Oskari Huttunen

Comparing the economic feasibility of transportation modes

Case Suupohja Railway

School of Technology and
Innovations
Industrial Management
Pro Gradu

Vaasa 2023

UNIVERSITY OF VAASA
School of Technology and Innovations
Author: Oskari Huttunen
Title: Comparing the economic feasibility of transportation modes : Case Suupohja Railway
Examination: Master of Science (Economics and Business Administration)
Subject: Industrial Management
Supervisors: Ville Tuomi, Jyri Naarmala
Year: 2023 **Pages:** 74

ABSTRACT:

This thesis comprehensively analyzes transportation economics, specifically focusing on the transportation corridors of the Suupohja region. The study addresses the problem of determining the required traffic volumes required for the economic feasibility of the Suupohja Railway. Drawing upon methodologies from analogous feasibility studies, the research contributes a unique dimension by incorporating a holistic framework. Key findings include the identification of Activity-Based Cost Models for unimodal road and multimodal rail-road transportation, demonstrating that multimodal transport costs are significantly lower than road transport costs with large volumes. The study pinpoints a break-even point at 880,000 net tonnes per year for the Suupohja region. Practical implications extend to decision-making for public administrations and industry logistics, suggesting a need to reconsider the appreciation framework for transportation infrastructure investments in Finland with a focus on increased sustainability considerations. Finally, the study contributes valuable knowledge to transportation economics literature.

TIIVISTELMÄ:

Tämä opinnäytetyö analysoi kattavasti kuljetusten taloutta, keskittyen erityisesti Suupohjan alueen kuljetuskäytäviin. Tutkimus käsittelee ongelmaa, joka liittyy tarvittavien liikennemäärien määrittämiseen Suupohjan rautatieosuuden taloudellisen kannattavuuden varmistamiseksi. Hyödyntäen vastaavien kannattavuustutkimuksien menetelmiä, tutkimus ottaa huomioon kokonaisvaltaisen viitekehyksen ja tuo siten ainutlaatuisen näkökulman ongelmaan. Keskeisiä löydöksiä ovat toimintolaskentaan perustuvien kustannusmallien tunnistaminen tien rahtiliikenteelle, sekä yhdistetyille rahtikuljetuksille osoittaen, että yhdistetyt kuljetukset ovat merkittävästi edullisempia suurilla liikennemäärillä verrattuna tieliikenteen kustannuksiin. Tutkimus havaitsi kannattavuusrajan olevan Suupohjan alueella 880 000 nettotonnia vuodessa. Tutkimuksen käytännön vaikutukset ulottuvat julkishallinnon ja teollisen logistiikan päätöksentekoon, ehdottaen Suomessa käytössä olevan liikenneväylähankkeiden arviointikehyksen uudelleenarviointia keskittyen etenkin kestävään kehitykseen. Lopuksi, tutkimus tuo arvokasta tietoa kuljetusten taloutta koskevaan kirjallisuuteen.

KEYWORDS: Transportation mode, Transportation corridor, Public investment, Economic feasibility, Life cycle costs, Activity-based costing, Cost model, Cost-benefit analysis

Table of contents

Figures

Tables

1 Introduction

Supply chain efficiency is becoming increasingly important in the globalizing and highly competitive business environment. Logistics are a vital part of any manufacturing company’s processes, and informed decision making is required thorough out the supply chain and product’s life cycle. Moreover, logistics are usually a substantial cost factor (Eliasson, 2012; Izadi et al., 2020; Kordnejad, 2014). Effective logistics management can therefore bring a major competitive edge. However, while companies make their own choices regarding operational logistics, they operate within a framework controlled by external factors (Wiegmans, 2018). Transportation infrastructure (TI) is a part of supply chain which every manufacturing firm requires, yet one they cannot individually implement (Janic, 2007).

1.1 Background and purpose

This study aims to examine the multifaceted nature of transportation economics. This is done through a feasibility comparison of alternative transportation corridors both from the perspective of public investment and the perspective of operational costs in different logistic scenarios. This study presents and answers two main research questions. The first research question (RQ1) will be answered with a literature review, and the second one (RQ2) with a quantitative case study. In order to conduct a feasibility comparison for the case, the relevant framework and factors for such an assessment need to be identified. Only after understanding the framework of transportation decision, it is possible to assess the case. Therefore, RQ1 is:

What factors need to be considered when assessing the feasibility of a transportation mode decision?

In this setting, only rail and road freight are considered. Rail freight typically presents high fixed costs and low operating costs compared to road transportation (Izadi et al., 2020; Kordnejad, 2014; Monios & Bergqvist, 2017; Wiegmans, 2018). The initial capital costs of the railway are higher compared to the road. However, after a certain point in traffic volumes and distance, the operating costs should be considerably lower using railway (Wiegmans, 2018). Thus, the hypothesis is that after a certain point transportation via railway should become economically feasible through total cost savings. Therefore, the second research question (RQ2) for this study is:

How large traffic volumes would be required for the Suupohja Railway for it to become a feasible transportation corridor?

The goal of the research is to produce a cost-benefit analysis that answers the RQ2 (Eliasson & Lundberg, 2012). A comparative life cycle cost calculation will be performed in different traffic scenarios. After this, it should be possible to determine a point in traffic volumes where the railway becomes more feasible through cost savings.

1.2 Description of the case

For this feasibility assessment, the Suupohja railway between Seinäjoki and Kaskinen is selected as a case example. The railway is under the threat of being discontinued as unfeasible, thus making it a useful subject for this kind of assessment (Finnish Transport Infrastructure Agency, 2023). The alternative costs of using truck transportation are examined as well to perform the comparison. The natural alternative to the Suupohja railway is the neighboring main road Kt67, thus it is selected as a comparative case.

The feasibility of the Suupohja Railway has been previously studied (Iikkanen & Lapp, 2017; Iikkanen & Lapp, 2021). However, previously described recent events affecting regional logistics do not appear in previous statements, and the subject has not been comprehensively observed from the perspective of alternative costs resulting from discontinuing the railway. This study will help policymakers and stakeholders make informed decisions by comparing the net economic benefits of different transportation modes.

1.3 Scope and limitations

This study is a case study and is therefore limited to determining the economic feasibility of the specific transportation corridor (Melo et al., 2018). This limits the examination to existing and potential material flows between the Port of Kaskinen and Seinäjoki. The study is also limited to comparing train transportation and trucking as viable transportation methods, excluding other modes of transportation.

The problem will be approached from a life cycle cost-benefit perspective. Detailed examination of possible indirect regional benefits resulting from i.e. industrial investments are beyond the scope of this study, though in real world they should be considered. Political aspects of public investments are also not examined. Furthermore, data can be limited and outdated. Some assumptions are needed regardless, which is the case in most feasibility assessments. This may compromise the validity of the results, so careful approach is needed.

1.4 Methodology

A comprehensive normative analysis was carried out to gain insights into the financial performance of the case example. This research employed decision support and business case development methods to assess the viability of the railway as a transportation corridor. Quantitative information, including vehicle details, traffic statistics and projections, and diverse cost-related data, was sourced from industries, publications issued by relevant transportation authorities and organizations, literature, and other publicly accessible sources. This collected data was then analyzed using spreadsheet tools, enabling the identification of various cost components and the overall cost structure.

2 Literature Review

A literature review was conducted using advanced search in Finna portal, Scopus, and Web of Science using relevant key words. Furthermore, Perplexity.ai, an artificial intelligence tool was used for screening academic literature as well. Perplexity.ai can access scientific databases, such as ScienceDirect, and in this research it was used to provide academic literature related to the subject in question. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication. Multiple searches were conducted with several combinations of keywords. The results were limited to peer reviewed papers from relevant subject areas. Furthermore, only recent papers were used on time sensitive subjects. After this, the relevant literature was identified from the remaining results by the title and the abstract.

2.1 Assessing the feasibility of investments

There are many factors influencing the feasibility assessment of an investment (Boehlje & Ehmke, 2007; IFAC, 2013). These factors span multiple dimensions, encompassing economic, financial, technical, environmental, and social considerations (IFAC, 2013). This study takes a primary focus on economic and financial dimensions. Economic factors involve an analysis of market, demand forecasts, and potential returns on the investment (Boehlje & Ehmke, 2007). Financial considerations refer to funding, the cost of capital, and the expected cash flows over the project's lifecycle (Boehlje & Ehmke, 2007).

2.1.1 Public investments

Public investment typically take several years to complete (Warner, 2014). This extended timeframe necessitates a careful examination of the factors influencing the success and efficiency of such projects. One critical aspect is the allocation of resources, including financial, human, and technological assets (Dabla-Norris et al., 2012). Effective planning and resource distribution are essential to ensure that public investments not only reach completion, but also deliver optimal outcomes. Moreover, the long duration of these projects introduces a dynamic element, as economic, social, and political landscapes may evolve during implementation.

Public investment are often have grand societal impact, and can be effective in resolving major constraints or bottlenecks, if directed in a productive way (Warner, 2014). Transportation infrastructure is typical example of this type of investment. Thus, a comprehensive evaluation framework is indispensable for assessing the impact of such investments on and estimating their overall contribution to societal development and well-being. Furthermore, when assessing the feasibility of a public investment, it is important to distinguish which benefits result from the completed investment directly (Warner, 2014).

2.1.2 Transportation infrastructure investments

Infrastructure investments exhibit seven key characteristics (Wiegmans, 2018). Firstly, these investments possess a long-expected life time, ranging from 20 years to over a century, with a corresponding payback period of 15–30 years. This alone leads to private investors rarely being affiliated with these investments. Secondly, substantial capital is required during construction, leading to immediate costs before revenue realization. Thirdly, a protracted waiting period, influenced by political decision-making, precedes infrastructure construction, subjecting projects to potential changes and cost implications. Fourthly, infrastructure investments are irreversible once initiated, heightening the minimum rate of return threshold. The fifth characteristic is a prolonged construction period lasting two to seven years, with no revenues but accruing interest payments and costs. Sixthly, each infrastructure project's uniqueness affects cost estimates due to limited experience, learning possibilities, and comparability challenges. Finally, the seventh characteristic involves relatively low operational costs, rendering infrastructure investments, including railways, unattractive to private investors who seek satisfactory returns. (Wiegmans and Behdani, 2018, p. 41)

The proper appraisal of TI investments necessitates the identification of cost structures and cost models in sufficient detail (Wiegmans, 2018). One critical aspect is the differentiation between fixed and variable costs, as well as the examination of their development over time (Izadi et al., 2020; Wiegmans, 2018). Additionally, the unique characteristics of each transportation mode, such as maintenance requirements, technological advancements, and regulatory changes, should be considered. The usage of a proper appraisal framework enables stakeholders to make informed decisions regarding the economic feasibility of TI projects.

2.1.3 Cost-benefit analysis

Cost-benefit analysis (CBA) is perhaps one of the most useful methods for assessing investments, especially when multiple investments are compared against each other (Eliasson, 2012). The idea is to determine the feasibility of an investment simply by comparing the resulting economic benefits to the investment cost. It is an intuitive and effective assessment tool generally supported by economists, and has been widely used to rank transport investments for decades (Eliasson, 2012). However, detailed knowledge of both cost factors and potential benefits is needed for a CBA to give a meaningful result.

In Finland, the government is responsible for investments in national and regional infrastructure, and local road networks and local public transport are a municipal responsibility (Torkkeli et al., 2022). These agencies operate with a given budget. Furthermore, there are often multiple investment plans competing for that budget. In such a situation, CBA can indeed be seen as an effective tool to rank these investments by the most socio-economic benefits for a given budget (Eliasson, 2012). In the case of TI, CBA can be used to allocate public funds to the most productive projects. Moreover, Eliasson and Lundberg (2012) found that besides affecting the investment selection process, utilizing CBA in decision making tends to force investments to be designed as more cost effective in the first place. However, due to the nature of public investments, the economic factors of an investment do not always determine the outcome. For example, political factors may result in the selection of an investment which might be less feasible economically.

One widely used form of CBA is the net benefit/ investment cost ratio (NBIR) (Eliasson, 2012). NBIR is defined as the net present value of all benefits (or disadvantages), divided by the investment cost. Besides the investment cost, this approach also considers the future variable costs (maintenance, etc.). Even though transport infrastructure is mainly funded publicly, the operational costs and benefits of infrastructure users (mostly private sector) are affected significantly by the infrastructure (Izadi et al., 2020). Consequently, it is not entirely explicit whether public investments should be appraised by the benefit cost ratio of only public expenses, or should the total socio-economic environment be taken into consideration, and in what quantity (Eliasson, 2012). Both approaches can be justified. In this research, a holistic perspective, considering both public and private expenses, is taken.

Perhaps the most criticized aspect of the CBA is that it might not be able to capture potential benefits which are not directly economic in nature (Eliasson, 2012). The exclusive focus on tangible economic outcomes may neglect the broader impact of a project or policy on the overall well-being of individuals and the community. This limitation in scope raises questions about the comprehensiveness of CBA in fully capturing the multifaceted dimensions of decision-making, especially in cases where qualitative aspects play a significant role in assessing project success and societal welfare. In the case of TI, aspects that are difficult to appraise are reduced delays or congestions, for example. (Eliasson, 2012)

2.1.4 Net present value

Net present value (NPV) is perhaps the most recognized metric for project valuation (Arnold, 2014; Boehlje & Ehmke, 2007; Burton & Sims, 2016; Eliasson, 2012; Grant-Muller et al., 2001; IFAC, 2013; Salling & Banister, 2009). The appeal of NPV lies in its intuitive nature, as it involves comparing the cash outflows (costs) with the cash inflows (benefits) to determine which is greater. Furthermore, the NPV calculation entails discounting all cash flows, including both inflows and outflows (Arnold, 2014). This incorporates the time value of money by considering factors such as inflation. In investment appraisal, NPV is often used in conjunction with CBA to determine the benefit cost ratio (BCR) (Eliasson, 2012; Salling & Banister, 2009).

NPV is a standard approach for the analysis of TI investments as well (Eliasson, 2012; Salling & Banister, 2009). One of the key strengths of NPV lies in its ability to incorporate the time value of money, thereby providing a more realistic assessment of the project's financial viability (Wu & Schonfeld, 2022). This temporal consideration enhances the precision of decision-making in the evaluation of transportation projects, which often involve substantial upfront costs and yield returns over an extended period. This approach allows decision-makers to weigh the long-term economic benefits of a TI investment against the immediate financial commitments, promoting a more informed and strategic evaluation of projects in the context of broader economic objectives.

2.2 Transportation decisions

Selecting the transportation mode and route are key decisions in logistics management and may result in competitive advantage (Meixell & Norbis, 2008). Together these decisions form the transportation corridor (Melo et al., 2018). This decision-making process extends beyond economic considerations, with environmental concerns gaining prominence, and regulations and taxes to encouraging a shift toward more sustainable solutions (SteadieSeifi et al., 2014). Transportation decisions are complex, and managers weigh multiple attributes in their decision-making. Cost and time are often the primary focus, yet other factors also exist, some of which are not as easily quantifiable (Eliasson, 2012; Izadi et al., 2020; Meixell & Norbis, 2008). Importantly, the significance of these factors, and therefore the optimal decision, varies across industries, companies, and even within a company from one facility to another, often requiring a case level examination (Meixell & Norbis, 2008; Tahvanainen & Anttila, 2011; Zgonc et al., 2019).

The increasing prevalence of road freight transport and it's adverse impacts have inspired numerous studies to explore the decision-making process between intermodal and unimodal road transport (Zgonc et al., 2019). However, as is the case with this study, it is worth noting that these studies often focus on specific geographical corridors, limiting their applicability to a broader assessment of the overall competitiveness of intermodal transport. (Zgonc et al., 2019)

2.2.1 Transportation mode

In this research, two distinctive modes of transportation are under examination: unimodal truck transportation, and multimodal rail-road transportation. Unimodal transportation refers to door-to-door transport chain using a single mode of transport (Zgonc et al., 2019). Multimodal freight transportation can be defined as the transportation of goods by a sequence of at least two different modes of transportation (Monios & Bergqvist, 2017; SteadieSeifi et al., 2014). This definition varies slightly from intermodal transportation, which is a particular type of multimodal transportation found often in the literature. Intermodal freight transportation can be defined as a transport chain where the load is transported door-to-door in the same intermodal transportation unit, e.g. a container without handling of the goods themselves when changing modes (Monios & Bergqvist, 2017; SteadieSeifi et al., 2014; Zgonc et al., 2019). In Finland, there is no infrastructure for intermodal transportation as such, therefore multimodal rail-road transportation is a more appropriate term to use in this research. Nevertheless, railway transportation also includes truck transportation in the form of pre- and end-haulage, which often even form a significant portion of the total transportation cost (Tahvanainen & Anttila, 2011).

