A common Nordic-Baltic costing framework for road, rail and sea transport of roundwood

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SAMMENDRAG/SUMMARY:

Transport cost calculations are fundamental for most types of transport research. Applications can range from estimating the cost benefits of developing transport technologies (e.g. increased truck GVWs) to comparing profitability between alternative infrastructure investments (e.g. rail or sea terminals). Most stakeholders rely on a favourite spreadsheet, however these vary considerably with respect to functionality, resolution and transparency.

During 2019 and 2020 the NB Nord Road and Transport group has worked towards a common Nordic-Baltic costing framework for road, rail and sea transport. The goal has been to propose a general model per transport method which is user-friendly, while retaining the necessary resolution and functionality to model actual costs for specific transport orders or contracts. The handbook provides: a) complete explanation of its formulas, b) calculation examples and c) a corresponding Excel spreadsheet.

The models were validated through national comparisons of market prices and calculated costs for a selection of transport orders. Sensitivity analysis is supported by the accompanying spreadsheets. The truck costing model accepts up to three transport environments with specified driving speeds and diesel consumptions. It also includes a function for estimating profitability levels where transport tariffs and driving distance distributions are available. The rail model is created for systems with up to three terminals with specified cycle element times. It includes links to national network statements for rail hire and traction current costs. The shipping model is relatively simple given the use of time-charter (TC) day rates for varying vessel capacities. It includes links to international sources for bunker costs.

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NB NORD publication for more efficient timber transport

NB NORD, the Nordic-Baltic Network for Operations Research and Development, is a CAR funded by SNS Nordic Forest Research. It is dedicated to developing economically, environmentally, and socially sustainable forest operations in the Nordic-Baltic area.

Roads and transportation constitute an important area of forest operations. Secondary transportation, roads, and terminals timber account for an increasing proportion of wood costs at mill gate. As for many applied sciences, a lack of common standards and tools for evaluation and comparison represents an obstacle to development.

For transport research in the timber industry NB NORD hopes to remedy the obstacle of common standards through the publication of this joint Nordic-Baltic framework for transport costing models. The models can be used to identify technological bottlenecks, compare available alternatives or support decisions on the most appropriate investments for future transport systems for road, rail and sea transport. This transparent framework enables straightforward comparisons and use of data from the whole Nordic-Baltic region.

The NB NORD handbook presents and explains the formulas used, provides tutorial examples, and is coupled with free corresponding spreadsheets. It is the result of a joint effort by the NB NORD Road and Transport Group, coordinated by Pirjo Venäläinen of Metsäteho, and consisting of transport researchers from all member institutes including: Dag Fjeld, Nibio, Kari Väätäinen, Luke, Henrik von Hofsten and Daniel Noreland, Skogforsk, Ingeborg Callesen, IGN KU and Andis Lazdins, Silava.

I am proud to announce A common Nordic-Baltic costing framework for road, rail and sea transport of roundwood! You may also download the transport costing spreadsheets from the following link: http://urn.fi/URN:NBN:fi-fe2021011511893.

Uppsala in January 2021

Rolf Björheden, Skogforsk
NB NORD Coordinator

Contents

1 Introduction

For bulk commodities such as roundwood, transport costs play a key role for competitiveness. For the forest sector, structural development towards fewer and larger mills drives increasing transport distances, annual transport output and transport capacity requirements. Research and development to mitigate the corresponding cost growth requires good cost modelling to estimate the effects of new development opportunities. As the proportion of multimodal transport increases with mill consumption, so must the toolbox of cost models.

A variety of spreadsheet-based costing models have been developed by service providers and buyers. These are typically specialized for regional or national assumptions, and therefore lack the transparency needed for comparison between countries. After an initial workshop in 2018 (Venäläinen & Fjeld 2018) the NB Nord Road and Transport group (coordinator Pirjo Venäläinen) started work on developing a common Nordic-Baltic costing framework for road, rail and sea transport of roundwood. The group consisted of researchers working in the fields of logistics and wood procurement at both research institutes and universities. Beyond principles for harmonizing transport costing, the discusssions have also facilitated a common understanding of the Nordic and Baltic transport systems and conditions. This report presents the current framework as a base for further development.

