76 tons). This was done to measure the increase in efficiency a HCT offers over these regular trucks on roundwood transports between RRT and pulp mills. For a regular year of operations in a base scenario, this difference is 34 650 € for HCT's advantage. Although this marks only an approximately 11.3 % rise on annual road transportation operation costs, it has a remarkable difference on the profitability of the whole novel logistics solution. The present value of all cost savings due to choosing HCT over the regular truck is 660 230 €. Considering only the roundwood transport supply chain, this difference would bring the project's NPV without synergy benefits down to -95 846 € if regular trucks were used instead of HCT. This result leads to a conclusion, that the novel logistics solution would not be profitable even on a very long time frame if it was operated with regular trucks. The higher freight capacity of HCT allows to capture savings on diesel, AdBlue and salary costs due to increased efficiency. For the same reason, more regular trucks would be required to complete the same amount of roundwood transports as HCT. This leads to higher investment and other costs (insurance, maintenance, management etc.) when regular trucks are used, even though these costs are lower on them on unit basis. On this research it was assumed that one HCT would be sufficient on base scenario, but utilization of regular trucks would require an average of 1.5 units in full time use.

Costs on container transport with regular truck were not calculated. However, acknowledging the fact that a regular truck would not be able to transport two FEU containers when measuring the backhaul synergies, these benefits are likely to also be lower when compared to those captured using HCT.

7 DISCUSSION

This chapter cover discussion over the results of analysis carried out on this research as well as few other topics considered to be relevant on the framework of the novel logistics solution. In addition to risk and possibilities of the studied supply chain concept, a free to use simulation tool based on analysis model used on this research, practical experiences on roundwood transports combining trains and trucks, potential terminal location in Southern Karelia, recent announcement of road tolls for road freight in Finland, and perspective on limits in capacity for pulp mill terminals and railroad routes are discussed.

7.1.1 Risks

As mentioned in the previous chapter, investments required for the novel logistics solution carry a considerable amount of risk. Although the NPV of this project is positive, PP is long even when the container backhauling synergies are taken in account. Values of multiple parameters in the model are likely to fluctuate over the years, which could have a remarkable negative impact on the cash flow estimations. This is possible even with small changes in multiple parameters, if the direction in which they turn works against profitability of the novel logistics solution. In medium and long term, drastic changes in single parameters are also possible. In such a case, this single change alone could have a major negative effect on the savings potential the novel logistics solution has over currently used direct train transports.

The downside risk on the novel logistics solution is tightly connected to terminal investments at the timber RRT. These investments on terminal field, rails, road, and other infrastructure need to be accomplished before the novel logistics solution can become operational. Compared to estimated annual savings on roundwood and container transportation, as well as to required investments on HCT and material handler, terminal infrastructure requires major investments. Therefore, a remarkable amount of capital is tied on this infrastructure. Would operating environment around the novel logistics solution turn remarkably worse considering its profitability in the long run, divestments on HCT and material handler are relatively simple. This is not the case with the timber terminal itself, which is a much more illiquid asset. Due to its high monetary value and specific purpose, markets on such an asset are narrow. A company or investor willing to purchase the terminal must have a reasonable amount of capital, which rules out the smallest players. Furthermore, in case the terminal needs to be sold, it is likely that the facility would no more be used for roundwood handling and storage. After all, this would be the primary reason why the terminal has to be sold in the first place. Developing the terminal for other purposes is likely to require significant additional investments, which would make the selling process even more complex.

An important mean to control risk on the novel logistics solution is taking advantage of the synergy benefits. Even though the estimated savings on container backhauling are not as great as with the roundwood transports, they play a crucial role to increase the total savings captured. This increases the project’s NPV, and perhaps even more important, cuts down the PP for several years. Therefore, the extra effort required to make the HCT capable to transport both roundwood and containers will turn out to be very crucial considering the overall profitability of the novel logistics solution. Also, if other synergy benefits arise before or during the novel logistics solution is operational, they should also be taken advantage of.