The primary sectors employing railway freight services in Finland encompass the forest, mining, and metal industries, with the forest industry constituting the most significant clientele (Iikkanen & Lapp, 2021; Tahvanainen & Anttila, 2011). In comparison to truck transportation, the organization of railway transportation is more complex. Until 2007, railway transportation in Finland operated as a state monopoly, and the participation of private operators remains negligible to the present day (Tahvanainen & Anttila, 2011). This arrangement has faced criticism due to elevated costs and suboptimal service, particularly concerning the scarcity of loading stations and suitable terminals. Criticisms extend to the suboptimal condition of infrequently utilized segments of the rail network, resulting in lower maximum loads and speeds. Furthermore, the sparse nature of the railway network constitutes an additional limiting factor. (Tahvanainen & Anttila, 2011)

2.2.2 Transportation route

A transportation chain can be conceptually divided into three segments: the pre-haul (or first mile, pertaining to the pickup process), the long-haul (extending from terminal to terminal), and the end-haul (or last mile, related to the delivery process) (Monios & Bergqvist, 2017; SteadieSeifi et al., 2014; Tahvanainen & Anttila, 2011; Wiegmans, 2018; Zgonc et al., 2019). Typically, pre-haul and end-haul transportation are conducted using road networks, while long-haul transportation allows for considerations of various modes, including road, rail, air, and water. As pointed out, this study considers unimodal truck and multimodal rail-road transportation as viable alternatives in the case of Suupohja.

Distance is often found to be a critical component in routing decisions, however the closest terminal does not always minimize the total cost (Tahvanainen & Anttila, 2011; Zgonc et al., 2019). Still, determining a break-even distance or average cost per distance for multimodal transportation are common approaches in the literature. However, approaching costs through distance dependency can be seen as meaningless when examining the feasibility of an existing corridor with a case study. Since the goods are required to use the corridor to reach their destination anyways, a more appropriate way may be to determine cost dependency on the flow of materials, i.e. traffic volume (Iikkanen & Lapp, 2021; Pettersson & Segerstedt, 2013; Wiegmans, 2018).

2.3 Costs accounting

The field of cost accounting provides organizations with systematic methodologies to evaluate, allocate, and manage costs across various operations (Baykasoğlu & Kaplanoğlu, 2008; Bierer et al., 2015; Korpi & Ala-Risku, 2008; Pirttilä & Hautaniemi, 1995). For both comprehensive and accurate cost estimation, methodologies such as Life Cycle Costing (LCC) and Activity-Based Costing (ABC) are used in this research. By utilizing these frameworks, cost structures for transportation infrastructure and operations are identified, and models created.

2.3.1 Life cycle costing

Life Cycle Costing (LCC) emerges as a crucial cost management method that comprehensively evaluates economic consequences, encompassing costs, revenues, and cash flows throughout an object's life cycle (Bierer et al., 2015; Korpi & Ala-Risku, 2008). This approach plays a pivotal role in informing cost-oriented decisions across various life cycle phases, aiding in cost driver identification, profitability assessment, and comparisons in product and production technology design and strategies (Bierer et al., 2015). It facilitates decision-making in diverse areas such as product and process design, equipment acquisition and replacement, capital allocation, budgeting, and supports investment decisions, particularly when considering the specific end use of the product (Bierer et al., 2015; Korpi & Ala-Risku, 2008). LCC can be deemed more relevant than

Total Cost of Ownership (TCO), which overlooks operations and maintenance costs, and Life Cycle Assessment (LCA), which emphasizes environmental impacts rather than serving as a costing tool (Korpi & Ala-Risku, 2008).

Cost estimation in LCC encompasses three primary methods: (1) engineering procedures, (2) analogy-based estimation, and (3) parametric estimating methods (Korpi & Ala-Risku, 2008). Additionally, more advanced approaches, such as Activity-Based Costing (ABC), have been proposed for LCC, although challenges arise in its adoption for unique investments due to the requirement for extensive activity-cost databases. Considering the future-oriented nature of LCC, accounting for the time-value of money is crucial, necessitating the discounting of future cash flows to present value, particularly in the case of long asset lifespans, such as transport infrastructure (Arnold, 2014; IFAC, 2013; Iikkanen & Lapp, 2021; Korpi & Ala-Risku, 2008; Wu & Schonfeld, 2022). Consequently, this research applies analogy-based and parametric cost estimation methods, as well as ABC and NPV.

The transportation industry is prominently featured in the LCC literature, making LCC applicable to this assessment (Korpi & Ala-Risku, 2008). Notably, transportation cases analyzed in previous studies exhibited a deterministic nature, potentially influenced by the prevalence of public statistics presented as singular figures, masking the true variability of costs (Korpi & Ala-Risku, 2008). This study found that transportation cost data can be difficult to acquire, and is often even deemed as a corporate secret. Yet, for reliability reasons, the reporting of cost information sources is important. Conducting sensitivity analyses is recommended to address uncertainty in life cycle cost assessments, with some methods proposing the use of Monte Carlo simulation for this purpose (Korpi & Ala-Risku, 2008). This study opted for weak market test for validating the results (Lukka, 2003).

2.3.2 Activity-based costing

Activity based costing is a widely used accounting method in the transportation sector (Izadi et al., 2020). ABC allocates costs by tracing them directly to the activities which consume resources, which tends to lead to accurate cost estimation (Baykasoğlu & Kaplanoğlu, 2008; Pirttilä & Hautaniemi, 1995). The cost objects can be other than products; market areas, customer segments, distribution channels, and other factors can also serve as cost objects (Pettersson & Segerstedt, 2013; Pirttilä & Hautaniemi, 1995). It is important to determine the type and scope of cost information to develop a relevant ABC system for the user. Moreover, linking the appropriate activities and their associated cost drivers is crucial. This involves breaking down complex operations into distinct activities and understanding the cause-and-effect relationships between these activities and resource usage. The type and scope of cost information required for an effective ABC system necessitate a thorough analysis of the organization's operations and processes. (Pirttilä & Hautaniemi, 1995)

When executed effectively, ABC can prove highly beneficial for decision makers and transportation companies in accurately assessing the costs associated with their operations (Baykasoğlu & Kaplanoğlu, 2008; Pirttilä & Hautaniemi, 1995). ABC can be utilized in strategy and policy decisions, monitoring and controlling, as well as pricing decisions (Pirttilä & Hautaniemi, 1995). Accurate cost information is essential for achieving reduced costs, influencing pricing strategies, and conducting effective performance assessments across all operations (Baykasoğlu & Kaplanoğlu, 2008). This is also vital for companies in the logistics and transportation sector. In today's challenging business landscape, maintaining satisfactory returns or profits has become increasingly challenging for logistics services. Consequently, the importance of accurate cost estimation for both products and services has risen.

However, one of the primary challenges faced by land transportation companies lies in the accurate determination and evaluation of the true costs incurred in their operations and services (Baykasoğlu & Kaplanoğlu, 2008; Pirttilä & Hautaniemi, 1995). A well-designed ABC system can provide accurate cost information on transportation, but it does not help in assigning transportation costs to any cost objects (Pirttilä & Hautaniemi, 1995). Consequently, there are various challenges in crafting a ABC system for transportation operations (Baykasoğlu & Kaplanoğlu, 2008; Pirttilä & Hautaniemi, 1995). Exceptions to daily operations pose unique challenges, as incorporating them into the ABC model results in model expansion and increased costs (Pirttilä & Hautaniemi, 1995). However, determining the costs of these exceptions is essential, particularly when considering pricing strategies. Furthermore, cost data in logistics is often fragmented or overly generalized, which may lead to inaccurate estimations (Pettersson & Segerstedt, 2013; Pirttilä & Hautaniemi, 1995). For instance, the recording of capacity utilization is not as precise as it is for production capacity (Pirttilä & Hautaniemi, 1995). Similarly to Baykasoğlu and Kaplanoğlu (2008), the first step in this study is to determine the activities and processes in transportation operations in detail.

2.4 Cost models for transportation

This chapter answers the RQ1. In this research, the total costs for freight transportation are comprised of infrastructure costs (IC) and operational transportation costs (OTC) (Figure 1). Both can be further divided into fixed and variable costs (Izadi et al., 2020; Wiegmans, 2018). To determine the total cost accurately requires a detailed examination of all related cost factors. Moreover, costs can be presented as average costs, meaning costs per unit of production (Wiegmans, 2018). In the literature, it is common to define a break-even distance for multimodal transportation (Meixell & Norbis, 2008; Zgonc et al., 2019). However, when assessing an existing transport corridor, rather than reflecting the costs based on distance, which is a usual approach in logistics, this study reflects on the flow of materials (Iikkanen & Lapp, 2021; Pettersson & Segerstedt, 2013; Wiegmans, 2018). Consequently, in this research, average total cost of transportation (ATC) (Formula 1) is presented per transported volume (€/net tonne).

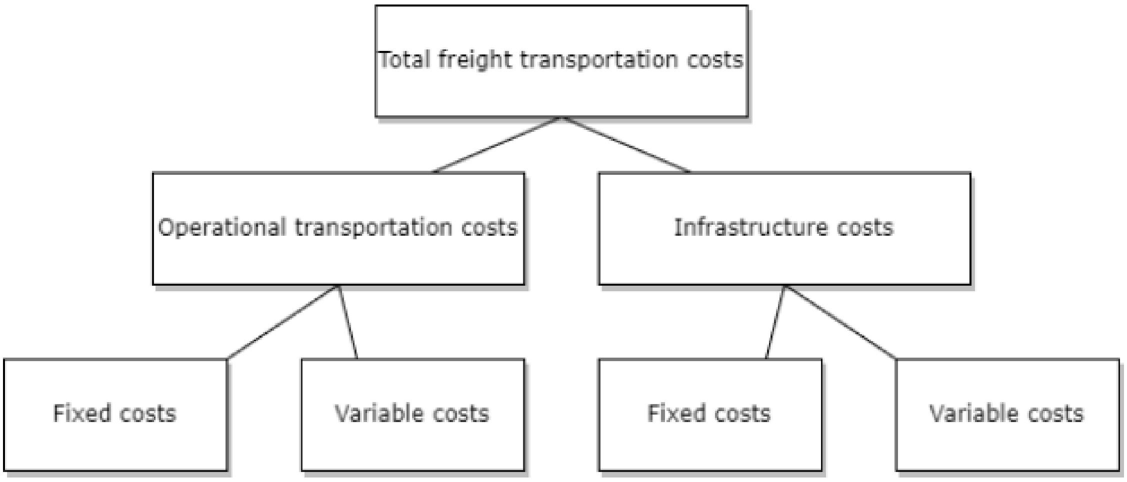


Figure 1. Freight transportation cost structure (adapted from Izadi et al., 2020).

$$ATC = AIC + AOTC \qquad (1)$$

, where ATC is average total cost (€/net tonne), AIC is average infrastructure cost (€/tonne), and AOTC is operational transportation cost (€/tonne

Estimating the break-even volume can be viewed as relevant, since transport cost is a critical factor in mode choice (Izadi et al., 2020; Janic, 2007; Kordnejad, 2014; Wiegmans, 2018; Zgonc et al., 2019). In practice, multimodal transport is viewed as a competitive substitute for unimodal road transport with greater annual volumes than the designated break-even volume. Thus, the break-even volume is specifically defined as the point where the costs of road transport align with those of multimodal rail-road transport (Zgonc et al., 2019).

2.4.1 Cost model for infrastructure

Infrastructure costs can be divided into fixed investment costs (such as planning and construction and interest) and variable costs (such as maintenance, emissions, and accidents) (Figure 2) (Iikkanen & Lapp, 2021; Wiegmans, 2018). The majority of the total costs for TI are often fixed costs, since the capital investments are significant (Wiegmans, 2018).

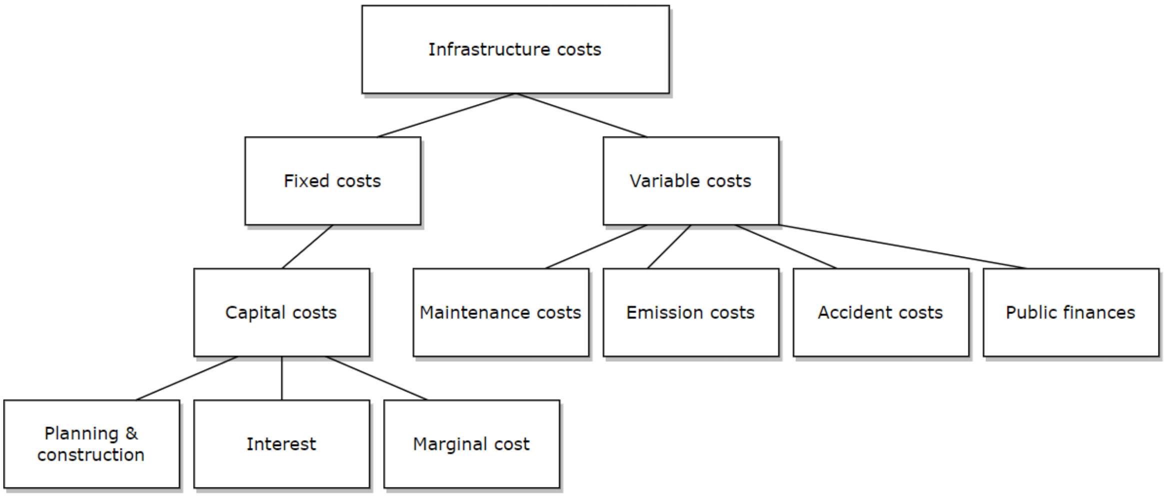


Figure 2. Infrastructure cost structure (adapted from Izadi et al., 2020; Torkkeli et al., 2022).

This research applies an existing appraisal framework for TI projects used in Finland (Torkkeli et al., 2022). This study takes particular focus on the economic factors keeping in line with the goals of the thesis. Thus, the framework is modified accordingly (Figure 3), though other dimensions are considered in the framework as well. The appraisal begins with setting the premise (Torkkeli et al., 2022). In the description of the premise, the needs, content and planning situation of the project, as well as cost estimates are explained. Furthermore, alternative project options are presented and compared, along with forecasts and assessments of the future development of the operating environment to perform a scenario analysis. Finally, the traffic forecast description highlights both the basic growth of traffic and the impact of the project on traffic demand. (Torkkeli et al., 2022)

The economic impacts of the project are directed towards the users of the routes and the investor, i.e., the public economy (Torkkeli et al., 2022). Users of the route include citizens traveling in their own vehicles, providers of transportation services, as well as users of transportation services. Public economy encompasses investment costs, operating and maintenance costs of the routes, as well as changes in tax and fee revenues. Finally, in this study, the impacts of the project are assessed through a feasibility calculation, which is a consistent monetary evaluation of effects carried out in various TI investments. (Torkkeli et al., 2022)

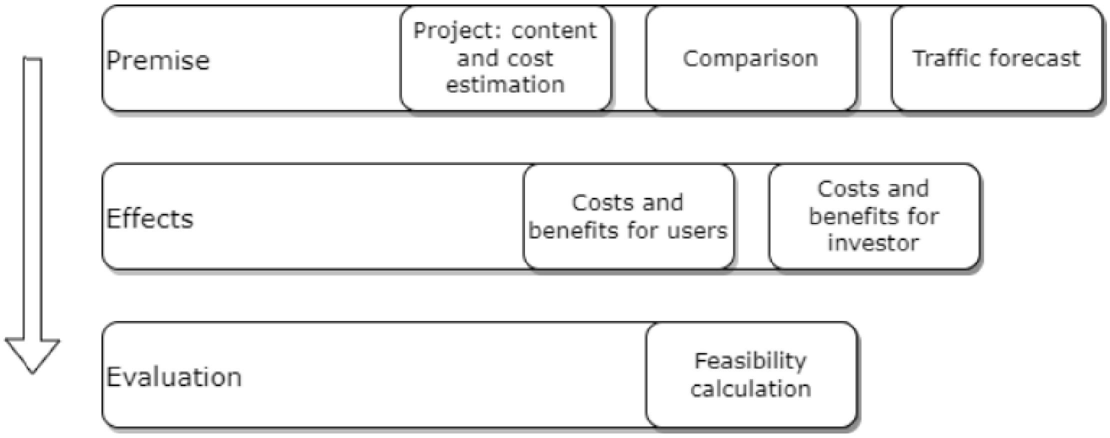


Figure 3. Infrastructure investment appraisal framework (adapted from Torkkeli et al., 2022).