The objective of the work was to propose general costing frameworks for the respective transport methods. Chapters 2, 3 and 4 present the respective models for truck, rail and shipping. Because all roundwood starts its journey by truck, most of the effort has been directed towards road transport (Ch 2; editor Kari Väätäinen) and this framework has the highest resolution. In contrast to many machine costing models which treat value depreciation as a fixed annual cost, the timber trucking model treats depreciation as a variable cost following the assumed wear of the main components (truck, trailer, loader) over their repective lifetimes , either in terms of distance driven or loads handled. As work progressed towards multimodal solutions (Ch 3, 4; editor Dag Fjeld), model resolution was reduced while still reflecting the relevant principles. Both road and rail frameworks model average resource costs over their assumed lifetimes, without the use of discounting associated with investment analysis. The modelling of resource costs are even simpler for the shipping model, where charter rates provide representative capacity costs for the respective markets.

Key parameters for all frameworks include the operating environment and cost driving factors for the respective transport system. Validation of the respective models was done underways by comparison of calculated costs against current market prices for specific cases (Väätäinen & Fjeld 2020). As deviations were found, the models were re-evaluated and modified to better reflect the specified conditions. Each chapter concludes with a sensitivity analysis to indicate which variables are most critical with respect to indata quality. Each chapter also provides sources and examples for input data. The report concludes with an appendix of the corresponding spreadsheet models, which can be accessed at http://urn.fi/URN:NBN:fi-fe202101151893.

The respective models can be used to predict both the cost of a single delivery, as well as the progression of costs with increasing distances to yield cost functions . In both cases, the effects of key factors such as payloads, transport distances, cycle times or fuel prices can be used to project future cost development scenarios.

2 Costing framework for truck transport

In general, the timber trucking costing model follows classical transport cost assessments for truck-trailer combinations. The model is aimed at calculating the annual operating costs of timber trucking. In addition, the model can be used for calculating performance indicators of timber trucking such as annual working hours, loads, transported tons of timber, driven distance etc. The user has an opportunity to define trucking conditions (e.g. distances, payload, road conditions, speeds, fuel consumptions and time duration of work elements) in order to compare alternative operating scenarios and their effects on costs. The model considers load and road dependent values both for fuel consumption and driving speed as well as the proportion of back-haulage. As an output, key performance indicators for costing include costs per metric ton, per km, per ton-kilometer, per load, per hour and per year. The transport distance distribution option enables evaluation of timber trucking cost in more detail.

The cost accounting model for timber trucking includes two types of annual accounting:

A. Cost accounting with the average transport distance (traditional accounting model)

B. Cost accounting with a distribution of transport distances

The timber truck combination in the NB Nord area typically consists of a truck, full trailer and a self-loader, each defining separate investment prices (Figure 1). The payload (timber) is defined in metric tons, which is the the most common pricing unit for the entrepreneur. The average load size for the calculated period (usually a year) is required. Payload capacity can be calculated by deducting the tare weight from the gross vehicle weight. However, the average payload is generally smaller than capacity due to varying timber dimensions and fresh weight densities. Snow and ice buildup during wintertime also reduces the available load. Moreover, having the self-loader on-board also reduces the payload (3 to 4 tons).

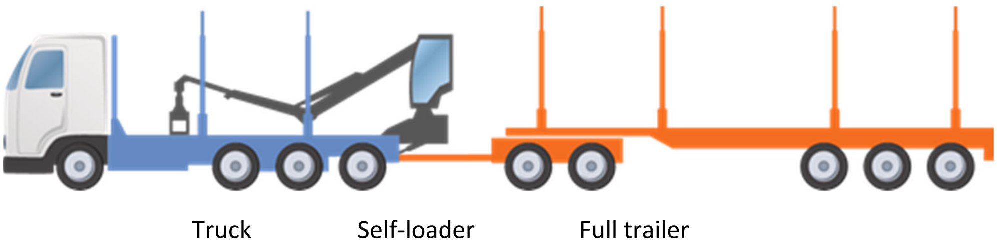

Figure 1. Typical Nordic timber truck combination consisting of the truck, full trailer and self-loader.

A load cycle is formed by the main time elements of driving unloaded from the latest delivery (e.g. mill, terminal, train station), loading at roadside (or in terminal), driving between landings to get a full load, driving loaded to the delivery destination, unloading and other times (e.g. lunch breaks, statutory breaks, re-fueling, maintenance etc.). For each element, the annual average driving distances are required. Other data required for describing the operating environment is presented under *Operations specific factors*.