A possible solution to control the risk connected to the illiquidity of the terminal is to separate its ownership and operations. According to the current plan on RRT as a whole, it will be constructed by, and remain under ownership of city of Kouvola. It would then rent rights to companies to operate at the terminal area. This solution would allow a company specialized in roundwood logistics to operate the timber section of RRT by paying the periodical rent for the owner of this facility. Would the novel logistics solution turn out to be unprofitable, operator of the timber section could simply terminate the rental contract and pay a fee for this action. City of Kouvola can then seek for alternative companies willing to use this section of the RRT either for roundwood handling and storage, or for other purposes, and rent it to them. This obviously concentrates the illiquidity risk on terminal infrastructure assets to city of Kouvola. In this research the interest was on total costs on the whole supply chain for both roundwood and containers. Therefore this notion is slightly off the framework of this research, and thus not covered in more detail.

7.1.2 Possibilities

On the other side of the risk spectrum, changes in environment around the novel logistics solution can also lead to significant positive effects on project's profitability. As discussed on the previous subchapter, minor changes in multiple critical parameters or a major change in one can lead to a remarkably different outcome than those on the base scenario of this research. Some such alternative scenarios are presented in more detail on Sub-Chapter 6.2.6. In these cases a change in just one parameter value causes a major upward change on NPV. As annual savings from choosing the novel logistics solution in these cases are greater than in the base scenario, also PP's are shorter. Would the four most critical parameters included in the sensitivity analysis have the most favorable values presented on Table 27 (terminal investment cost: 3 300 000 €, wagon cycle time at UPM Kymi: 7 days; annually transported roundwood: 400 000 tons; exchange rate: 40 RUB/€), NPV on the novel logistics solution would be almost 10 million €. Also, the PP would be as short as 7 years in such a positive scenario. These examples clearly illustrate the possibilities the novel logistics solution has in terms of capturing savings on roundwood and container transportation costs on the whole supply chain level.

7.1.3 Forio simulation tool

Hilmola (2017) constructed a simulation tool based on the analysis model used on this research. It is freely available, easy to use, and can be run on an internet browser. This tool covers the financial side of the analysis covered on this research, but does not include measurement and comparison of external costs. Using this simulation tool, practically anyone can run various alternative scenarios on the novel logistics solution profitability analysis not covered on this research, extend the sensitivity analysis from that presented in Sub-Chapter 6.2.5, or even adjust the tool to appropriately represent an alternative network of pulp mills, border crossing point, terminal, and port used for container exports. One can adjust values on four most critical parameters – wagon cycle times individually for each of the four pulp mills, terminal investment cost, ruble-euro -exchange rate, and volume of annually transported roundwood. In addition to this, also distances between locations, terminal lot rent, and roundwood allocation between the four pulp mills can be adjusted. The simulation can be run on five or ten year intervals, between which the parameter values can be changed. Results of the simulation are presented visually on six graphs. They are available year by year and in cumulative measures, in real and present values, and for situations with and without the synergy benefits of container backhauling. This tool is very powerful as it provides a possibility to study numerous different scenarios and parameter combinations, and results of the analysis are presented easily readable and understandable manner.

7.1.4 Combining rail and road transportation – practical experience from Sweden

In northern Sweden, a major forestry company has used a supply chain concept very similar to the novel logistics solution studied on this research. It utilizes train transports of roundwood to a road-railroad terminal, efficient material handler to lift the roundwood off the train and on a truck, and purpose built trucks on roundwood transports to the nearby pulp mill. Terminal size and pavement material, its distance from the pulp mill, volume of annually transported roundwood, and material handler are very close to those modelled on the calculations of this research. Compared to the novel logistics solution, there are two major differences. First, the roundwood is not imported, but harvested from Sweden. Second, instead of HCT, multiple trucks that meet the standard Swedish regulations are used. This solution has been in operation for 25 years. Its annual operation costs (excluding train transport costs) are very close to those estimated for the novel logistics solution on this research. The forestry company manages roundwood flow on this part of its supply chain, but has outsourced operations at the terminal and on roundwood transports. (Forestry company 3, 2017)