In the case of TI it can be assumed that average fixed costs per unit of production (AFC) decline with the increase in production (transport volume) (Wiegmans, 2018). For simplicity, it can be assumed variable costs increase with volume, and therefore average variable costs (AVC) stay relatively constant (Wiegmans, 2018). Furthermore, revenue consists of taxes and other payments, which are dependent on the traffic volume (Iikkanen & Lapp, 2021). Therefore, the average revenue (AR) can be assumed to be constant. This leads to an average infrastructure cost (AIC) equation (Formula 2) which declines with increasing production, therefore returns to scale (RTS) are expected. The average cost curves of a TI investment are presented in Figure 4. The investment is economically feasible, if the average revenue exceeds the average total costs.

$$AIC = AFC + AVC - AR = (FC + VC - R) * V^{-1} \qquad (2)$$

, where AIC is average infrastructure cost (€/tonne), AFC is average fixed cost (€/tonne), AVC is average variable cost (€/tonne), AR is average revenue (€/tonne), FC is fixed cost (€), VC is variable cost (€), R is revenue (€), and V is transport volume (net tonne)

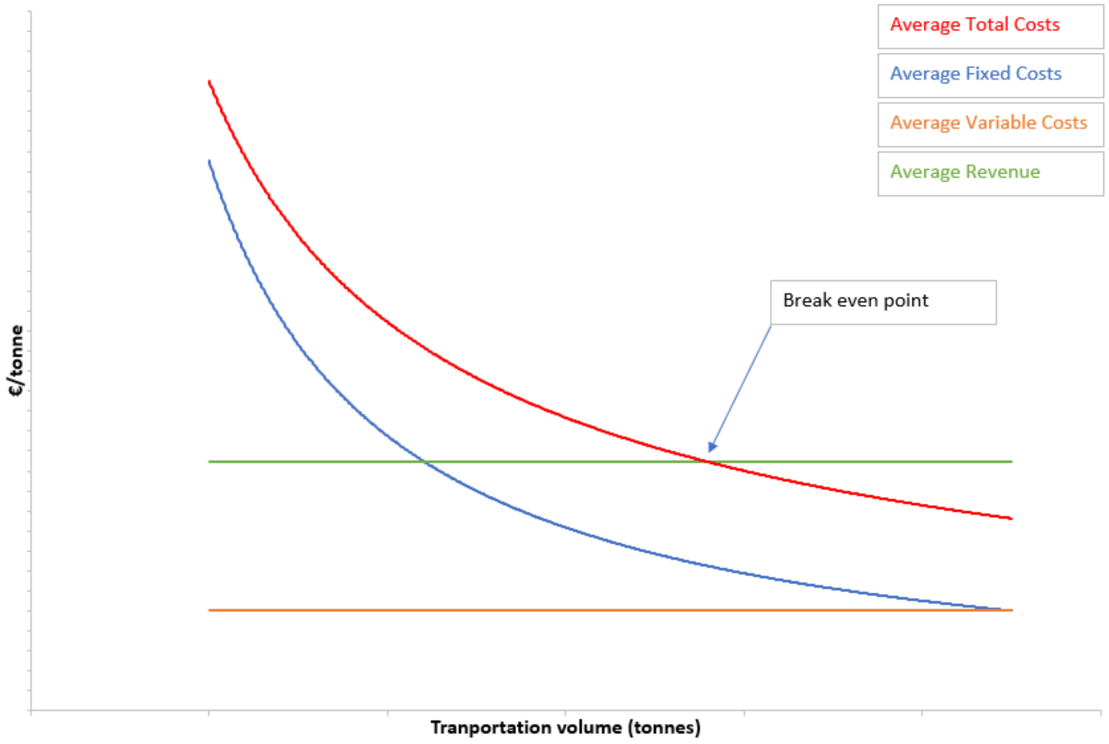


Figure 4. Average cost curves of transportation infrastructure investment (adapted from Wiegmans, 2018).

However, due to the insufficient revenue model the infrastructure is never economically feasible from the investor's point of view (Iikkanen & Lapp, 2021). Nevertheless, the regional industry requires some form of infrastructure to operate. Thus, in this research the feasibility is searched from the cost saving perspective in relation to alternative transportation corridor. This leads to a comparative cost-benefit model presented in Table 1.

Table 1. Infrastructure Cost-Benefit model (adapted from Torkkeli et al., 2022; Iikkanen & Lapp, 2021).

Costs
Investment costs Planning and construction Interest from construction period Marginal cost of public funds
Benefits (or disadvantages)
Infrastructure maintenance Track maintenance Road maintenance
Emission costs Train traffic emissions Road traffic emissions
Accident costs Level crossing accidents Road traffic accidents
Public finances (taxes and fees) Railway Road
Salvage value
NPV

2.4.2 Cost model for operational transportation

Freight transportation cost has emerged as a crucial economic indicator influencing the efficiency of supply chains (Izadi et al., 2020). The classification of freight transport costs can be examined from three distinct perspectives (Izadi et al., 2020; Janic, 2007): (1) from the viewpoint of freight transport operators, these costs encompass the operational costs. (2) From the perspective of freight owners, these costs primarily entail the prices or charges paid to freight transport operators. (3) From a national standpoint, freight transport costs encompass social, environmental, and economic aspects, collectively referred to as external costs. In this research, the OTCs are considered from the freight owner's perspective. The costs are first calculated from the operator's perspective, and then operators margin is added. The external costs are included in the operator's costs. Therefore, this can be deemed as a comprehensive approach.

OTCs can be divided into fixed and variable costs (Figure 5) (Izadi et al., 2020; Wiegmans, 2018). Fixed costs encompass vehicle-related expenses unaffected by usage frequency, such as vehicle price, depreciation, insurance, as well as labor costs (Izadi et al., 2020). Variable costs vary with actual vehicle usage, and include maintenance, energy, and external costs. This type of cost structure is similar in both railway and truck transportation. In this research, railway transportation refers more accurately to multimodal freight transport, which typically encompasses pre-haulage by truck, handling, long haulage via railway, additional handling, and end-haulage stages (Monios & Bergqvist, 2017; SteadieSeifi et al., 2014; Wiegmans, 2018; Zgonc et al., 2019).

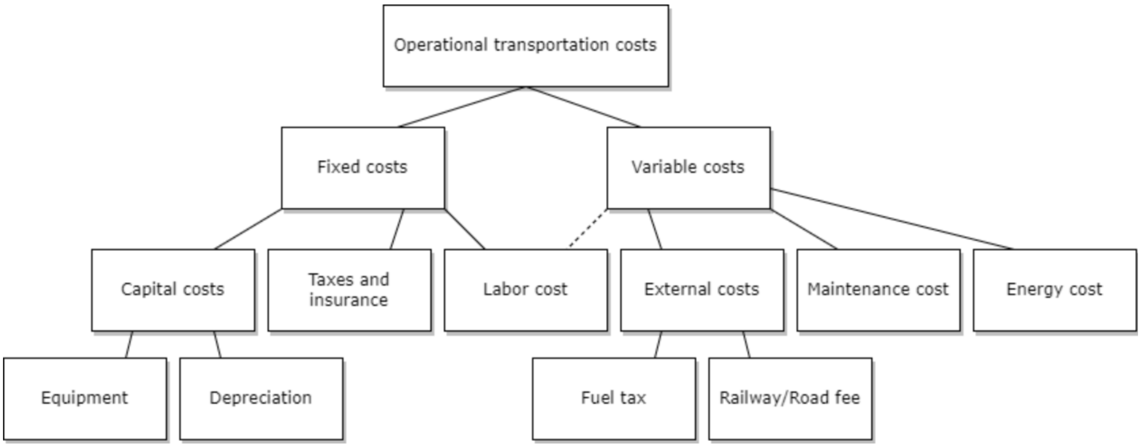


Figure 5. Operational transportation cost structure (adapted from Izadi et al., 2020).

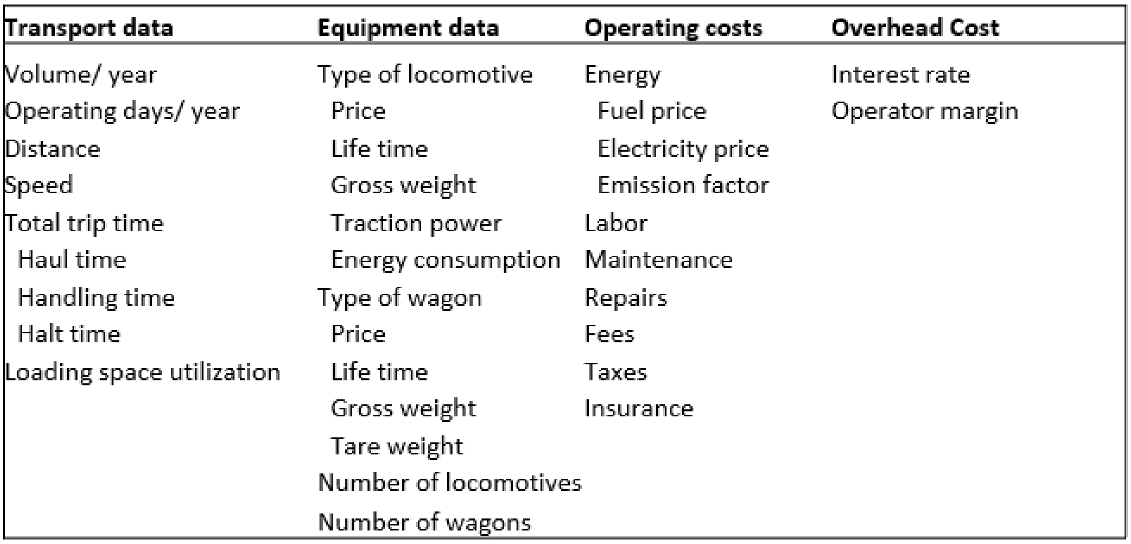
Similarly to TI, the average operational transportation costs (AOTC) is the sum of AFC and AVC for transportation (Formula 3) (Janic, 2007; Wiegmans, 2018). AOTC is calculated from the freight owner's perspective, hence there are no revenues. The feasibility is approached through comparative cost savings. It can be again assumed, that positive RTS exist (Wiegmans, 2018). Furthermore, the cost curve for AOTC is of similar shape to AIC cost curve, i.e. exponentially decreasing function (Janic, 2007; Wiegmans, 2018).

$$AOTC = AFC + AVC = (FC + VC) * V^{-1} \qquad (3)$$

, where AOTC is average operational transportation cost (€/tonne), AFC is average fixed cost (€/tonne), AVC is average variable cost (€/tonne), FC is fixed cost (€), VC is variable cost (€), and V is transport volume (net tonne)

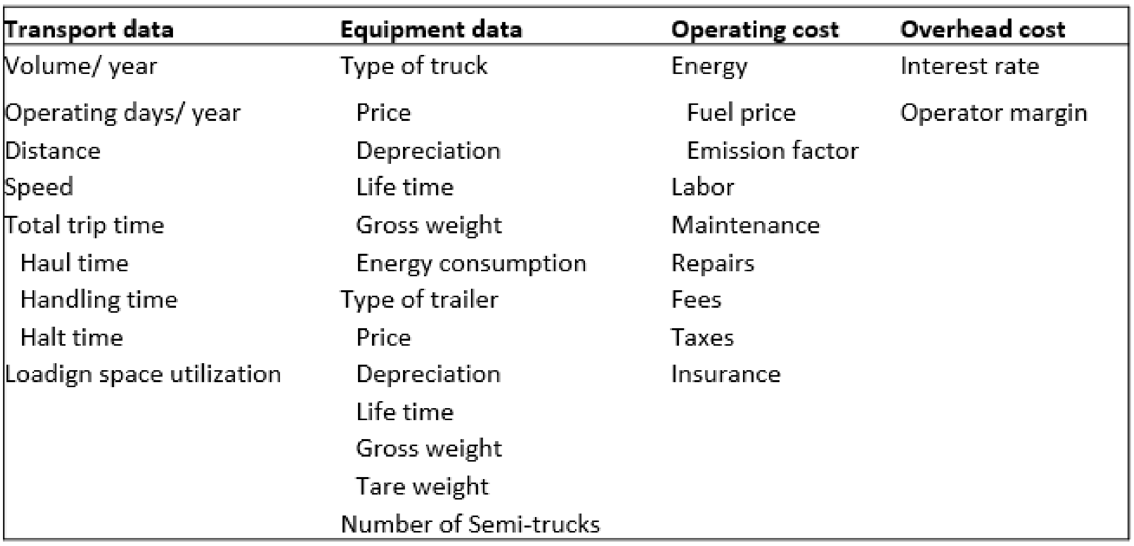
For meaningful freight transportation cost modeling, appropriate level of detail and accuracy in cost data gathering and analysis are imperative (Izadi et al., 2020; Janic, 2007). Thus, ABC was utilized, since it enables the recognition of true cost drivers and accurate cost estimation in the modeling process (Baykasoğlu & Kaplanoğlu, 2008; Izadi et al., 2020; Pirttilä & Hautaniemi, 1995). Findings show that the total operational transport cost in multimodal transport chains is comprised of the overall cost generated by the main rail haulage, as well as pre- and post-haulage, and the total cost for handling (Janic, 2007; Kordnejad, 2014). For road freight, the costs include haulage and handling costs. The activity-based cost models used in this study are presented in Table 2 and Table 3.

Table 2. Activity-based cost model for railway transportation (adapted from Janic, 2007; Kordnejad, 2014; Zgonc et al., 2019)



Transport data	Equipment data	Operating costs	Overhead Cost
Volume/ year	Type of locomotive	Energy	Interest rate
Operating days/ year	Price	Fuel price	Operator margin
Distance	Life time	Electricity price	
Speed	Gross weight	Emission factor	
Total trip time	Traction power	Labor	
Haul time	Energy consumption	Maintenance	
Handling time	Type of wagon	Repairs	
Halt time	Price	Fees	
Loading space utilization	Life time	Taxes	
	Gross weight	Insurance	
	Tare weight		
	Number of locomotives		
	Number of wagons		

Table 3. Activity-based cost model for road transportation (adapted from Janic, 2007; Kordnejad, 2014; Zgonc et al., 2019)



Transport data	**Equipment data**	**Operating cost**	**Overhead cost**
Volume/ year	Type of truck	Energy	Interest rate
Operating days/ year	Price	Fuel price	Operator margin
Distance	Depreciation	Emission factor	
Speed	Life time	Labor	
Total trip time	Gross weight	Maintenance	
Haul time	Energy consumption	Repairs	
Handling time	Type of trailer	Fees	
Halt time	Price	Taxes	
Loadign space utilization	Depreciation	Insurance	
	Life time		
	Gross weight		
	Tare weight		
	Number of Semi-trucks		

3 Methodology

3.1 Research approach

The study aims to examine the multifaceted nature of transportation economics, undertaking a comprehensive feasibility analysis comparing alternative transportation corridors. This examination was conducted considering both the perspective of public investment and the operational costs across various logistic scenarios. The Suupohja railway segment spanning from Seinäjoki to Kaskinen was chosen as a case study. The railway is under the threat of being discontinued, thus making it a useful subject for this kind of assessment (Finnish Transport Infrastructure Agency, 2023). The natural alternative to the Suupohja railway is the neighboring main road Kt67, thus it was selected as a comparative case. Rail freight typically presents high capital costs and low operating costs compared to road transportation (Monios & Bergqvist, 2017; Izadi et al., 2020; Kordnejad, 2014). Thus, the hypothesis was that after a certain point in traffic volumes and distance, transportation via railway should become more economically viable through total cost savings.

3.2 Research design

Firstly, a literature review was performed with relevant key words using databases such as Finna, Scopus, and Web of Science. AI (Perplexity.ai) was also used for screening academic literature. In the empirical part of the study, the Suupohja Railway was selected as a case study, and a comprehensive normative analysis was carried out to gain insights into its financial performance. This research employed decision support and business case development methods to assess the viability of the railway as a transportation corridor.