The logic of the traditional costing model (a) is to insert and define the representative operations environment, set the values for costing indicators and then calculate the annual costs of trucking. The costs presented are representative for the given conditions and average transport distance of the year.

Alternatively, the optional transport distance distribution model (b), calculates the cost indicators specifically for each transport distance class. For this option, the same operations specific factors are required as for the traditional costing model. However, these factors need to be inserted to each distance class (e.g. 50 km, 100 km, 150 km, etc). Note that distance-dependent variables vary with distance. This concerns indicators for e.g. fuel consumptions, distances in public paved roads, driving speeds of public paved roads, and driving times for each driving element. Moreover, the durantion of other work time elements (breaks, re-fueling, interruptions etc.) increase when the transport distance and load cycle time increases. Loading and unloading times per load cycle can be assumed to be independent of transport distances, so average values can be used. The distances over lower road classes (public gravel roads and forest roads) can be assumed to be fixed and independent of distance class.

By adjusting the share of operating hours in each transport distance class, the user can define the targeted distance distribution for the costing case (Figure 2). This distributes the annual operating hours over distance classes and forms the number of loads for each class. Furthermore, for each load cycle in each class, cost calculation is conducted.

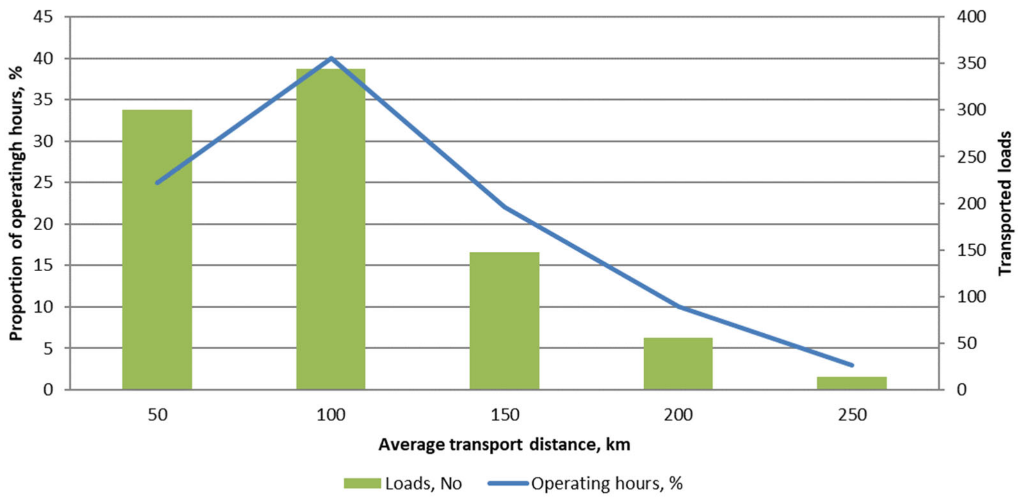

Figure 2. Defining the proportion of operating hours and loads (y-axis) for each distance distribution class (x-axis). Example of a case-entrepreneur.

After the definition of operation specific factors for each class, annual operations are summed and counted in order to calculate fixed costs, variable costs and trucking costs per year. With the use of the annual costing and distance class dependent values, such as operating hours, loads or driven kilometers, costs are then calculated for each transport distance class. For example, if the fixed annual costs for the calculation case is 150 k€, the fixed cost per load for the distance class of 50 km is calculated as follows:

Annual fixed cost	***Afc*** *= 150,000 €*
Share of operating hours in dist. class of 50 km	***S_OpH*** *= 25%*
Load cycles in the distance class of 50 km	***Ls*** *= 300 loads*
Fixed cost of the distance class	***Fc_ds*** *= Afc x (S_OpH/100) / Ls*
	= 150 000 € x 0,25 / 300 loads = 125 €/load.

On the other hand, for the variable costs, the principle of the calculation is distance dependent. Therefore, the cost is determined by multiplying the values of variable cost in €/km with driving distance of each distance class. However, per unit fuel consumption is typically higher for short distances. The same logic follows for the repair costs due to higher share of low-quality roads for short distances.