This example from Sweden provides evidence that a roundwood supply chain based on the same principal foundations as the novel logistics solution concept can be, and indeed has been, a feasible choice on roundwood transports. A key here is to consider costs on the whole supply chain level, rather than optimizing its subparts. In general railroad freight of roundwood is more cost efficient than road transportation on extended distances, and vice versa. On the example case from Sweden, no railroad connection to factory existed, but there was plenty of room for a roundwood terminal next to a railroad routed through a nearby town (Forestry company 3, 2017). Lifting the roundwood off the train and on a truck causes additional costs, but planning the operations in an effective manner, these costs can be kept in control. In this case, combining road and railroad transports was a more cost effective alternative than direct long distance truck transports. Considering the case analyzed on this research, railroad logistics to and at the pulp mills set limits on how efficient the direct train transports can be at best. Utilizing strengths of the RRT, cost savings on train transportation of roundwood can be met due to increased efficiency. Keeping the costs on terminal, material handler, and HCT transports in control with appropriate planning and high efficiency, savings on a whole supply chain level can be achieved. Furthermore, possibility to combine roundwood and container transports is a remarkable opportunity to gain synergy benefits. The RRT can provide these costs savings due to the fact that its primary purpose is efficient container logistics.

7.1.5 Mustola port – potential terminal hub in Southern Karelia

The novel logistics solution studied is a general concept. It could therefore be executed also in locations other than those modelled on this research. This covers also the existing road-railroad terminals that are suitable for the novel logistics solution. Up-front investment costs on terminal field and facilities are substantial when screened against the expected cost savings. The concept itself is new in Finland, and thus not yet tested in practice. These two dimensions mark for a remarkable risk. This risk can be significantly lowered, if an existing terminal in a favorable location can be rented for a reasonable cost. Utilization of such terminal also provides a possibility to pilot the novel logistics solution in practice. This would allow collection of information not only on costs, but also other important factors on the modelled supply chain, with a rather low risk.

Mustola port in Lappeenranta would suit very well for a terminal hub in a novel logistics solution applied in Southern Karelia (location: Google Maps, 2017h). Railroad imports of Russian roundwood could be transported there via two alternative border crossing points, Vainikkala and Imatrankoski. Furthermore, Mustola port has a railroad connection to Kotka port for container exports. The road connections from this terminal to nearby pulp mills are also good. Proper terminal field and facilities exist in Mustola, and it is capable to accept long train units. Different kind of logistics services are already provided there, but as some terminal fields are not in active use, roundwood terminal operations would be very welcome there (Other expert 3, 2017). Multiple forestry industry factories are located in close range from Mustola. The most important of these are UPM Kaukas, Metsä Group Joutseno, and Stora Enso Imatra. All these three are pulp mills.

The analysis model built to carry out this research can be adjusted to measure the cost savings potential and change in external costs for a novel logistics solution in Southern Karelia, where Mustola port acts as a central terminal hub through which roundwood and containers are transported. Most of the parameter values require no changes. However, three factors need to be adjusted for the model to properly represent the situation of interest. First, distances between the locations included in the model need to be measured. Second, wagon cycle times at Mustola and the pulp mills not studied in this research need to be estimated. Third, terminal investment and operating costs must be paid close attention. It is likely that a launch of the novel logistics solution through Mustola would require very little investments in addition to a material handler and HCT. However, annual rental costs for the terminal field and facilities are likely to be considerably higher than lot rent at the RRT in Kouvola. Imbalance of roundwood supply and demand is even greater in Southern Karelia than it is in Kymenlaakso, and it is located near the Russian border. Therefore, analysis on Mustola port similar to the one carried out in this research could prove to be valuable for both local authorities in Southern Karelia and companies operating the pulp mills in the area.