Quantitative data, such as vehicle specifications, traffic volumes and forecast, and various cost data was used. The data was collected from industries, publications from relevant transport authorities and organizations, literature and other public sources. The collected data was analyzed with spreadsheets and various cost factors and the cost structure were identified. An investment cost model for transportation infrastructure, as proposed by Iikkanen and Lapp (2017; 2021), was employed. Additionally, Activity-Based Costing Models (ABC Models) were constructed for both train and truck transportation. Total costs were calculated across various traffic scenarios, spanning a 30-year timeframe, providing the basis for a comprehensive comparative lifetime feasibility assessment. The economic feasibility was evaluated using a net benefit to investment cost ratio (NBIR) analysis (Eliasson, 2012).

Capital and operational cost calculations were made for both rail and road infrastructure. Furthermore, a cost model for train and truck transportation were created. The total costs were calculated in various scenarios and for a 30-year time period (Iikkanen & Lapp, 2017; Iikkanen & Lapp, 2021). A total of seven traffic scenarios were used, one being the present state. With the collected data, three main future scenarios were developed, each with two sub scenarios (one where the track is renovated and one where it is not). The overall feasibility was assessed with cost-benefit analysis and net present value from both perspectives as wells as using a combined approach. Lastly, total cost functions for this specific case were derived from the results.

3.3 Reliability and validity

The research employed a triangulation approach by collecting data from various sources, fostering a comprehensive and robust dataset. Assumptions and simplifications, inherent in most feasibility studies, were employed to facilitate the analysis. Key constants for calculations were derived from prior studies within the same field, ensuring a contextualized framework. Importantly, the results align with the established theoretical foundation. To validate the findings, a weak market test was conducted, involving both experts and practitioners in the field, leading to the acceptance of the results (Lukka, 2003).

It is noteworthy that the outcomes are specifically applicable to the Suupohja transportation corridor, with only partial generalizability to other contexts. The study deliberately refrained from an exhaustive exploration of potential indirect regional benefits, such as the attraction of industrial investments due to the presence of a railway, as this extends beyond the designated scope of the research. While acknowledging the importance of such considerations in practical applications, their detailed examination falls outside the scope of this study.

4 Findings and Results

4.1 Description of the case

The Suupohja railway between Seinäjoki and Kaskinen was selected as a case for this study. The track is currently in poor condition and scarcely used, and would require a substantial renovation for the traffic to continue (Finnish Transport Infrastructure Agency, 2023). However, the transport volumes, and thus the significance of the railway may increase in the near future due to several factors. These include the planned Metsä Board carton mill in Kaskinen, the realization of the inland material flow potential, as well as factors concerning security of supply (Metsä Board, 2023; Pohjanmaan liitto, 2023). The Port of Kaskinen is the second terminus of the railway, which may bring synergy benefits to the use of the railway from the perspective of foreign trade. At the moment, this potential is not being realized.

In this section of the study, the feasibility of the Suupohja railway and an alternative transportation corridor (Kt67) are compared in different traffic scenarios. Continuing operations on the Suupohja railway requires extensive renovation, estimated to cost €240 million (Finnish Transport Infrastructure Agency, 2023a). This refurbishment includes electrifying the railway, repairing the basic structure, and implementing measures to improve level crossing safety. The improvement would enable operations to continue for 30 years with routine maintenance (Iikkanen & Lapp, 2021). For comparison, this work package also assesses the pavement costs of Kt67 for the same period. Continuous maintenance costs for both transportation routes are also estimated. By comparing these costs in different traffic scenarios, the profitability of the public investment in railway refurbishment can be evaluated from the perspective of alternative costs.

Additionally, the transportation costs have been calculated from the perspective of the freight owner, both for rail and road transport in the specified scenarios. The aim is to assess the potential transportation cost savings enabled by multimodal transport. The calculation uses Metsä Board as an illustrative example, a company planning an investment in a carton mill in Kaskinen (Metsä Board, 2023). If realized, the mill would significantly increase freight traffic in the area. As a result of the Environmental impact assessment procedure, the chosen implementation option would involve approximately 2,2 million tonnes of raw materials directed to the factory, of which about 1,16 million tonnes would be transported by rail. The majority of this consists of raw wood, fitting well into the transportation profile of the Suupohja railway.

The most significant difference compared to previous feasibility assessments is that this modeling considers the costs equivalent to the renovation of the alternative transportation corridor, in this case, the re-pavement costs of Kt67 (Iikkanen & Lapp, 2021). In previous studies, this alternative cost has likely been overlooked, possibly because the road needs to be maintained in the area for other traffic regardless. However, the road carries significant amounts of freight traffic, which substantially affects its wear and tear. Additionally, the share of freight traffic is likely to increase in the future, depending on the scenario. A usable railway would allow the shift of freight traffic to the tracks, significantly reducing road maintenance costs while improving traffic safety and flow.

Additionally, the use of ABC modeling enables accurate cost models. The transportation cost savings identified in this modeling are estimated to be significantly higher than in previous feasibility assessments. One reason for the increased savings is the growth in traffic volumes, especially in scenarios where Metsä Board's carton mill investment in Kaskinen is realized. The mill is in the planning phase, and if realized, the transportation associated with the factory would constitute the largest portion of rail transport.

4.2 Traffic scenarios

The traffic volume scenarios used in the assessment are described in Table 4. In the sub-scenarios a, the railway is renovated and in operation, while in the sub-scenarios b, the railway is discontinued. The traffic volumes are based on publicly available information and the estimates derived from that information (Metsä Board, 2023; Pohjanmaan liitto, 2023).

Table 4. Traffic volume scenarios.

Scenario	**S0**	**S1a**	**S1b**	**S2a**	**S2b**	**S3a**	**S3b**
Vol/a on railway (t)	415 000	1 580 000	0	855 000	0	2 020 000	0
Vol/a on road (t)	2 400 000	3 400 000	4 980 000	2 400 000	2 815 000	3 400 000	4 980 000

S0 represents the current state. The Suupohja railway currently handles approximately 415 000 tonnes of freight per year, consisting almost entirely of raw wood shipments to the Metsä Board BCTMP mill in Kaskinen (145 000 tons) and wood shipments from Teuva to Seinäjoki (270 000 tons) (Metsä Board, 2023). It is estimated that Kt67 currently accommodates around 2,4 million net tons per year. This estimate is based on the traffic volume projections presented in section 4.3.1 and the capacities of the transportation equipment.

S1 describes the scenario where the carton mill in Kaskinen is realized. In the sub-option S1a, in addition to the current transports on the railway, there are 950 000 tonnes of raw wood shipments and 215 000 tonnes of pulp from the Äänekoski factory to the carton mill. On the road, the existing transports continue, along with one million tonnes of various raw materials to the carton mill (Metsä Board, 2023). In the sub-option S1b, the aforementioned rail transports shift to the road.

In S2, the carton mill is not implemented, but the untapped transport potential of the railway is realized. Potential transports that could utilize the Suupohja railway, but currently do not, are estimated in this study to be approximately 440 000 tonnes per year (Pohjanmaan liitto, 2023). This quantity includes 250 000 tonnes of nickel ore, 120 000 tonnes of animal feed, 50 000 tonnes of sawn timber, and 20 000 tonnes of scrap metal. In sub-option S2a, these potential transports, in addition to the current transports, use the railway. In S2b, the existing railway transports shift to the road. The potential material flows have been considered in a way that either they are already included in the current traffic volumes of Kt67, or if they use another transportation corridor entirely, they would not shift to Kt67 due to the closure of the railway.

In option S3, both the carton mill and the untapped potential of the railway are realized. In sub-option S3a, the current transports by rail, the planned transports for the carton mill, and other untapped potential all use the railway. On the road, the existing transports continue, along with the transports for the carton mill. In sub-option S3b, rail transports shift back to the road, excluding various untapped potentials.

4.3 Infrastructure cost model

In this section, the costs of the railway have been assessed from the perspective of public investment, considering both the renovation and annual operating costs. Kt67 is a natural alternative as a transportation corridor for the material flow on the Suupohja railway. The costs associated with the road are of a similar nature, and for comparison, they have also been estimated in this section. The costs attributed to the road are assumed to include only pavement costs, but in reality, other factors related to road improvement, such as the cost of the roadbed or bridge enhancements, are possible. Such costs could significantly increase the overall costs of the road. However, the assessment of these costs has been excluded from this study.

4.3.1 Capital cost

Railway: The Suupohja railway refurbishment has recently undergone two project assessments based on the 2011 action plan (Iikkanen & Lapp, 2017; Iikkanen & Lapp, 2021). The refurbishment includes the following project components: replacement of the track structure (change of support layer and installation of 60 E1 rails on concrete sleepers), frost protection and ground reinforcement work, refurbishment or replacement of bridges and culverts, improvement of track geometry, replacement of track signs, elimination of 73 level crossings with alternative level crossings, and the closure of the Närpiö and Lohiluoma traffic stations. The cost estimates for the extensive refurbishment were 130.2 million euros (2017) and 159.6 million euros (2021) in the project assessments. In both assessments, the refurbishment of the railway was deemed highly unprofitable. (Iikkanen & Lapp, 2017; Iikkanen & Lapp, 2021)

In this study, the cost estimate is, like before, based on the general guidelines of Finnish Transport Infrastructure Agency for the project evaluation of traffic routes (Torkkeli et al., 2022). The investment costs include construction and design costs, interest from construction period, as well as the marginal cost of public funds. According to the latest estimate from the Finnish Transport Infrastructure Agency, the cost estimate for the refurbishment of the railway is currently 240 million euros (Finnish Transport Infrastructure Agency, 2023a). This estimate is not based on the 2011 action plan; instead, a new condition assessment of the railway has been conducted. The new plan includes electrification of the railway. Additionally, some elements, such as the railway bridges, are in worse condition than before, significantly increasing the repair costs.

Table 5 presents the cost estimate for the railway refurbishment in terms of construction and planning costs in this study. The cost structure of the estimate is based, in other respects, on the 2011 improvement plan, but the relative costs of bridges have been increased by 50%. Bridge repairs are typically expensive, and as they are now in worse condition, the adjustment was considered realistic. The refurbishment needs according to the 2011 plan are no longer relevant, but for the sake of simplification, no other changes have been made. The specific prices for the refurbishment components have been estimated based on the MAKU index (2020=100) to correspond to the 2023 price level (Statistics Finland, 2023a). Additionally, this estimate includes electrification of the railway, for which a unit price (approximately €320,000/km) has been estimated using comparable electrification projects. In this estimate, electrification has been added as a separate item for the sake of simplification. Based on the estimate, the construction and design costs amount to approximately €210 million.

Table 5. The cost estimation for planning and construction of the Suupohja railway.

	Cost estimation	
Track section	M€	%
Ground, foundation, and rock structures	30,6	14,5 %
Paving and surface structures	72,7	34,6 %
Safety equipment	2,8	1,3 %
Bridges	14,7	7,0 %
Contractor costs	22,6	10,8 %
Planning	5,3	2,5 %
Construction management tasks	25,3	12,1 %
Electrification	36,2	17,2 %
Sum	210,1	100,0 %

Table 6 shows the total costs for the railway refurbishment, where construction and design costs are supplemented with construction period interest and the marginal cost of public funds (Finnish Transport Infrastructure Agency, 2022). The marginal cost of public funds indicates how much it costs to increase public spending, considering the increase in taxation and efficiency losses. In this study, the marginal cost is 20%. The construction period is estimated to be five years in this research, instead of the four years for previous projects, due to increased workload, including electrification. A 4.25% interest rate has been used for determining construction period interest (Bank of Finland, 2023). With construction and design costs totaling €210.1 million, construction period interest amounts to approximately €28.4 million. The marginal cost of public funds is €47.7 million, resulting in a total project cost estimate of €286 million.

Table 6. The overall cost estimate for railway refurbishment.

Design and construction (M€)	210,1
Years of construction	5
Interest rate	4,25 %
Interest during construction (M€)	28,4
Marginal cost of public funds (M€)	47,7
Total costs (M€)	**286,1**

For the investments, the salvage value can be calculated for the structures which's lifespan exceeds the investment lifetime period (30 years) (Iikkanen & Lapp, 2021). These structures include substructures, bridges, and culverts. The salvage value is 40% of the construction costs, and a discount rate of 3.5% is used. The estimated costs for ground, foundation, rock structures, and bridges are €45.3 million, with project management costs for these estimated at €18.4 million. The salvage value at the end of the calculation period is €30.5 million, which, discounted to 2023, is €10.9 million.

Road: On the main road 67, approximately 7 300 to 12 000 vehicles travel daily, of which heavy freight traffic constitutes about 540 to 830 vehicles, accounting for approximately 7% (2019) (Finnish Transport Infrastructure Agency, 2023b). The traffic volume is expected to increase to 12 000 – 14 000 vehicles per day by the year 2050. The road is considered a heavily trafficked highway and falls into the pavement repair class 1 (PK1), the highest repair class (ELY Centre, 2023a; ELY Centre, 2023b). According to the ELY Centre, the average age of pavement on similar road sections is 5-6 years. For moderately busy highways (PK2), the average age of pavements is approximately 9 years. However, traffic is not evenly distributed across the entire road, so to calculate pavement costs, the average traffic volume for the road has been estimated. According to an estimate made using the Finnish Transport Infrastructure Agency's map service, the current average daily traffic on the entire main road 67 is approximately 4,700 vehicles, with an estimated 340 of them being heavy vehicles (Finnish Transport Infrastructure

Agency, 2023c; Traficom, 2021). In this study, it is estimated that depending on the scenario, the average daily traffic on main road 67 varies between 4,700 and 5,400 vehicles (Table 7), with the number of heavy vehicles ranging from approximately 330 to 660 (Metsä Board, 2023). The traffic volume is assumed to affect pavement wear linearly (Unhola, 2004; ELY Centre, 2023b). In this study, the pavement age is estimated to be 7 years when the daily traffic volume is between 4,700 and 5,100, and 6 years when it is between 5,100 and 5,400. Over a period of 30 years (the rail investment lifespan), the road will be paved 5 or 6 times.

Table 7. Daily traffic on Kt67.

Daily traffic on Kt67						
S0	S1a	S1b	S2a	S2b	S3a	S3b
4 732	5 174	5 352	4 732	4 778	5 174	5 352

Table 8 presents the paving costs for main road 67 over 30 years, depending on the unit cost of paving and the paving interval. The calculation assumes that the entire road section is repaved every 6 to 7 years. The road length is 115 km. Based on the Finnish Transport Infrastructure Agency's regional paving plans for the year 2023, the estimated cost for paving work on a highway is approximately €110 000 to €160 000 per kilometer. Future costs have been discounted to the year 2023. With these background assumptions, paving works are estimated to cost approximately €63 million to €110 million over the 30-year period at the 2023 cost level. In scenarios S0, S2a, and S2b, the paving costs average €77,7 million, while in scenarios S1a, S1b, S3a, and S3b, the average is €93,2 million.

Table 8. Re-pavement costs of Kt67 over the investment lifespan (2023 cost level).

Re-pavement costs of Kt67 over the investment lifespan (2023 cost level)						
Pavement price (1000€/km)	110	120	130	140	150	160
Cost, 7 year interval (S0, S2a, S2b) (M€)	63,3	69	74,8	80,5	86,3	92
Cost, 6 year interval (S1a, S1b, S3a, S3b) (M€)	75,9	82,8	89,7	96,6	103,5	110,4

4.3.2 Maintenance cost

Railway: The infrastructure maintenance costs for the railway consist of upkeep expenses and costs arising from the wear and tear of the track (Iikkanen & Lapp, 2021). For the refurbished track, equipped with concrete sleepers and heavy rails, the unit upkeep cost is €12 540/track km per year. In the current condition, the unit cost for the track is €28 500/track km per year. The unit cost for wear and tear in electric freight transport is €0.16/ton-km. Annual maintenance costs are detailed in Table 9. (Iikkanen & Lapp, 2021)

Table 9. Annual maintenance costs for the railway.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
upkeep/a (€)	3 220 500	1 417 020	0	1 417 020	0	1 417 020	0
wear and tear/a (€)	126 625	639 588	0	299 999	0	812 962	0
sum.	**3 347 125**	**2 056 608**	**0**	**1 717 019**	**0**	**2 229 982**	**0**

Road: In addition to major improvement measures, the road also requires regular maintenance activities to remain operational. These include winter maintenance, renewing road markings, and repairing the pavement. In addition to these upkeep costs, the overall maintenance expenses also cover the costs associated with road wear and tear, similar to the railway. The Finnish Transport Infrastructure Agency monitors the condition of roads and conducts measurements to assess their condition (Finnish Transport Infrastructure Agency, 2023d). The condition rating for National Road 67 is mostly good between Seinäjoki and Kauhajoki, but between Kauhajoki and Kaskinen, the road is in satisfactory or even poor condition in many parts (Finnish Transport Infrastructure Agency, 2023c; Finnish Transport Infrastructure Agency, 2023d). The unit upkeep cost is €2 095/km per year (Finnish Transport Infrastructure Agency, 2023f). For wear and tear costs, €0,12/vehicle-km is used for passenger traffic and €4,99/vehicle-km for heavy traffic (Unhola, 2004; Iikkanen and Lapp, 2021). The road maintenance costs are presented in Table 10.