The variable cost for diesel consumption for the distance class of 150 km can be assessed as follows:

Loaded fuel consumption in dist. class of 150km	***L_Fc_150*** *= 60 liters/100 km*
Driving between decks fuel consumption in dist. class of 150km	***Dbd_Fc_150*** *= 70 liters /100 km*
Unloaded fuel consumption in dist. class of 150km	***Ul_Fc_150*** *= 35 liters /100 km*
Driving distance as loaded in dist. class of 150km	***D_L_150*** *= 140 km*
Driving distance as driving between decks in dist. class of 150km	***D_Dbd_150*** *= 10 km*
Driving distance as unloaded in dist. class of 150km	***D_Ul_150*** *= 130 km*
Cycle distance of one trip	***Cdist*** *= 140+10+130 = 280 km*
Fuel price	***Fp*** *= 1,0 €/l*

Fuel cost of driving in dist. class of 150km for one trip

Fc_150_trip *= ((L_Fc_150 / 100 x D_L_150) + (Dbd_Fc_ppr_150 / 100 x D_Dbd_150)*
+ (Ul_Fc_ppr_150/100 x D_Ul_150)) x Fp

= ((60 liters/100km / 100 x 140km) + (70 liters/100km / 100 x 10km)
+ (35 liters/100km / 100 x 130km)) x 1,0 €/km

= 136,5 €/trip (load)

Fuel cost of driving one km in dist. class of 150km

Fc_150_1km *= Fc_150_trip / Cdist = 136,5 €/load / 280 km = 0,4875 €/km*

After determining fixed and variable costs for each distance class, costs are added, resulting in key performance indicators. An example of results from the distance dependent model is presented in Figure 4.

Using the annual accounting model

The use of the traditional annual accounting model (A) has three steps; 1) operating environment, 2) cost factors and 3) cost accounting.

2.1 Step 1 – Operating environment

The text below presents the costing steps with the traditional annual accounting model for an annual average transport distance. While describing operating conditions, vehicle parameters and work element durations in moderate detail, the costing model allows cost assessment for a variety of operational scenarios. The data quality and resolution have a direct impact on the accuracy and reliability of the costing model. Table 1 presents the operations specific factors used in costing model in timber trucking.

Table 1. Operations specific factors used in the timber trucking costing mode.

Factor	Description	Units
Mass of vehicle and payload	Gross vehicle weight (GVW, max. allowed weight in tons by the national road traffic law). Average payload derived from all transported loads over the year in tons	metric tons
Load cycle specific distances	Driven distances for the average load cycle, starting with driving unloaded from the previous delivery site and ending at the final delivery destination including i) distances of driving between decks, ii) driving loaded, and iii) driving unloaded. *Uncompensated driving* has been excluded from normal load cycle specific distances (driving to repair, washing, inspection etc.), and it is presented as km per annum.	km
Road classes	Road class definition for three classes and their respective shares according to the average load cycle distance: i) public paved roads, ii) public gravel roads and iii) private roads (e.g. forest roads)	%, km
Driving speeds	Average driving speeds for each road class	km/h
Time elements	Main time elements and time durations for the average load cycle (loading, unloading, driving loaded, driving between decks, driving unloaded, other time). *Additional work time for drivers* is excluded from the average load cycle and presented as a percentage per operating hour. Additional work time for drivers is calculated and added to costing at the end.	h
Fuel consumption	Average fuel consumptions for the driving time elements (driving loaded, driving unloaded and driving between decks).	l/100 km
Annual operating hours	Normal working time, which is directly linked to timber trucking cycles	h

After assessing operations specific parameters, the user can check performance indicators of annual operations, which allows validation and modification of parameter values before the assessment of cost parameters (Table 2).

Table 2. Annual performance indicators for timber trucking. Performance data is calculated for the defined values of operations specific factors.

Annual performance indicators	
- Average transport distance, km	- Annual operating hours, h
- Average load cycle distance, km	- Annual working hours, h
- Average cycle time, h	- Loads per year
- Average driving speed, km/h	- Transported tons per year, ton
- Average fuel consumption, l/100 km	- Annual driving, km
- Average fuel consumption, l/tkm	- Share of empty running of the average load cycle distance, %
- Annual fuel consumption, l/year	

2.2 Step 2 - Cost factors

In the second step, all the required cost parameters and prices related to timber trucking must be set. In the costing model, as for typical cost accounting, all prices are without value added tax (VAT). Annual capital costs, investment prices, lifetimes and residual values are required for the truck, trailer and self-loader, separately (Table 3). The inclusion of tire prices in the investment price of truck and trailer varies between contexts. Therefore, the user can select from two options. If tire costs are excluded in the investment prices of the truck and trailer, tire prices are considered in a separate tire costing formula. For this option, prices are specified for new tires (truck and trailer separately), prices for tire re-coating, number of tires in truck and in trailer, and lifetime of tires (see example in Table 4). The alternative option is to directly determine a kilometer-based total tire cost.