7.1.6 Road tolls

In April 2017 Finnish government made a decision to introduce road tolls on heavy freight trucks using Finnish road network. Multiple details on this process, including schedule for regulation and pricing of these tolls, are still unclear. The type of this toll is to be vignette, which is a time based payment. Both domestic and foreign truck would have to cover this vignette payment. However, Finnish government has a plan to compensate this cost for domestic trucks according to the EU maximum allowance. (Keskisuomalainen, 2017)

A wide variety of different vignettes and tolls are enforced around European countries. Required payments on these are based either on time, distance or a specific route. For example, common Euro-Vignette is used in Sweden, Denmark, Netherlands, and Luxembourg. In this system payments are determined by vehicle’s emission class (Euro 0 / Euro I / Euro II, III, IV, V) and axle number (3 / 4 or more). Vignette can be paid for a day, week, month or year. Extending the payment period offers discount on price per day. Russia enforces its own Platon system, in which toll payments are based on distance driven. (DKV, 2017)

Considering roundwood transports within Finland and from Russia, road tolls on both sides of the border are likely to raise the costs on road transports. This is the case especially for Russian standard trucks used to import roundwood to Finland. In the future their operators will have to cover not just the Platon payments for using Russian road network, but also the vignette required in Finland. Neither of these payments are enforced on railroad transports, which further supports the notion that train transports are very important on roundwood imports to Finland. It is still unclear to which degree the vignette payments will be compensated for Finnish truck operators. Due to EU regulation it is possible that this can’t be done on the whole payment, even if this was Finnish government’s goal. Regardless of this compensation level, the cost effect of vignette payments on HCT transports as modelled on this research is likely to be lower than that of a comparable Finnish standard truck with 76 maximum gross weight. In Euro-Vignette system the payment level is same for all long or heavy trucks that have four or more axles (DKV, 2017). Would the vignette payments in Finland be similarly set, HCT would benefit from its higher freight capacity and efficient utilization rate as multiple drivers operate one vehicle in shifts.

How exactly the vignette system for heavy freight trucks will be arranged in Finland was still very unclear at the time this research was completed. Therefore, it is not included in the DCF calculations presented on this thesis in any way. However, the analysis horizon for the novel logistics solution extends to over 30 years in the future. Finnish vignette payment regulation might or might not make a considerable difference on the total cost estimations on alternative supply chains modelled on this research. Keeping this in mind, it would be worthwhile to include the vignette payments' cost effect on calculations presented here when their terms and payment policy is decided.

7.1.7 Limits in capacity – railroads and pulp mill terminals

Utilization of the novel logistics solution provides additional storage room for roundwood at the timber RRT. Using this solution would also half the number of trains required to carry out the same amount of transports when compared to direct train transports that rely on shorter train units. Monetary benefits of these factors when choosing the novel logistics solution were not included on the profitability or external cost analysis on this research. However, on a bigger picture these could be quite important to some interest groups.

Multiple interviewees working on timber harvesting and roundwood supply chain operations pointed out, that difficulties due to weather on reaching the harvested roundwood in forests have increased in recent years (Metsäteho, 2016c&d). Climate change was seen to play a major role on this change in environment, and it was widely expected to get worse. This problem causes uncertainty on pulp mills' roundwood supply. From some locations, it is practically impossible to collect the roundwood in order to deliver it to a pulp mill, if the environmental conditions are unfavorable. Terminals were seen as a crucial tool to manage this issue. During favorable conditions roundwood can be transported to a terminal for safety stock. Due to this safety stock enough roundwood can be delivered to a pulp mill also on times when the condition of forest roads are too harsh for heavy trucks. In addition to accepting train transports of Russian roundwood, the timber RRT could also serve as a backup storage for close by pulp mills. Routes from timber RRT to UPM Kymi and Stora Enso Anjala could be used for road transports of roundwood around the year regardless of environmental conditions.