Table 10. Annual maintenance costs for Kt67.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
upkeep/a (€)	240 925	240 925	240 925	240 925	240 925	240 925	240 925
wear and tear/a (€)	879 334	1 179 027	1 518 721	879 334	953 909	1 179 027	1 518 721
sum.	**1 120 259**	**1 419 952**	**1 759 646**	**1 120 259**	**1 194 834**	**1 419 952**	**1 759 646**

4.3.3 Emission cost

Railway: The emission costs of railway transportation consist of the carbon dioxide equivalent emissions from line haul, as well as pre-haul and end-haul by truck. The emissions were calculated using the Y-HIILARI emission calculator from Finnish Environment Institute (Syke, 2023). The unit cost of carbon dioxide equivalent emissions is €85/tonne (Trading Economics, 2023). Annual emission costs are presented in Table 11.

Table 11. Annual emission costs for the railway.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
Emission costs/a (€)	69 969	102 129	0	83 415	0	121 117	0

Road: The emission costs of unimodal transportation consists of carbon dioxide equivalent emissions from line haul by truck. The emissions were calculated similarly to multimodal transport, using Y-HIILARI to determine the quantity of emissions and the unit price of €85/tonne. Annual emission costs are presented in Table 12.

Table 12. Annual emission costs for Kt67.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
Emission costs/a (€)	1 491 832	2 129 905	2 889 887	1 491 832	1 658 676	2 129 905	2 889 887

4.3.4 Accident cost

Railway: The accident costs of rail transportation consist of the costs of level crossing accidents (Iikkanen & Lapp, 2021). According to the estimate by Iikkanen and Lapp (2021), in Scenario S0, the accident forecast is 1,306 accidents per year. On the refurbished track, it was predicted that there would be 1,036 accidents per year with a transport volume of 450 000 tonnes per year. In this study, accident rates for different scenarios have been estimated by linear scaling to traffic volumes. The unit cost of a level crossing accident is €840 000 (Iikkanen & Lapp, 2021). The total costs are presented in Table 13.

Table 13. Annual level crossing accident costs.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
Accident costs/a (€)	1 098 346	3 529 304	0	1 655 424	0	4 486 001	0

Road: In the assessment of the number of road traffic accidents, a rate of 7,3 accidents per 100 million vehicle kilometers was used (Iikkanen and Lapp, 2021). The unit cost of an accident is €442,000. Annual accident costs are presented in Table 14.

Table 14. Annual road traffic accident costs.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
Accident costs/a (€)	6 145 479	6 719 507	6 939 158	6 145 479	6 193 701	6 719 507	6 939 158

4.3.5 Government finances

Railway: The share of taxes and fees in railway transportation consists of track fees (0,147 cents/tonne-km) and the fuel tax caused by the shunting locomotive (0,28 €/liter) (Finnish Transport Infrastructure Agency, 2023e; Tax Administration, 2023). The electricity used by train traffic is not taxed (Iikkanen and Lapp, 2017). Public revenue is presented in Table 15.

Table 15. Annual public revenue of railway traffic.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
Rev./a (€)	121 021	608 199	0	287 419	0	774 597	0

Road: Public revenues from road traffic consist of fuel taxes for both passenger and heavy-duty vehicles. For heavy-duty vehicles, the fuel tax for diesel oil (0,5948 €/liter) was used, and for passenger vehicles, the average of the fuel taxes for diesel oil and gasoline (0,7596 €/liter) was used, resulting in an average tax of 0,6772 €/liter. Annual tax revenues from road traffic are presented in Table 16.

Table 16. Annual public revenue of road traffic.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
Rev./a (€)	9 855 075	11 698 648	13 358 779	9 855 075	10 219 535	11 698 648	13 358 779

4.4 Transportation costs and volumes

In this study, the calculation of transportation costs is based on ABC. A similar calculation method has been utilized in other research within the field (Izadi et al., 2020; Janic, 2007; Kordnejad, 2014). The model allows for the estimation of OTCs from the freight owner’s perspective. In this study, a 15% profit margin is used as the operator's markup. The model enables the prediction of multimodal transportation costs and traffic volumes if annual transportation needs (net tonnes) are known. Due to the general nature of the cost model, some simplifications and assumptions have been made. The model includes operational costs such as capital, maintenance, energy, and labor costs, as well as external costs (Figure 5).

In the assessment of capital costs for equipment, the acquisition cost and lifespan of the equipment were determined. The used data is based on public information regarding equipment acquisition in Finland. An annuity for the equipment was determined (Formula 4) using a discount rate of 4.25% (Bank of Finland, 2023). Furthermore, a time value (€/min) was determined from the annuity to represent the service-related capital cost (Formula 5) (Pirttilä & Hautaniemi, 1995). The calculation of capital costs assumes that the equipment is purchased new, excluding used equipment and leasing options. Additionally, it is assumed that the operator uses the equipment during other times, rendering no costs to the freight owner under examination during periods of non-use of the transportation service. Salvage value for train equipment was not considered due to insufficient aftermarket conditions.

$$Annuity = (P_f - \frac{(1+ i)^n * i}{(1+ i)^n - 1}) * \frac{V_s}{(1+i)^n} \tag{4}$$

, where P_f is the price of equipment (€), *i* is the interest rate (%), *n* the number of years, and V_s salvage value (€).

$$Capital\ cost = (t_t + t_h + t_l) * V_f \tag{5}$$

, where t_t is travel time (min), t_h is halt time (min), t_l is loading or unloading time (min), and V_f is the time value of the equipment (€/min).

In the model, both transportation modes incur variable maintenance costs, which depend on either distance or operating time (Formula 6). These include, for example, service, repair, and tire costs. Additionally, some of the maintenance-related costs, such as insurance and operating fees, are fixed. The unit prices used are based on the 2022 price level.

$$Maintenance\ costs = s * V_m \tag{6}$$

, where s is distance (km) or time (min) and V_m is unit value for maintenance (€/km or €/min).

Energy costs are based on consumption data dependent on distance and vehicle characteristics (mass and average speed) and average energy consumption data (Formula 7) (Iikkanen, 2013; Nylund, 2006). Energy prices are the average unit prices for the year 2023 (Statistics Finland, 2023b; Statistics Finland, 2023c).

$$Energy\ costs = s * C_e * P_e \tag{7}$$

, where *s* is distance (km) or time (min), C_e is energy consumption (l/min or kWh/km or l/km) and P_e is the price of energy (€/l or €/kWh).

Labor costs are based on the estimate of the average salary provided by Palkkavertailu.com (18.8.2023) (Palkkavertailu, 2023). Using this salary information, employer costs have been calculated with salary calculator from Ilmarinen (Ilmarinen, 2023). Similar to capital costs, labor costs (Formula 8) have a calculated time value, and they are assumed to apply to the freight owner only during the time when the service is used. This makes the labor costs partly a variable cost.

$$Labor\ costs = (t_t + t_s + t_l) * V_s \tag{8}$$

, where t_t is travel time (min), t_h is halt time (min), t_l is loading or unloading time (min), and V_s time value for staff (€/min).

Taxes and fees consist of fuel tax and mode-specific transportation fees (Tax Administration, 2023; Finnish Transport Infrastructure Agency, 2023e). These costs are also unit costs and depend on the mode of transport, energy consumption, transport distance, and traffic volume. Track fee (Formula 9) applies only to rail transport. Fuel tax (Formula 10) applies to rail transport only in the case of shunting work, as electric locomotives are used otherwise.

$$Track\ fee = s * m * V_t \tag{9}$$

, where *s* is distance (km), *m* is the gross mass of the train, and V_t is the unit price of the track fee (€/gross tonne km).

$$Fuel\ tax = s * c * V_d \tag{10}$$

, where s is time (min) or distance (km), c is fuel consumption (l/min or l/km) and V_d is the unit price for fuel tax (€/l).

4.4.1 Transportation costs and traffic volumes for railway

The operational costs of railway transportation were calculated using the ABC model for different scenarios as described above. In the model, it is assumed that train traffic operates in a way that the arriving loaded train returns empty to its departure location. Some wood transports from Teuva travel to Seinäjoki (79 km), and the remaining transports travel from Seinäjoki to Kaskinen (113 km). For Teuva's wood transports, a 50 km pre-haul with an 84-tonne truck combination has been included. Other pre- and end-hauls happen outside the transport corridor of Suupohja, hence they are excluded from this examination. The costs of road transport are detailed in Chapter 4.4.2. Currently, there are few railway transports departing from Kaskinen (Iikkanen and Lapp, 2021). In the model, one ten-minute stop has been calculated for these routes, for example, for overtaking, and at both ends, there is a 15-minute loading/unloading time and a 60-minute shunting time.

In line haulage, a Sr2 electric locomotive with an average speed of 80 km/h was used, allowing one locomotive to pull a train weighing 2000 tons (Iikkanen, 2013). The wagons are loaded to 80% of capacity, which depending on the type of cargo and wagon, leads to a train of approximately 25 to 26 wagons at its longest. Capacity is measured in mass (net tonnes), fitting the product profile (wood and bulk material) of Suupohja railway (Metsä Board, 2023). The capacity of the wagon fleet varies depending on the type of wagon (Table 17). Along with capacity, the tare weight, referring to the weight of an empty wagon, changes with the wagon type. The parallel use of another locomotive would allow for a longer train, but such trains cannot operate on the Suupohja railway. For simplicity in the model, each type of cargo is assumed to have its own transport; mixed transports are not modeled. Depending on the type of cargo, the estimated annual transport volumes are partly so small that they do not form daily transports of reasonable size. Therefore, the transports are organized in a way that the train is always 20 to 26 wagons long, allowing for some types of cargo to be transported every few days. On the other hand, for example, raw wood is transported several times a day in some scenarios.

Table 17. Masses and capacities of different wagon types (VR, 2023).

Equipment	Tare (t)	Max load (t)	80% load (t)
Wood wagon: Snpss, Snps	24,5	65,5	52,4
Pulp wagon: Hain, Hans	25,6	64,4	51,5
Sawn timber wagon: Habbin	30,5	59,5	47,6
Ore wagon: Sgmmn	20,5	69,5	55,6
Feed wagon (common wagon): Gbln	14,6	28	22,4
Scrap wagon: Obrk	24,9	55	44

The estimated purchase price for the Sr2 locomotive is 3,75 million euros, with a projected lifespan of 30 years. No salvage value was assumed, and the discounted rate for annual capital costs was set at 4,25%. This resulted in a calculated value of 0,43 €/min for one locomotive. The diesel locomotive Dr14, used for shunting, was priced at 2,5 million euros, also with a lifespan of 30 years, and a calculated value of 0,28 €/min. The cost for each wagon was set at 100 000 €, with a lifespan of 20 years, and a value of 0,014 €/min. Maintenance costs are 1,04 €/km (Sr2); 0,08 €/km (wagon); and 0,116 €/km (shunting locomotive) (Iikkanen, 2013).

The energy consumption of the Sr2 locomotive in the described operation ranges from 13 to 45 kWh/km, depending on the train's mass (Iikkanen, 2013). The consumption also considers the additional energy use caused by stops. The shunting locomotive's consumption is 26 l/h. The electricity price used is the average for 2023 (for business and corporate customers, annual consumption 70,000 – 150,000 MWh), which is 8,08 cents/kWh (Statistics Finland, 2023d). The average price of sulfur-free diesel fuel without value-added tax in 2023 has been 1,38 €/l (Statistics Finland, 2023e).

Labor costs consist of the employer's total costs calculated using Ilmarinen's salary calculator and time-based unit costs (€/min) allocated to them. The cost was calculated for a locomotive driver (0,59 €/min), a shunting supervisor (0,48 €/min), and one yard worker (0,42 €/min). Data from Palkkavertailu.com was used in the calculation. In the model, it is assumed that labor costs for the freight owner only incur during the time when the service is used.

In the model, the share of taxes and fees for railway transport consists of track fees (0,147 cents/tonne-kilometer) and the fuel tax incurred by the shunting locomotive (0,28 €/l) (Finnish Transport Infrastructure Agency, 2023e; Tax Administration, 2023). The electricity used by train traffic is not taxed (Iikkanen and Lapp, 2017).

Figure 6 and Table 18 show the traffic volumes on the Suupohja railway in different scenarios. The numbers represent round-trips: for example, two trains per day refer to a single train that delivers a cargo to a specific location and then returns empty. In the current state (S0), there is approximately one round-trip of the track per day. The traffic mainly consists of timber transports from Teuva to Seinäjoki or from Seinäjoki to Kaskinen. In scenarios where the track is not renovated, there is naturally no traffic on the track. In scenarios where the track undergoes renovation (S1a, S2a, and S3a), the traffic volumes on the track increase significantly compared to the current state. This study estimates between 4 to 11 round-trips per day, depending on the scenario. Annual traffic volumes are based on 350 transportation days per year.

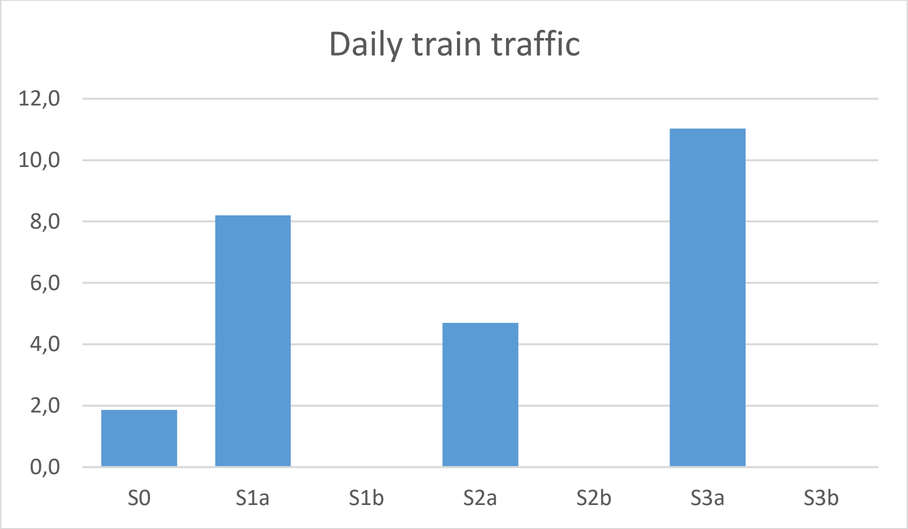


Figure 6. Daily train traffic in different scenarios.

Table 18. Train traffic in different scenarios.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
Trains per day	1,9	8,2	0,0	4,7	0,0	11,0	0,0
Trains per year	653,3	2870,0	0,0	1645,0	0,0	3861,7	0,0

Figure 7 and Table 19 present the OTCs. In the current state, the annual OTCs for the Suupohja railway are estimated to be around 3 million euros. In scenarios where the track is renovated and operations continue, the annual transportation costs are estimated to be approximately 4,4 to 7,3 million euros, depending on the scenario. The pre-haul transport in Teuva's timber transports plays a significant role in the overall costs. The share of rail transportation increases almost proportionally to traffic volumes (average around 1260 – 1340 €/train). However, considering the pre-haul, the cost of multimodal transport ranges from 1900 to 4550 €/train. Teuva's timber transports are the most expensive. Other factors influencing the average train price include the type of cargo and transportation distance, although the impact is minimal. There are no transportation costs incurred for rail transport if the track is not renovated.