Table 3. Factors for the capital costs for the main elements of a timber truck (truck, trailer and self-loader). Presented values are averages from the participating countries of Road and Transport working group.

	Investment, purchase price	Lifetime	Residual value
Truck	180 000 €	860 000 km	21%
Trailer	60 000 €	1 200 000 km	12%
Self-loader	58 000 €	5 400 loads	11%

Table 4. Example of tire costing with detailed data for a 9-axle 76 ton timber truck.

	Tire(s) for truck	Tire(s) for trailer
a. Unit price of tire for truck, €	a1 = 650	a2 = 350
b. Number of tires	b1 = 12	b2 = 20
c. Lifetime of new tires, km	c1 = 120 000	c2 = 120 000
d. Lifetime-% of re-coated tires related to new	d1 = 90 %	d2 = 90 %
e. Re-coating of tire, €/tire (averaged for both)	e1 = 350	e2 = 350

Alternatively, the total tire costs per driven kilometer can be calculated by the presented formula (1).

*Tire cost (€/km) = ((a1+e1)*b1) / (c1+d1/100 *c1) + ((a2+e2)*b2) / (c2+d2/100*c2)* (1)

A combined factor of fixed cost for taxes, traffic costs and insurances is used in the costing model. Traffic costs include e.g. annual taxes of vehicle, inspection cost and a cost of operating license. Another factor for the fixed costs is a combination of administration and maintenance costs presented in euro per year. The cost of diesel (€/l) is determined as an average liter cost for the calculated year. In addition, the cost of AdBlue can be calculated separately by defining the consumption of AdBlue in l/100 km and determining the price per liter (e.g. 2l per 100 km and 0,6 €/l), or by including the cost to fuel (diesel) costs. Repair and service costs can be defined either directly in €/kilometer or per year, depending on the source to be used. Repair and service costs can be allocated separately to a) truck-trailer unit and b) self-loader, if the repairing/servicing cost for self-loader can be expressed as euros per load.

Personnel salary costs are based on average driver's wage cost (direct and indirect costs). The direct wage cost is presented as euro per working hour and indirect cost as percentage of the direct cost. In some cases, daily allowances are included in personnel salary costs. In the model, these can be defined in euro per year. While defining the personnel costs, work time distribution for normal working hours, shift work and weekend work influence the average wage cost. Particularly in cases with high operating hours per year, higher rates of evening/night work and weekend work increase the wage cost considerably. Country specific collective agreement documents can be utilized to determine the wage prices per case.

Other data to be defined in costing factors include the interest rate (%), profit margin as percentage share of calculated trucking costs and the extent of using the self-loader for unloading. The interest rate typically used has been the loan rate plus loan servicing costs and additional expenses for financing e.g. value added tax for the first year (rest of additions representing roughly 0.5 percent-unit increase in the loan rate). The profit margin represents the entrepreneur risk factor, if wanted. In recent years, the profit margin of timber trucking business has been 2-5% in the Nordic countries. In Table 5, typical cost factors are presented with value examples.

Table 5. Cost parameters for timber trucking. The costing parameters represent average values from inquiries to the participating NB Nord countries of Road and Transport working group (spring 2020 excluding VAT).

Cost factor	Average values (price values without VAT 0%)
Use of self-loader from all unloading cycles, %	50
Tire costs, €/km	0,08
Taxes, traffic costs and insurances, €/year	6 900
Administration and maintenance, €/year	8 000
Diesel price, €/l	1,0
Repair and service, €/km	0,21
Interest rate, %	4,1
Driver's wage cost, €/h	22,6
Indirect wage cost, %	40
Profit margin, %	3,0

2.3 Step 3 - Cost accounting

In the third step, firstly, costs are calculated and divided into fixed and variable costs. All costs which remain stable through the year being independent of the trucking operating hours are presented as fixed costs. The interest cost per year is calculated for each unit of truck-trailer combination by using formula (2):

*Interest cost (truck, trailer, self-loader) = interest rate * ((investment + residual value)/2)* (2)