In just few years, UPM has initiated two investment projects to remarkably extend the pulp production capacity at its Kymi mill. When a second one of these is completed in 2017, this mills annual pulp production capacity will rise to 870 000 tons from 2014's 530 000 tons (UPM Pulp, 2016). This marks for a 64 % increase. It is clear that demand for the most important raw material on pulp production, fiber timber, will increase in somewhat a same proportion. Production processes at pulp mills require constant and steady flow of raw material, and shortages in roundwood supply cause major losses to companies operating these factories. Adjustments in processes cause additional costs and production downtime cuts the revenues from those levels they could potentially be without interruptions. As the production volumes increase, so does the requirement to hold a sufficient safety stock at the pulp mill terminal. Building additional terminal facilities at a pulp mill will cause major costs, and might turn out to be challenging due to pulp mill's location. For example, UPM Kaukas is located between the suburbs of Lappeenranta and lake Saimaa, which leaves very little room to extend the pulp mill facilities. Similarly as with the challenges on road transportation due to environmental conditions, the timber RRT could serve nearby pulp mills as "a factory safety stock located outside the factory". Possibility to serve multiple pulp mills from the same terminal might provide cost savings as extensions are not required on several locations. Also the issue of limited land available adjacent to the existing pulp mill facilities can be tackled with the novel logistics solution.

Utilization of longer train units provides a possibility to raise efficiency of railroad transportation on two routes connected to the RRT. First one of these is the Kouvola-Luumäki-Vainikkala -route. Vainikkala is a very important border crossing point on railroad transports to and from Russia. The rail stretch between Kouvola and Luumäki is the most heavily utilized railroad link when measured in gross freight tons (Finnish

Transport Agency, 2015, 29). Also the second route of interest here, Kouvola-Kotka/Hamina, is important for freight transports. Heavy traffic on these two routes can cause congestion as a single freight train might need to wait for an appropriate time slot for a considerably long time. The fact that especially Kouvola-Luumäki-Vainikkala -route is important also for fast passenger trains, makes the issue even more complicated. Ministry of Transport and Communications (2015, 39) has indeed announced, that freight train unit sizes should be increased in order to decrease the number of train units driven on the heavy traffic railroad routes in Southeastern Finland. The overall length of a train unit does not have effect on how much time it needs to travel a certain railroad link. Thus, holding the annual freight volume constant, doubling the train size will require only half the number of train units than before. This releases precious time slots for other trains, and is important especially on railroad links that already have heavy traffic and tight schedules. Would railroad freight volumes on these two routes rise remarkably in the future, the novel logistics solution is able to free a considerable amount of time slots on them. This is due to fewer train units required to complete the desired transports of roundwood and containers. Keeping the train unit sizes short requires remarkable investments in railroad capacity if the overall freight volumes are expected to increase (Ministry of Transport and Communications, 2015, 38). Therefore, the novel logistics solution and other operation models that increase the train unit sizes on railroad freight transports between Finland and Russia can possibly yield significant savings on public sector responsible of railroad infrastructure investments and upkeep in Finland.

8 CONCLUSIONS

Imports of Russian roundwood have a major role in fulfilling pulp mills' demand in Southeastern Finland. On this research feasibility of a novel logistics solution to transport this roundwood was studied. The novel logistics solution solution would utilize long train units, a HCT truck, and terminal facilities at the Kouvola RRT. Currently used direct railroad transports relying on short train units were used as a reference point. Costs on a whole supply chain level of these two were first estimated and then compared. In addition to roundwood supply chain, synergy benefits on intermodal container backhauling from pulp mills to RRT for further train transports were studied.

CBA was chosen for the evaluation method. This method is based on DCF calculations, and takes in account both financial cash flows and economic external costs in monetary terms. Profitability of the novel logistics solution was evaluated based on estimated cost savings in comparison to the currently used transportation solution. Analysis period is long and extends to 33 years in the future.