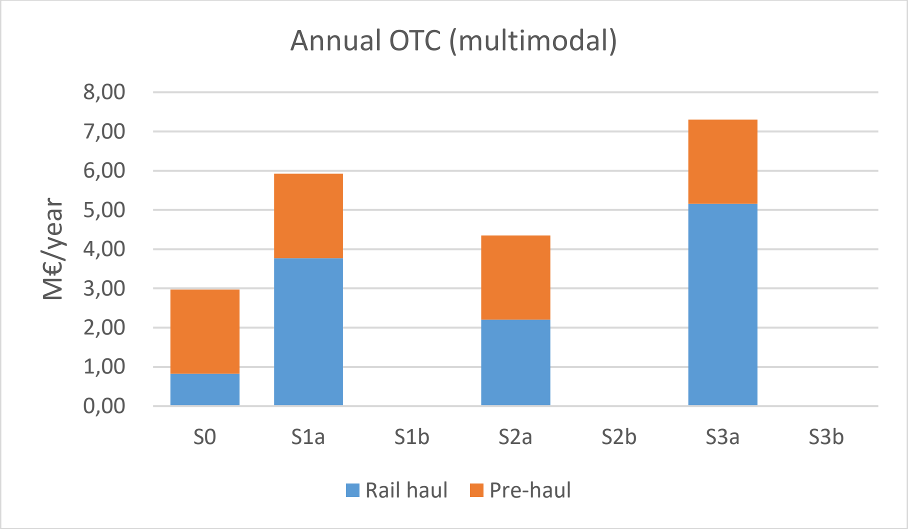


Figure 7. Annual OTCs for multimodal transportation in different scenarios.

Table 19. OTCs in different scenarios.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
€ per day	8 488,13	16 915,48	0,00	12 431,54	0,00	20 858,89	0,00
M€ per year	2,97	5,92	0,00	4,35	0,00	7,30	0,00

4.4.2 Transportation costs and traffic volumes for road

The costs of road transportation were calculated, similar to rail transport, for different scenarios using activity-based costing and considering round-trips. All transports travel between Seinäjoki and Kaskinen, except for Teuva's timber transports. In the model, it is assumed that the truck does not stop during this journey. A loading or unloading time of 30 minutes is assumed at both ends of the route.

Several different combination vehicles can be used in unimodal transportation, and they are usually classified by max gross weight (Table 20) (Pöyskö et al., 2014; Venäläinen & Korpilahti, 2015; Venäläinen & Poikela, 2022). To simplify the model, the average characteristics of these combinations, such as weight, capacity, and fuel consumption, were used in the assessment of traffic and transport volumes. Only a portion of timber transports was designated to use the 84-tonne combination. Each truck is always loaded to 90% of its capacity (by mass) (Pöyskö et al., 2014). Trucks make multiple trips each day in every scenario, so lesser loads were not assumed.

Table 20. Masses of vehicle combinations (Venäläinen & Poikela, 2022).

Combination	44t	60t	64t	68t	76t	84t	Average
Tare (t)	19,0	20,0	20,0	20,5	23,3	24,0	21,1
Load (t)	25,0	40,0	44,0	46,3	52,2	60,5	44,7
90% load (t)	22,5	36,0	39,6	41,6	47,0	54,5	40,2

The estimated purchase price for the truck unit is 200 000 €, and depending on the combination, for the trailer, it ranges from 90 000 to 200 000 € (Venäläinen & Korpilahti, 2015). The truck unit was assigned a lifespan of 7 years, and for the trailers, it was set at 12 years. The salvage value of the equipment was considered with a 20% annual depreciation rate. Similar to the train, an annuity with a 4,25% interest rate was calculated for the vehicle combinations, and from this, a time value (€/min) was derived. The truck unit was assumed to be the same in every combination, a 3-axle truck, with a time value set at 0,054 €/min. The time value for the trailers varies between 0,018 and 0,039 €/min. The vehicle combinations were also assigned running costs, including maintenance, insurance, and repair and maintenance costs, ranging from 0,22 to 0,36 €/km, depending on the combination.

Fuel consumption varies for the vehicle combinations: with load 33–65 l/100 km and unloaded 22–43,3 l/100 km (Nylund, 2006; Anttila, 2015). The price of diesel fuel used is the tax-free average price for 2023; 1,93 €/l (Statistics Finland, 2023e).

Labor costs consist of time-based unit costs (€/min) derived from the total employer costs calculated with Ilmarinen's salary calculator. The cost was calculated for the truck driver at 0,46 €/min. Data from Palkkavertailu.com were used in the calculation. In the model, it is assumed that labor costs are incurred for the freight owner only during the time when the freight owner uses the service.

In the model, the share of external costs of road transport consists of traffic fees (vehicle tax and inspection fees) and fuel tax, depending on the combination. The diesel fuel tax in 2023 is 0.59 €/l (Finnish Tax Administration, 2023).

Figure 8 and Table 21 depict traffic volumes (round-trips) on main road 67 in different scenarios. In the current state (S0), an average of 332 trucks travel the entire route of Kt67 per day. In scenarios where the railway is renovated and the board mill is realized (S1a and S3a), road traffic volumes increase to 474 vehicles, which is a 42% increase compared to the current state. In scenario S2a, traffic volumes remain unchanged. In scenarios where the railway is not renovated, and the carton mill is realized (S1b and S3b), freight traffic on Kt67 nearly doubles. Annual traffic volumes are estimated based on the assumption of 350 transport days per year.

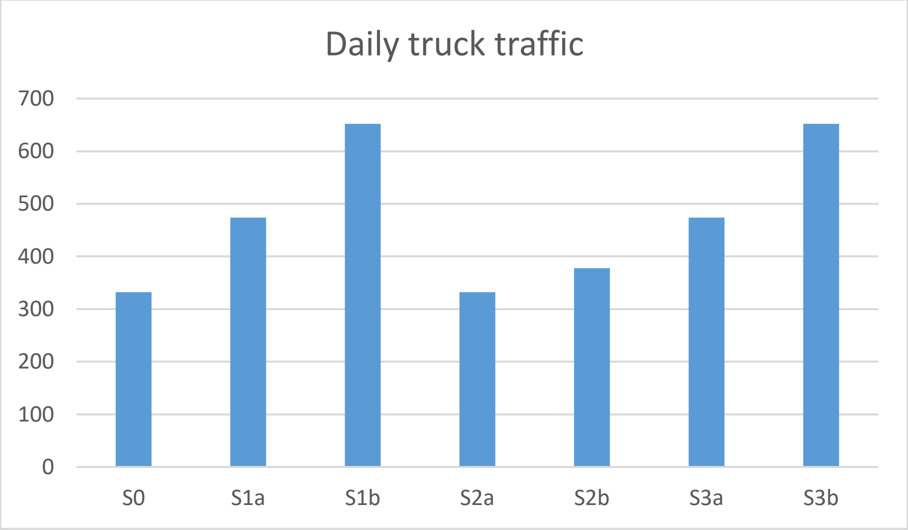


Figure 8. Daily truck traffic in different scenarios.

Table 21. Truck traffic in different scenarios.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
Trucks per day	332	474	652	332	378	474	652
Trucks per year	116 200	165 900	228 200	116 200	132 300	165 900	228 200

Figure 9 and Table 22 show the OTCs for unimodal transportation. In the current state, this model estimates annual transport costs for Kt67 to be approximately 41 million euros. In scenarios where the railway is renovated and the carton mill is realized (S1a and S3a), unimodal transportation costs amount to 58,4 million euros, representing a 42% increase compared to the current state. Transport costs increase almost proportionally to traffic volumes. In scenarios where the railway is not renovated, and the carton mill is realized (S1b and S3b), costs nearly double.

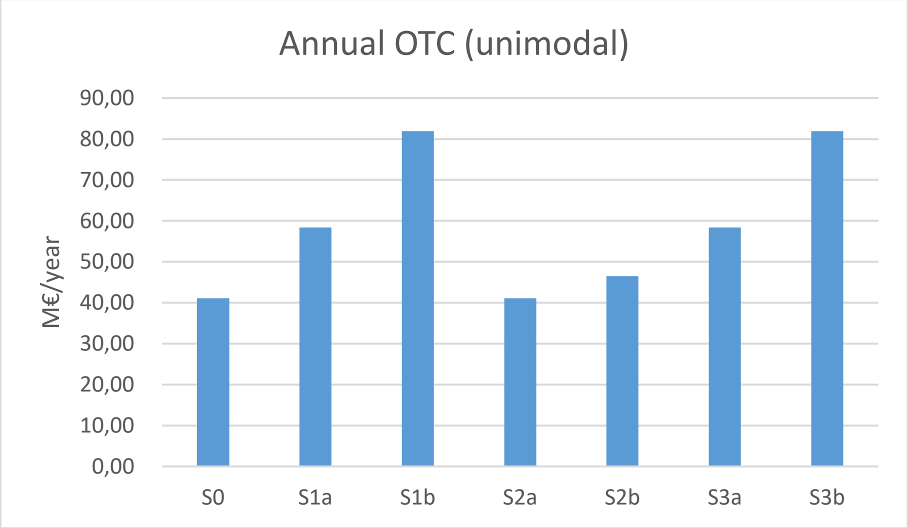


Figure 9. Annual OTCs for unimodal transportation in different scenarios.

Table 22. OTCs for unimodal transportation in different scenarios.

Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
€ per day	117 409	166 804	234 296	117 409	132 979	166 804	234 296
M€ per year	41	58	82	41	47	58	82

4.5 Feasibility assessment

The feasibility of the railway renovation was assessed from the perspective of public investment based on the comparative cost calculations presented in Section 4.3. The resulting economic net benefits (or drawbacks) were estimated over a calculation period of 30 years. A cost-benefit analysis was implemented in different scenarios by subtracting the investment costs from sum of net benefits, resulting in NPV for the investment (Table 23).

The investment costs consist of the renovation of the railway, the paving of the road, as well as the salvage value of the railway. The renovation of the railway constitutes a significantly larger portion of the investment costs in scenarios where the decision is made to repair the track. The model does not consider the possible costs of dismantling the railway. The costs of re-paving the road average 85,4 million euros over a period of 30 years. However, when considering the costs of the road, it is important to consider that the road serves as an essential transportation route for both freight and passenger traffic in the area, and therefore, shutting it down, like the railway, is not an option. On the other hand, the shift of heavy traffic to the rails significantly reduces the wear and tear on the road. Additionally, the costs of road improvement may be considerably higher than estimated in this study, especially if, for example, the roadbed needs to be enhanced with groundwork.

The maintenance costs of the infrastructure comprise the expenses related to the upkeep and wear and tear of both the railway and the road. The ongoing maintenance costs of the railway are inherently higher than those of the road. They constitute the second-largest cost item for the railway.

Emission costs constitute the second largest component of road transportation expenses. The railway's basic improvement plan includes electrification, so electric locomotives are expected to be used in rail traffic. In this case, the emission costs of multimodal transportation mainly arise from emissions resulting from pre and end-haul.

In the model, the highest cost item in infrastructure costs for both unimodal and multimodal transportation arise from accident-related expenses. The improvement plan includes the removal of level crossings and the enhancement of safety devices, which has a decreasing impact on accident rates compared to the current situation. However, as traffic volumes increase, the number of accidents eventually rises. Nevertheless, the costs of level crossing accidents remain lower than those of road traffic accidents in every scenario. In this model, the shift of heavy traffic to the road does not significantly affect the number of accidents, as the accident rate depends on the total vehicle kilometers traveled. However, in reality, it can be assumed that an increase in heavy traffic has a greater impact on accident risk than a similar increase in passenger traffic.

From the perspective of the feasibility of public investment, the railway essentially incurs costs that increase with the length of the transportation route and the volume of traffic (maintenance, wear and tear, accidents, emissions). In the feasibility calculation, the only revenue generated from the TI is the share of taxes and fees. In the case of railway transportation using electricity, tax revenues do not arise because the electricity used by trains is exempt from taxation. Additionally, the income generated from track fees is minimal. On the other hand, the fuel taxes from road transportation generate public revenue that is significantly higher than that from railway transportation. This sets a major bias for the road in cost-benefit perspective.

Table 23. Cost-benefit analysis of the Suupohja transport corridor in different scenarios.

Cost-benefit analysis for IC (M€/30v)							
Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
Investment costs	**77,7**	**368,4**	**93,2**	**352,9**	**77,7**	**368,4**	**93,2**
Track renovation	0,0	286,1	0,0	286,1	0,0	286,1	0,0
Road pavement	77,7	93,2	93,2	77,7	77,7	93,2	93,2
Salvage value	0,0	10,9	0,0	10,9	0,0	10,9	0,0
Net benefits	**-98,9**	**-109,5**	**53,1**	**-62,1**	**35,2**	**-139,0**	**53,1**
Infrastructure maintenance costs	**-134,0**	**-104,3**	**-52,8**	**-85,1**	**-35,8**	**-109,5**	**-52,8**
Track maintenance costs/year	3,3	2,1	0,0	1,7	0,0	2,2	0,0
Road maintenance costs/year	1,1	1,4	1,8	1,1	1,2	1,4	1,8
Emission costs	**-46,9**	**-67,0**	**-86,7**	**-47,3**	**-49,8**	**-67,5**	**-86,7**
Rail transport emissions/year	0,07	0,10	0,00	0,08	0,00	0,12	0,00
Road transport emissions/year	1,5	2,1	2,9	1,5	1,7	2,1	2,9
Accident costs	**-217,3**	**-307,5**	**-208,2**	**-234,0**	**-185,8**	**-336,2**	**-208,2**
Level crossing accidents/year	1,1	3,5	0,0	1,7	0,0	4,5	0,0
Road traffic accidents/year	6,1	6,7	6,9	6,1	6,2	6,7	6,9
Public revenues (taxes and fees)	**299,3**	**369,2**	**400,8**	**304,3**	**306,6**	**374,2**	**400,8**
Rail revenues/year	0,1	0,6	0,0	0,3	0,0	0,8	0,0
Road revenues/year	9,9	11,7	13,4	9,9	10,2	11,7	13,4
NPV of investment	**-176,6**	**-477,9**	**-40,0**	**-415,1**	**-42,5**	**-507,4**	**-40,0**

Evaluating the feasibility of TI investment solely based on the cost-benefit analysis of direct public economic impacts (ICs) may provide an incomplete picture. In this case, compared to multimodal transportation, unimodal transport is inherently a more profitable option for the public economy. With this assessment method, the most profitable railway is one that is as short as possible and has minimal traffic. Therefore, it is justified to criticize the use of such a model for assessing and comparing the feasibility of investments related to TI.

Thus, this study aimed to do a comprehensive analysis on OTCs to gain a holistic picture of freight transportation costs. OTCs were initially separated from the feasibility assessment of the investment because, unlike ICs, OTCs have a more direct link to transportation service users (e.g. businesses) rather than the public economy. However, by taking OTCs into account, a more holistic feasibility assessment for TI can be achieved, with the mindset that the government supports business by improving national infrastructure. Besides the potential OTC savings for business, this support can be justified for example by the growth in business tax revenue and regional economic benefits, such as attracting investments.

Consequently, this study calculated the ICs and OTCs for two distinctive transport modes in potential traffic scenarios over a 30-year calculation period. This allows for a comprehensive comparison of TCs in situations where railway transportation is possible (S1a, S2a, and S3a) against situations where it is not possible (S1b, S2b, S3b). Thus, the possible TC savings enabled by railway transport can be determined. Moreover, by determining the net benefit/ investment cost ratio (NBIR) using TC savings and investment costs, the feasibility of a transportation corridor can be assessed comprehensively. For the investment to be feasible, the savings compared to the alternative should be greater than the investment cost. This study has already established that barely considering the ICs in a CBA yields a negative NPV for the railway investment in every scenario, making it an unfeasible investment. However, it was also established that OTCs for multimodal transportation were significantly lower compared to unimodal transport. Therefore, the possible feasibility comes through savings in OTCs.

Indeed, considering the OTCs during the investment life cycle greatly improves the feasibility of multimodal transportation compared to unimodal transportation. In fact, this study found the comparative TC savings to exceed the railway investment costs in two (S1a and S3a) of the three scenarios presented. The largest TC savings during the calculation period are achieved in scenario S1a (€366,8 million) compared to option S1b, making S1a the most feasible option with a NBIR of 1,33 (above 1 indicates a profitable investment). S3a was found to be feasible with a NBIR of 1,07, presenting lower TC savings compared to S1a due to having similar unimodal volume, but higher multimodal volume. The results are presented in Table 24.

Table 24. Feasibility of the railway investment considering TCs.