Results indicate that the novel logistics solution has a positive NPV in the base scenario and could thus be considered financially profitable. This is the case with and without the synergy benefits possible to be captured by container backhauling. However, PP of this project is long in both cases. Due to uncertainty in multiple parameters and illiquidity of the terminal investment, this marks for a considerable downside risk. Although the container backhauling synergy benefits do not yield as great savings as the roundwood transports do, they are major of importance in controlling the fore mentioned risk. The key here is that in order to capture these synergies, basically no additional investments are required as long as this possibility is paid attention when investing in a HCT vehicle for it to be capable to transport both roundwood and containers. Utilizing this potential synergy will lead to better values in all investment criteria chosen for this research. Higher NPV, IRR and PI, and shorter DPP and PP.

In contrast to the downside risk, upside potential of the novel logistics solution is high. Would the environment turn more favorable to this solution than expected, it would be remarkably more profitable in terms of NPV, and have a rather short PP considering that majority of the required investment to bring this solution operational are of infrastructure type. An alternative scenario proved that just by servicing two pulp mills instead of one, and raising the volume annually transported roundwood by 200 000 tons would have such effect. According to the sensitivity analysis carried out, results are particularly sensitive to changes in terminal investment cost, wagon cycle times, volume of transported roundwood, and ruble-euro -exchange rate.

On this research only negative external costs of five types due to transportation were considered: congestion, accidents, air pollution, noise, and climate change. These external costs are somewhat higher on the novel logistics solution than on the direct train transports used as a reference point. However, this difference is not remarkable. Combining the financial and external cost comparisons on a CBA, the novel logistics solution still has positive overall NPV on the base scenario, both with and without synergy benefits. Thus the novel logistics solution would seem to be feasible both from financial and wider economical perspectives. Due to the risks connected to this project, and particularly its long PP in the base scenario, an investor must consider carefully whether to make the required investments in terminal infrastructure that enable the novel logistics solution to be brought operational.

8.1.1 Managerial implications

This research provides valuable information to three major interest groups. First, to city of Kouvola decision makers. They are responsible of making the investment decision to construct Kouvola RRT. Although roundwood logistics' importance on this site is minor, results of this research reveal the possibilities Kouvola RRT is able to provide in addition to container logistics.

Second, to pulp mill managers at UPM Kymi and Stora Enso Anjala. Analysis points out remarkable savings potential especially on logistics costs on imported roundwood. Fulfilling the need for roundwood at pulp mills at a lower cost will result in a rise in profits, which is naturally in interest of these companies. On a broader level, pulp mill managers elsewhere in Finland could see these results as an inspiration to launch a study if a similar concept would be able to cut logistics costs on their site.

Third, to logistics operators interested in participating to the novel logistics solution. These are railroad transport service providers, companies specialized in terminal logistics, and road transport service providers. Laying out the concept studied on this research, and the results that it could yield cost savings over the currently used solution, can inspire companies in each of these three categories to consider how they could participate in this alternative mean to structure roundwood and container supply chains.

8.1.2 Limitations

There are four major limitation on this research. First, the analysis is carried out on the whole supply chain level. This was necessary to grasp an understanding on whether the novel logistics solution would provide possibilities for cost savings and if so, how. In practice different parts of the supply chain is likely to be operated by multiple parties. This research does not provide answers on questions such as how to divide risks and benefits between these parties, or how to solve the issue on possible separation of terminal ownership and operations.

Second, location of the RRT is unique. Transportation distances have a major impact on profitability of the novel logistics solution. They are very unlikely to be the same between any other terminal location and other locations of interest. Suitable road and railroad connections to a terminal are also important. In order to accept long train units, a terminal needs to have appropriate facilities. To utilize HCT transports, road connections to a terminal need to meet specific standards.

Third, regulations on road and railroad transportation are often nation specific. This research concentrates in a case in Finland. Possibilities to utilize the novel logistics solution in some other country might be greater or worse depending on local regulations. This is the case especially with HCT and its maximum gross mass.