NBIR including OTCs (M€/30y)							
Scenario	S0	S1a	S1b	S2a	S2b	S3a	S3b
Net benefits	**-98,9**	**-109,5**	**53,1**	**-62,1**	**35,2**	**-139,0**	**53,1**
OTCs	**1 322,1**	**1 929,3**	**2 458,7**	**1 363,5**	**1 394,6**	**1 970,7**	**2 458,7**
Rail TCs/year	3,0	5,9	0,0	4,4	0,0	7,3	0,0
Road TCs/year	41,1	58,4	82,0	41,1	46,5	58,4	82,0
NPV with OTCs	**-1 421,0**	**-2 038,8**	**-2 405,6**	**-1 425,6**	**-1 359,4**	**-2 109,7**	**-2 405,6**
Comparative saving		*366,8*		*-66,2*		*295,9*	
Rail investment cost	0,0	*275,3*	0,0	*275,3*	0,0	*275,3*	0,0
NBIR		**1,33**		**-0,24**		**1,07**	

Finally, to answer RQ2 explicitly, ATC functions (Formula 11 and Formula 12) for multimodal and unimodal transportation in the Suupohja region were generated based on Formula 1. By comparing the TC of the scenarios to the transport volumes, it is possible to determine the ATC in the Suupohja region (€/net tonne). Using this principle, cost functions were created for the multimodal and unimodal transport respectively. The functions have been defined based on the information presented in this report and are thereby not directly applicable to other similar cases. However, in the case of Suupohja, they can be used to estimate the average costs for freight transportation based on annual volume of transport need.

$$y \approx 157\ 170€ * x^{-0,659} \tag{11}$$

, where y is €/net tonne for multimodal transportation, and x is annual volume in net tonnes

$$a \approx 49{,}772€ * b^{-0,07} \tag{12}$$

, where a is €/net tonne for unimodal transportation, and b is annual volume in net tonnes

The cost curves presented in Figure 10 and Figure 11 were determined using the cost functions. The model estimated that the total costs per net tonne for multimodal transport become lower than road transportation in the Suupohja region when the annual transport volume exceeds approximately 880 000 net tonnes (break-even volume). This is visualized in Figure 12. At the break-even volume, the ATC for multimodal transportation is 19,01 €/tonne, whereas for road transportation, it is 19,09 €/tonne.

In Figure 10, Figure 11 and Figure 12;
AR = average revenue
AFC = average fixed costs
AVC = average variable costs
AOTC = average operational transportation costs
ATC = average total cost

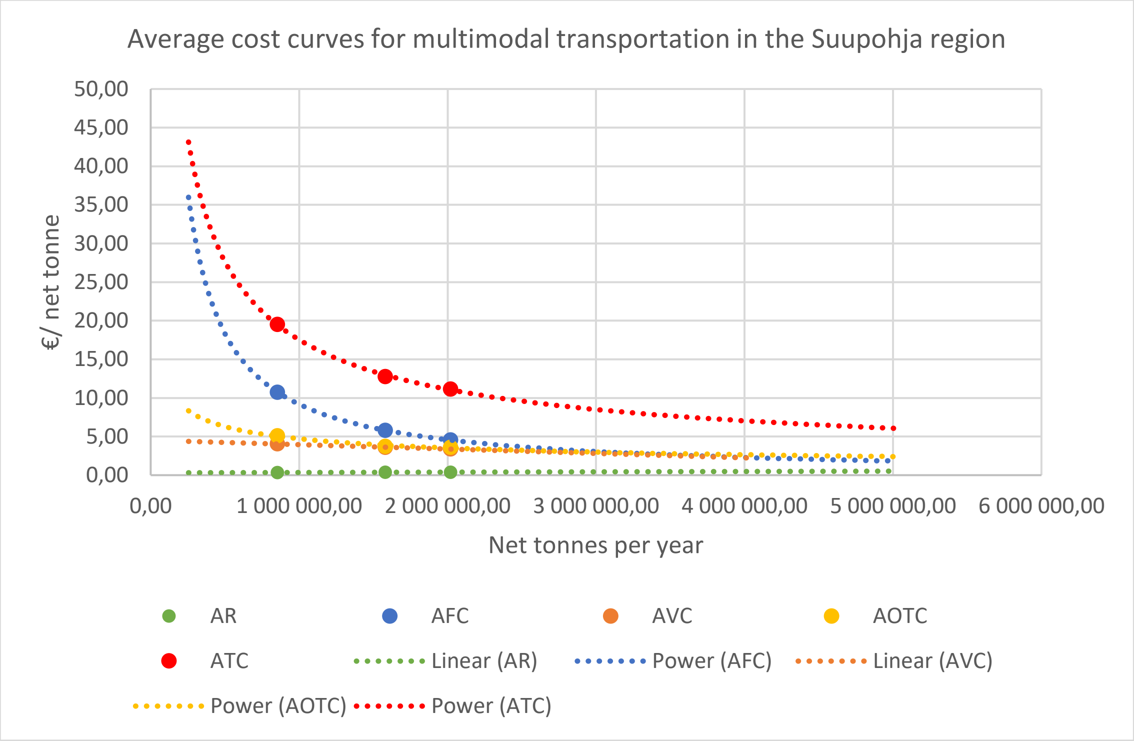


Figure 10. Average cost curves for multimodal transportation in the Suupohja region.

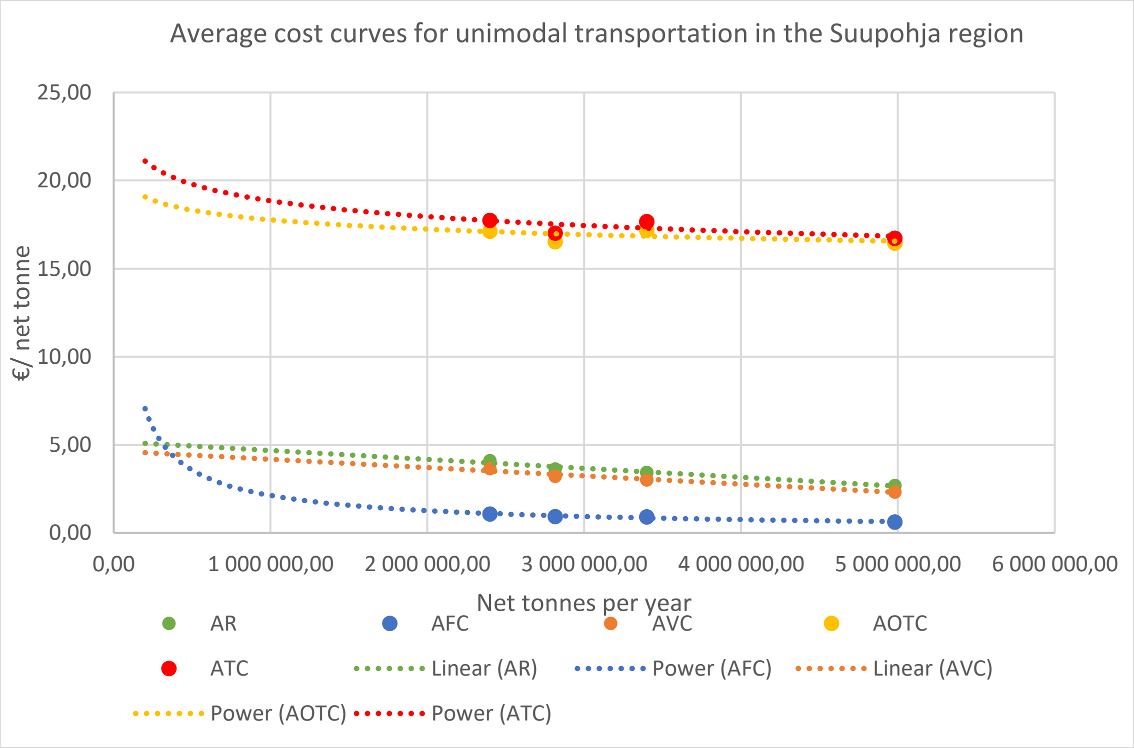


Figure 11. Average cost curves for unimodal transportation in the Suupohja region.

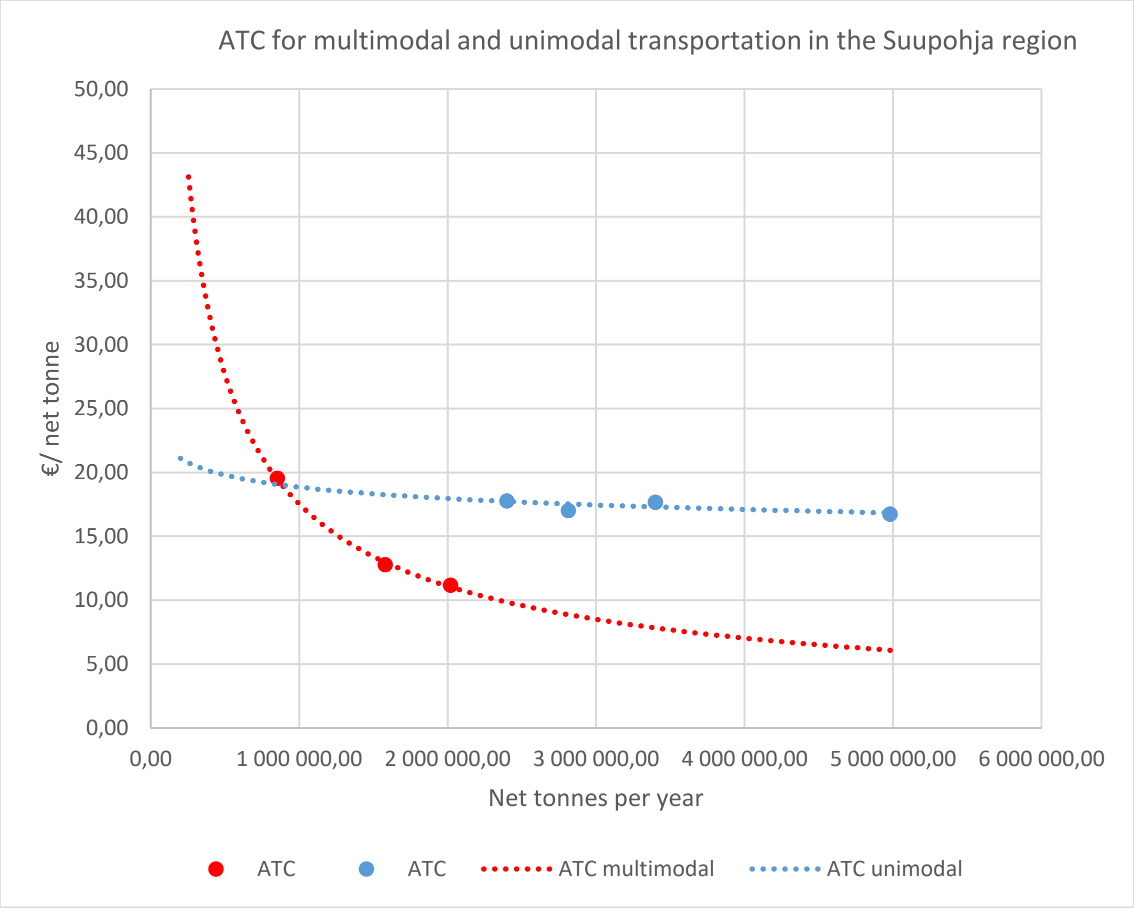


Figure 12. ATC for multimodal and unimodal transportation in the Suupohja region.

5 Conclusion and discussion

5.1 Conclusion

This study aimed to comprehensively analyze the multifaceted realm of transportation economics, comparing alternative transportation corridors. The primary goal was to conduct a robust cost-benefit analysis, evaluating the Suupohja Railway's economic viability, particularly in terms of potential transportation cost savings through multimodal transport. For this analysis, two research questions were answered:

RQ1: *What factors need to be considered when assessing the feasibility of a transportation mode decision?*
RQ2: *How large traffic volumes would be required for the Suupohja Railway for it to become a feasible transportation corridor?*

Addressing the first research question involved a literature review, laying the foundation for exploring the second research question. As an answer to RQ1, the study identified cost structures and activity cost models for transportation infrastructure and operational transportation. Firstly, Figure 1 presents the division of total freight transportation costs to infrastructure costs (IC) and operational transportation costs (OTC). Then, Figure 2 presents the cost structure of ICs, and Figure 5 presents the cost structure of OTCs. Both are further divided into fixed and variable costs. Further addressing RQ1, Table 1 presents the cost-benefit analysis model for infrastructure, and activity based cost models (ABCM) for railway and road transportation are presented in Table 2 and Table 3, respectively. For infrastructure, initial capital costs tend to be high, with variable costs presenting increasing significance over time. The ABCMs for operational transport were found to be fairly similar between modes, with energy costs accounting for the largest portion of OTCs. The Overall, the study sought a holistic understanding of freight transportation costs and factors influencing transportation corridor feasibility.

To answer RQ2, the study utilized scenario analysis to identify a traffic volume threshold where the railway becomes more economically feasible due to comparative cost savings. Furthermore, distinct cost functions were created for Suupohja's road and rail freight to examine operational cost savings. Notably, the research establishes that with large enough volumes, average total costs for multimodal transport are indeed significantly lower than road transport costs, pinpointing a break-even point at 880 000 net tonnes per year in the case of Suupohja. The ICs for multimodal transport are higher, and the savings compared to unimodal transportation are derived from significantly lower OTCs. The scenario analysis revealed varying economic viability, with S1a and S3a demonstrating positive net benefit/ investment cost ratio (1.33 and 1.07, respectively), while S2a yields a negative ratio (-0.24), emphasizing the nuanced economic implications of specific transportation scenarios.

5.2 Discussion

Several limitations should be acknowledged in the context of this study. First, certain assumptions and simplifications were employed during the analysis, a common practice in feasibility studies. Additionally, constant values used in the calculations were derived from previous studies in the same domain, introducing an element of reliance on external data. Moreover, while the results align with the underlying theoretical framework and underwent a preliminary assessment through a weak market test among industry experts and practitioners, the absence of a sensitivity analysis represents a potential limitation in assessing the robustness of the findings. Importantly, it is imperative to recognize that the results hold applicability primarily within the Suupohja transportation corridor, and their generalizability to other contexts may be limited to some extent. Additionally, the scope of this study formed a limitation which excluded the evaluation of broader regional economic advantages; nonetheless, this constraint unveils a prospect for future research endeavors in the domain of such assessments. Specifically, the viability of the rail infrastructure could be approached by examining indicators such as the stimulation of local business expansion and the subsequent augmentation in tax revenue.

This study situates itself within prior research in the field, drawing upon methodologies and findings of analogous feasibility studies. Notably, practices concerning the comparative analysis of costs associated with unimodal and multimodal transportation have achieved a degree of standardization within the scholarly discourse. The adoption ABC as a recommended methodology for precise cost comparison has been reaffirmed in prior works and is consistently applied in this study. Furthermore, the alignment of the results with antecedent research underscores the reliability and validity of the study. Notably, while extant literature frequently addresses the comparative costs of transportation modes, there exists a relative scarcity of studies concerning transportation infrastructure costs, highlighting a distinctive facet of this research. Finally, the study's distinctive contribution lies in its holistic framework, which encompasses a comprehensive evaluation of various dimensions, thereby contributing in the examination of transportation infrastructure viability.

This research contributes to transportation literature, as well as practical implementation. As a practical implication, this research provides a comprehensive analysis for assessing the feasibility of the Suupohja railway and transportation infrastructure investments in general. Furthermore, this research contributes to holistic understanding of the current and future transportation landscape in the Suupohja region. Importantly, the utilization of a long-term perspective in assessing feasibility further enhances the robustness of the analytical framework. Finally, it gives a holistic perspective for assessing transport infrastructure and operational transportation cost for unimodal truck and multimodal rail-road haulage by conducting a multi variable analysis. Therefore, it contributes to the decision-making process concerning logistics of both public administrations and industry.

Based on the findings of this research, it is suggested to rethink the appreciation framework for transportation infrastructure investments in Finland. Even though road and rail are often compared as inland transportation modes, the appreciation of investments between the two modes differ. This is especially evident in freight transportation. In the case of Suupohja, the railway would be used solely for freight transportation, whereas Kt67 is an important passenger way as well. This sort of setup sets a road bias, since it can be deemed as indispensable. Furthermore, from the investor’s perspective, the revenue from transportation corridors consists mainly of energy taxes. Railway fees are insignificant, and similar fees do not exist for road use in Finland. Fuel taxes from road transportation form a significant source of revenue, whereas the electricity used in train transportation is not taxed. This again, sets a bias for the road. Due to the insufficient revenue model the infrastructure is never economically feasible from the investor’s point of view. Nevertheless, the regional industry requires some form of infrastructure to operate. Additionally, in the current NBIR model, the weight of sustainability is relatively insignificant. Consequently, it is recommended future research should consider how to further incorporate sustainability into the appreciation framework.

References

Anttila, N. (2015). Yrityksen kalustovertailu. Retrieved 19.9.2023 from https://www.theseus.fi/bitstream/handle/10024/90276/Anttila_Niklas.pdf?sequence=1

Arnold, T. (2014). How Net Present Value Is Implemented. In T. Arnold (Ed.), A Pragmatic Guide to Real Options (pp. 1–13). Palgrave Macmillan US. https://doi.org/10.1057/9781137391162_1

Bank of Finland. (2023). Korot. Retrieved 5.9.2023 from https://www.suomenpankki.fi/fi/Tilastot/korot/

Baykasoğlu, A., & Kaplanoğlu, V. (2008). Application of activity-based costing to a land transportation company: A case study. International Journal of Production Economics, 116(2), 308–324. https://doi.org/10.1016/j.ijpe.2008.08.049

Bierer, A., Götze, U., Meynerts, L., & Sygulla, R. (2015). Integrating life cycle costing and life cycle assessment using extended material flow cost accounting. Journal of Cleaner Production, 108, 1289–1301. https://doi.org/10.1016/j.jclepro.2014.08.036

Boehlje, M., & Ehmke, C. (2007). Capital Investment Analysis and Project Assessment. Purdue University. Retrieved 12.11.2023 from https://www.extension.purdue.edu/extmedia/ec/ec-731.pdf

Burton, M., & Sims, C. (2016). Understanding Railroad Investment Behaviors, Regulatory Processes, and Related Implications for Efficient Industry Oversight. Review of Industrial Organization, 49(2), 263–288. https://doi.org/10.1007/s11151-016-9519-y

Dabla-Norris, E., Brumby, J., Kyobe, A., Mills, Z., & Papageorgiou, C. (2012). Investing in public investment: An index of public investment efficiency. Journal of Economic Growth, 17(3), 235–266. https://doi.org/10.1007/s10887-012-9078-5

Eliasson, J. (2012). Do Cost-Benefit Analyses Influence Transport Investment Decisions? Experiences from the Swedish Transport Investment Plan 2010-21. Transport Reviews, 32(1), 29. https://doi.org/10.1080/01441647.2011.582541

ELY-keskus. (2023a). Päällysteet. Retrieved 4.9.2023 from https://www.tienpidonsuunnitelma.fi/yhteistyolla-turvallista-ja-sujuvaa-liikennetta/tieverkon-kunnossapito/paallysteet/#:~:text=P%C3%A4%C3%A4llysteiden%20ik%C3%A4%20on%20alueella%20keskim%C3%A4%C3%A4rin%20kuusi%20vuotta%20vilkkailla,vilkkaan%20tien%20p%C3%A4%C3%A4llysteen%20tulisi%20kest%C3%A4%C3%A4%20keskim%C3%A4%C3%A4rin%2023%20vuotta.

ELY-keskus. (2023b). Päällysteiden korjaus. Retrieved 4.9.2023 from https://www.ely-keskus.fi/keski-suomi-paallysteiden-korjaus

Finnish Transport Infrastructure Agency. (2022). Vesiväylähankkeiden arviointiohje. Retrieved 5.9.2023 from https://ava.vaylapilvi.fi/ava/Julkaisut/Vaylavirasto/vo_2020-38_vesivaylahankkeiden_arviointiohje_web.pdf

Finnish Transport Infrastructure Agency. (2023a). Heikkokuntoinen Suupohjan rata ei kestä liikennöintiä. Retrieved 4.9.2023 from https://vayla.fi/-/heikkokuntoinen-suupohjan-rata-ei-kesta-liikennointia

Finnish Transport Infrastructure Agency. (2023b). Kt67 Ilmajoki-Seinäjoki. Retrieved 4.9.2023 from https://vayla.fi/documents/25230764/35412234/TIE+Kt+67+Ilmajoki+-+Sein%C3%A4joki.pdf/fc2c4121-6a49-464c-a472-279bf22bf43d/TIE+Kt+67+Ilmajoki+-+Sein%C3%A4joki.pdf?t=1686035823734

Finnish Transport Infrastructure Agency. (2023c). Suomen väylät. Retrieved 5.9.2023 from https://suomenvaylat.vayla.fi/theme/1/432350/7120403/11/

Finnish Transport Infrastructure Agency. (2023d). Tien kunnon arviointi. Retrieved 11.9.2023 from https://vayla.fi/kunnossapito/tieverkon-kunnossapito/tien-kunnon-arviointi

Finnish Transport Infrastructure Agency. (2023e). Ratamaksu. Retrieved 11.9.2023 from https://vayla.fi/palveluntuottajat/ammattiliikenne-raiteilla/rataverkon-kaytto/ratamaksu

Finnish Transport Infrastructure Agency. (2023f). Maanteiden hoidon kilpailuttamisen tuloksia 2023. [Powerpoint] Retrieved 18.9.2023 from https://vayla.fi/palveluntuottajat/hankinnat/tieurakat

Grant-Muller, S. M., MacKie, P., Nellthorp, J., & Pearman, A. (2001). Economic appraisal of European transport projects: The state-of-the-art revisited. Transport Reviews, 21(2), 237–261. https://doi.org/10.1080/01441640151098097

IFAC. (2013). Project and Investment Appraisal for Sustainable Value Creation | IFAC. Retrieved 10.11.2023 from https://www.ifac.org/knowledge-gateway/preparing-future-ready-professionals/publications/project-and-investment-appraisal-sustainable-value-creation

Iikkanen, P. (2013). Rautatieliikenteen kustannusmallit. Liikenneviraston tutkimuksia ja selvityksiä 15/2013. Retrieved 22.8.2023 from https://www.doria.fi/bitstream/handle/10024/121463/lts_2013-15_978-952-255-283-9.pdf?sequence=1&isAllowed=y

Iikkanen, P., & Lapp, T. (2017). Seinäjoki–Kaskinen-radan perusparannuksen ja tehostetun kunnossapidon jatkamisen hankearviointi. Retrieved 7.9.2023 from https://www.doria.fi/bitstream/handle/10024/133650/ls_2017-02_978-952-317-363-7.pdf?sequence=2&isAllowed=y

Iikkanen, P., & Lapp, T. (2021). *Seinäjoki-Kaskinen-radan peruskorjaus*. Retrieved 7.9.2023 from https://www.doria.fi/bitstream/handle/10024/182864/vj_2021-75_978-952-317-926-4.pdf?sequence=1&isAllowed=y

Ilmarinen. (2023). Palkkalaskuri. Retrieved 18.8.2023 from https://www.ilmarinen.fi/tyonantaja/tyonantajan-laskurit/palkkalaskuri/

Izadi, A., Nabipour, M., & Titidezh, O. (2020). Cost Models and Cost Factors of Road Freight Transportation: A Literature Review and Model Structure. *Fuzzy Information and Engineering*, *0*(0), 1–21. https://doi.org/10.1080/16168658.2019.1688956

Janic, M. (2007). Modelling the full costs of an intermodal and road freight transport network. *Transportation Research Part D: Transport and Environment*, *12*(1), 33–44. https://doi.org/10.1016/j.trd.2006.10.004

Kordnejad, B. (2014). Intermodal Transport Cost Model and Intermodal Distribution in Urban Freight. *Procedia - Social and Behavioral Sciences*, *125*, 358–372. https://doi.org/10.1016/j.sbspro.2014.01.1480

Korpi, E., & Ala‐Risku, T. (2008). Life cycle costing: A review of published case studies. Managerial Auditing Journal, 23(3), 240‐261. https://doi.org/10.1108/02686900810857703

Lukka, K. (2003). The Constructive Research Approach. In Case Study Research in Logistics (pp. 83–101)

Meixell, M., & Norbis, M. (2008). A Review of the Transportation Mode Choice and Carrier Selection Literature. International Journal of Logistics Management, The, 19, 183–211. https://doi.org/10.1108/09574090810895951

Melo, I. C., Junior, P. N. A., Perico, A. E., Guzman, M. G. S., & Rebelatto, D. A. do N. (2018). Benchmarking freight transportation corridors and routes with data envelopment analysis (DEA). Benchmarking: An International Journal, 25(2), 713–742. https://doi.org/10.1108/BIJ-11-2016-0175

Metsä Board. (2023). Ympäristövaikutusten arviointiselostus. Retrieved 5.9.2023 from https://www.ymparisto.fi/sites/default/files/documents/Mets%C3%A4%20Board%20Oyj%20Kaskisten%20kartonkitehdas%20YVA-selostus%2022.5.2023.pdf

Monios, J. & Berqvist, R. (2017). Intermodal Freight Transport & Logistics. CRC Press. ISBN: 978-1-4987-8512-9. https://doi.org/10.1201/9781315177762

Nylund, N. (2006). Raskaan ajoneuvokaluston energiankäytön tehostaminen ”HDEnergian”: Yhteenvetoraportti 2003-2005. VTT. Retrieved 23.8.2023 from http://www.motiva.fi/files/1026/HDEnergia_yhteenvetoraportti_lopullinen_viim.pdf

Palkkavertailu. (2023). Haku. Retrieved 18.8.2023 from https://palkkavertailu.com/

Pettersson, A. I., & Segerstedt, A. (2013). Measuring supply chain cost. International Journal of Production Economics, 143(2), 357–363. https://doi.org/10.1016/j.ijpe.2012.03.012

Pirttilä, T., & Hautaniemi, P. (1995). Activity-based costing and distribution logistics management. International Journal of Production Economics, 41(1), 327–333. https://doi.org/10.1016/0925-5273(94)00085-9

Pohjanmaan liitto. (2023). Suupohjan radalle kuljetuksia 2 miljoonaa tonnia vuodessa. Retrieved 5.9.2023 from https://www.obotnia.fi/fi/pohjanmaan-maakunta/ajankohtaista-liitosta/aktuellt-fran-forbundet-fi-fi/suupohjan-radalle-kuljetuksia-2-miljoonaa-tonnia-vuodessa

Pöyskö, T., Sirkiä, A. & Lapp, T. (2014). ELY-keskus. Raskaan liikenteen uudet enimmäismitat ja -massat: Toimenpideselvitys Uudenmaan ELY-keskuksen alueella. Retrieved 18.9.2023 from https://www.doria.fi/bitstream/handle/10024/97265/Raportteja_25_2014.pdf?sequence=2

Salling, K. B., & Banister, D. (2009). Assessment of large transport infrastructure projects: The CBA-DK model. Transportation Research Part A: Policy and Practice, 43(9), 800–813. https://doi.org/10.1016/j.tra.2009.08.001

Statistics Finland. (2023a). Maarakennusalan kustannukset nousivat vuoden 2023 kesäkuussa 0,8 % vuodentakaisesta. Retrieved 4.9.2023 from https://www.stat.fi/julkaisu/cl8lfpcq4nnl30dukgkqnet9q

Statistics Finland. (2023b). Sähkön hinta kuluttajatyypeittäin, 2008M01-2023M04. Retrieved 11.9.2023 from https://pxdata.stat.fi/PxWeb/pxweb/fi/StatFin/StatFin__ehi/statfin_ehi_pxt_13rb.px/

Statistics Finland. (2023c). Polttonesteiden kuluttajahinnat (sisältää alv:n), 1988M01-2023M05. Retrieved 11.9.2023 from https://pxdata.stat.fi/PxWeb/pxweb/fi/StatFin/StatFin__ehi/statfin_ehi_pxt_12ge.px/

Statistics Finland. (2023d). Sähkön hinta kuluttajatyypeittäin, 2008M01-2023M07. Retrieved 12.9.2023 from https://pxdata.stat.fi/PxWeb/pxweb/fi/StatFin/StatFin__ehi/statfin_ehi_pxt_13rb.px/table/tableViewLayout1/

Statistics Finland. (2023e). Polttonesteiden kuluttajahinnat (sisältää alv:n), 1988M01-2023M07. Retrieved 12.9.2023 from https://pxdata.stat.fi/PxWeb/pxweb/fi/StatFin/StatFin__ehi/statfin_ehi_pxt_12ge.px/

SteadieSeifi, M., Dellaert, N. P., Nuijten, W., Van Woensel, T., & Raoufi, R. (2014). Multimodal freight transportation planning: A literature review. European Journal of Operational Research, 233(1), 1–15. https://doi.org/10.1016/j.ejor.2013.06.055

Syke. (2023). Y-HIILARI Hiilijalanjälki -työkalu. Retrieved 15.9.2023 from https://www.syke.fi/fi-FI/Tutkimus__kehittaminen/Kiertotalous/Laskurit/YHiilari

Tahvanainen, T., & Anttila, P. (2011). Supply chain cost analysis of long-distance transportation of energy wood in Finland. Biomass and Bioenergy, 35(8), 3360–3375. https://doi.org/10.1016/j.biombioe.2010.11.014

Tax administration. (2023). Nestemäisten polttoaineiden verotaulukot. Retrieved 11.9.2023 from https://www.vero.fi/yritykset-ja-yhteisot/verot-ja-maksut/valmisteverotus/nestemaiset-polttoaineet/verotaulukot/

Torkkeli, M., Joutsensaari, J., Nummelin, M., Toivola, J., & Antikainen, T. (2022). Liikenneväylien hankearvioinnin yleisohje. Retrieved 7.9.2023 from https://ava.vaylapilvi.fi/ava/Julkaisut/Vaylavirasto/vo_2020-36_liikennevaylien_hankearvioinnin_web.pdf

Trading Economics. (2023). EU Carbon Permits. Retrieved 19.9.2023 from https://tradingeconomics.com/commodity/carbon

Traficom. (2021). Liikenne ja liikenne-ennuste maanteillä. Retrieved 7.9.2023 from https://tieto.traficom.fi/fi/tilastot/liikenne-ja-liikenne-ennuste-maanteilla

Traficom. (2023). Maailmanpoliittisen tilanteen vaikutuksia liikennejärjestelmään. https://tieto.traficom.fi/fi/tilastot/maailmanpoliittisen-tilanteen-vaikutuksia-liikennejarjestelmaan

Unhola, T. (2004). Liikenne- ja viestintäministeriö. Nastarenkaiden kuluttavuus: Ajoneuvotekijöiden vaikutus, Yliajokoe 2004. Retrieved 17.9.2023 from https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/78599/1_Julkaisuja_72_2004.pdf?sequence=1&isAllowed=y

Venäläinen, P. & Korpilahti, A. (2015). Työ- ja elinkeinoministeriö. HCT -ajoneuvoyhdistelmien vaikutus puutavarakuljetusten tehostamisessa. Retrieved 19.9.2023 from https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/75029/TEMjul_30_2015_web_23042015.pdf?sequence=1&isAllowed=y

Venäläinen, P. & Poikela, A. (2022). Metsäteho. Puutavara- ja hakeajoneuvojen massojen noston vaikutukset. Retrieved 19.9.2023 from https://www.metsateho.fi/wp-content/uploads/Raportti-265-Puutavara-ja-hakeajoneuvojen-massojen-noston-vaikutukset.pdf

VR. (2023). Kalusto. Retrieved 12.9.2023 from https://www.vrtranspoint.fi/fi/vr-transpoint/asiakkaan-opas/kalusto/

Warner, A. M. (2014). Public Investment as an Engine of Growth. International Monetary Fund. Working paper WP/14/148. Retrieved 12.11.2023 from https://www.imf.org/external/pubs/ft/wp/2014/wp14148.pdf

Wiegmans, B. (2018). A review and analysis of the investment in, and cost structure of, intermodal rail terminals. Transport Reviews, 38(1), 33–51. https://doi.org/10.1080/01441647.2017.1297867

Wu, F., & Schonfeld, P. (2022). Optimized two-directional phased development of a rail transit line. Transportation Research Part B: Methodological, 155, 424–447. https://doi.org/10.1016/j.trb.2021.12.007

Zgonc, B., Tekavčič, M., & Jakšič, M. (2019). The impact of distance on mode choice in freight transport. European Transport Research Review, 11(1), 10. https://doi.org/10.1186/s12544-019-0346-8