Fourth, estimations on terminal investment costs is based on a terminal dedicated to roundwood handling and storage. Other freight types might require considerably higher investments on terminal infrastructure. Terminal investment costs is a major determinant on profitability of the novel logistics solution. Therefore studying this concept's potential to capture cost savings on other freight types would require appropriate appraisal on costs to construct suitable terminal infrastructure for them.

8.1.3 Suggestions for further research

Mustola port in Lappeenranta has all the critical features demanded from a terminal facility in order to operate a novel logistics solution through it. As terminal infrastructure already exists and free space is available on its premises, it would actually seem like an optimal location in Southern Karelia to pilot the novel logistics solution in practice. Therefore further research is needed to analyze if this would be profitable. With relatively minor changes the analysis model used on this research can be adjusted to study a novel logistics solution operated through Mustola port.

Another interesting topic for further research is an alternative routing solution for the HCT. In this operating model the HCT could be used to transport containers directly from pulp mill to Kotka port. From there it could backhaul containers to RRT. This would allow fast and flexible container logistics outwards from the pulp mills and inwards to RRT. Similarly to the novel logistics solution studied on this research, this kind of operating model benefits from the synergy potential on combining roundwood and container logistics, and efficient transports in which the HCT is rarely driven empty. As this operating model requires basically the same investments as the novel logistics solution, it's worthwhile to study if it would in fact yield greater cost savings in comparison to currently used transportation methods. Also this topic could be analyzed by adjusting the analysis model constructed to carry out this research.

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APPENDICES

Appendix 1. Timber RRT initial infrastructure investment cost breakdown

INVESTMENT COSTS				
	Unit	**Amount**	**Unit cost**	**Total cost**
RRT COSTS ALLOCATED TO TIMBER TERMINAL				**2 211 000**
Rails	m	1 000	900	900 000
Switches		2	150 000	300 000
Road	m	1 000	650	650 000
Fencing	m	2 000	30	60 000
Buildings		1	100 000	100 000
Planning, supervising & permits	out of all other costs	1	10 %	201 000
TIMBER TERMINAL SPECIFIC COSTS				**2 072 840**
Field, total	m2	33 000	*45*	1 485 000
Field, asphalt	*0 %*	*0*	*70*	*0*
Field, gravel	*100 %*	*33 000*	*45*	*1 485 000*
Transport & protection, land mass		1	100 000	100 000
Ditch	m	200	7	1 400
Sewer, runoff water	m	350	350	122 500
Sewer, waste water	m	350	250	87 500
Water connection	m	350	180	63 000
Electricity connection		1	10 000	10 000
Lights		3	5 000	15 000
Planning, supervising & permits	out of all other costs	1	10 %	188 440
TOTAL COST				**4 283 840**
Years to build				3
Investment cost per building year				**1 427 947**

Appendix 2. Material handler cost breakdown

Vehicle characteristics			
Material handler lifting capacity, MAX		tonnes	6.7
Timber grabbler lifting capacity, MAX		tonnes	7.0
Practical effective lifting capacity, out of MAX	90 %	tonnes	6.0
Timber lifting and handling		out of effective operating time	75 %
Machine moving and safety claw adjustments		out of effective operating time	25 %
Load handling time		min/grabbler load	0.5
Timber handling capacity		**tonnes/h**	**543**
Technical life span / full depreciation time		**years**	**15**
Machine purchasing cost			
Material handler, Atlas 270 MH (2012)		€	90 000
Shipping to Finland		€	2 500
Timber grabbler		€	3 119
Grabbler attachment device		€	4 500
Total, machine ready for use		**€**	**100 119**
Fuel prices and consumption			
Diesel cost		**€/l**	**1.00**
AdBlue cost		**€/l**	**0.35**
Diesel consumption		**l/h**	**18.0**
AdBlue consumption		**l/h**	**0.90**
Salary costs			
Operator breaks, vehicle checks and other tasks		**out of total work time**	**9 %**
Effective operating time		out of total work time	91 %
Driver salary		**€/hour**	**14.15**
Indirect salary costs		**out of total driver salary**	**68 %**
Other costs			
Maintenance and upkeep		€/year	5 000
Insurance		€/year	750
Management		€/year	2 163
Total		**€/year**	**7 913**
NOTE: All prices are VAT 0%			

Appendix 3. HCT cost breakdown

Vehicle characteristics			
Truck	3 axles		
Trailers	4 axles + 5 axles		
Maximum total weight		tonnes	94
Vehicle weight, without freight		tonnes	28
Maximum freight weight		**tonnes**	**66**
Technical life span / full depreciation time		**years**	**15**
Vehicle purchasing cost			
Vehicle (truck, trailers, tires)		€	335 000
Truck tires	10	€	6 000
Trailer tires	36	€	18 000
Vehicle without tires		**€**	**311 000**
Fuel and tire prices			
Diesel		**€/l**	**1.00**
AdBlue		**€/l**	**0.35**
Truck tire		€/tire	600
Trailer tire		€/tire	500
Tire refurnish		€/tire	280
Fuel consumption and tire costs			
Diesel consumption, average		**l/100 km**	**50.5**
Diesel consumption, maximum freight		l/100 km	67.0
Diesel consumption, no freight		l/100 km	34.0
AdBlue consumption, average		**l/100 km**	**2.53**
AdBlue consumption, maximum freight		l/100 km	3.35
AdBlue consumption, no freight		l/100 km	1.70
Tire cost, purchasing and refurnishing		**€/km**	**0.1276**
Tire durability, average		km	130 000
Maximum refurnishment for tires		refurnishing/tire	2
Salary costs			
Driver breaks, vehicle checks and other tasks		**out of total work time**	**9 %**
Effective driving time		out of total work time	91 %
Driver salary		**€/hour**	**14.15**
HCT driving bonus		**€/hour**	**1.00**
Indirect salary costs		**out of total driver salary**	**68 %**
Other costs			
Maintenance		€/year	8 736
Insurance		€/year	11 021
Vehicle tax and other payments to government		€/year	5 376
Management		€/year	6 720
Upkeep		€/year	3 494
Total		**€/year**	**35 347**

Appendix 4. Regular truck cost breakdown

Vehicle characteristics			
Truck	4 axles		
Trailers	5 axles		
Maximum total weight		tonnes	76
Vehicle weight, without freight		tonnes	21.5
Maximum freight weight		**tonnes**	**54.5**
Technical life span / full depreciation time		**years**	**15**
Vehicle purchasing cost			
Vehicle (truck, trailers, tires)		€	275 000
Truck tires	14	€	8 400
Trailer tires	20	€	10 000
Vehicle without tires		**€**	**256 600**
Fuel and tire prices			
Diesel		**€/l**	**1.00**
AdBlue		**€/l**	**0.35**
Truck tire		€/tire	600
Trailer tire		€/tire	500
Tire refurnish		€/tire	280
Fuel consumption and tire costs			
Diesel consumption, average		**l/100 km**	**44.4**
Diesel consumption, maximum freight		l/100 km	58.0
Diesel consumption, no freight		l/100 km	30.8
AdBlue consumption, average		**l/100 km**	**2.22**
AdBlue consumption, maximum freight		l/100 km	2.90
AdBlue consumption, no freight		l/100 km	1.54
Tire cost, purchasing and refurnishing		**€/km**	**0.0960**
Tire durability, average		km	130 000
Maximum refurnishment for tires		refurnishing/tire	2
Salary costs			
Driver breaks, vehicle checks and other tasks		**out of total work time**	**9 %**
Effective driving time		out of total work time	91 %
Driver salary		**€/hour**	**14.15**
Indirect salary costs		**out of total driver salary**	**68 %**
Other costs			
Maintenance		€/year	7 208
Insurance		€/year	9 093
Vehicle tax and other payments to government		€/year	4 436
Management		€/year	5 545
Upkeep		€/year	2 883
Total		**€/year**	**29 164**