This is the average annual interest cost over the lifetime of the vehicle. Because of the varying lifetime for the different parts of the vehicle, this must be calculated separately for the truck, trailer and loader. In the costing model for timber trucking salary costs are presented in the fixed cost category. Fixed and variable costs are presented in Table 6. Depreciation costs are expressed as variable costs separately for truck, trailer and loader. This is because component wear depends on the kilometers driven or loads handled. For the truck and the trailer, costs are calculated per km, and for the self-loader per load handling. The formula used in determining depreciation per year is:

Depreciation cost = (investment – residual value) / annual distance or number of loadings handled by self-loader (3)

Both the tire and the repair and service costs are included in variable costs (Table 6) and presented as driven kilometers. If repair and service costs of self-loader has been separated, fixed costs of the self-loader are expressed as €/load. Diesel (incl. AdBlue) costs are calculated either as €/km or €/load by considering work element specific fuel consumptions by using the following formulas.

Fuel cost for driving loaded and driving between decks (€/km):

$$FuelCost_{DL\&BT} = (FCons_{DL}*DL_{km}+FCons_{DBD}*DBD_{km})/(DL_{km}+DBD_{km})/100*FC \quad (4)$$

where,

$FCons_{DL}$	= fuel consumption while driving loaded,	l/100 km
$FCons_{DBD}$	= fuel consumption while driving between decks,	l/100 km
DL_{km}	= loaded driving distance for average load cycle,	km/load
DBD_{km}	= distance driving between decks for average load cycle,	km/load
FC	= fuel cost,	€/l

Fuel cost for driving empty and other driving (€/km):

$FuelCost_{DE} = (FCons_{DE}*DE_{km})/100*FC$ (5)

where,

$FCons_{DE}$	= *fuel consumption while driving empty,*	*l/100 km*
DE_{km}	= *empty driving distance for average load cycle,*	*km*
FC	= *fuel cost,*	*€/l*

Fuel cost for using self-loader (€/load):

$FuelCost_{S\text{-}L} = (L_{time} + UL_{Share}/100*UL_{time}) * FCons_{S\text{-}L} * FC$ (6)

where,

$FCons_{S\text{-}L}$	= *fuel consumption of self-loader,*	*l/load*
L_{time}	= *loading time for one full load,*	*h/load*
UL_{time}	= *unloading time for one full load,*	*h/load*
UL_{Share}	= *share of unloading by self-loader,*	*%*
FC	= *fuel cost,*	*€/l*

The cost of uncompensated driving is calculated by multiplying kilometers of uncompensated driving with fuel costs for driving empty in euros per km. This cost is included in load cost for driving empty and other driving.

Table 6. Typical levels of fixed and variable costs in the timber trucking costing model (average values for cases from participating countries).

Fixed annual costs	Average values
Interest of truck, €/year	4 450
Interest of trailer, €/year	1 310
Interest of self-loader, €/year	1 290
Taxes, traffic costs and insurance, €/year	6 900
Administration and maintenance, €/year	8 000
Wages (and allowances), €/year	112 000

Variable costs	Average values
Depreciation of truck, €/km	0,17
Depreciation of trailer, €/km	0,04
Depreciation of self-loader, €/load	9,97
Tires, €/km	0,08
Repairs and service, €/km	0,21
Diesel (incl. AdBlue)	
Driving loaded and driving between decks, €/km	0,61
Driving empty and other driving, €/km	0,45
Loading/unloading, €/load	7,94

In the results, the costing values for the average timber load are presented first. These are then presented as a) distance dependent variable costs, b) self-loader dependent variable costs and c) fixed costs. In addition to total cost per load, the profit margin of the load is expressed separately. Finally, key performance indicators and costing values are presented at the end of costing model (Table 7).

Table 7. Key performance indicators of the costing model with average values for cases from participating countries.

Key performance indicator	Average costing value
Cost per load, €/load	380
Cost per tkm, €/tkm	0,11
Cost per metric ton, €/ton	9,04
Cost per operating hour, €/h	83,2
Cost per load cycle km, €/km	2,36
Cost per transport distance km, €/km	4,47
Cost of the vehicle, €/year	282 000

Impact of costing indicators

The relative impact of the nine most influencing factors are illustrated in Figure 3. The payload has the clearly biggest influence on trucking cost. One must bear in mind that the effects presented are calculated only by changing one factor at the time without consideration to possible interactions with other factors. For example, an increase in payload will increase both the fuel consumption and the terminal time (i.e. loading and unloading). However, the presentation highlights the factors where it is most important to have correct values.

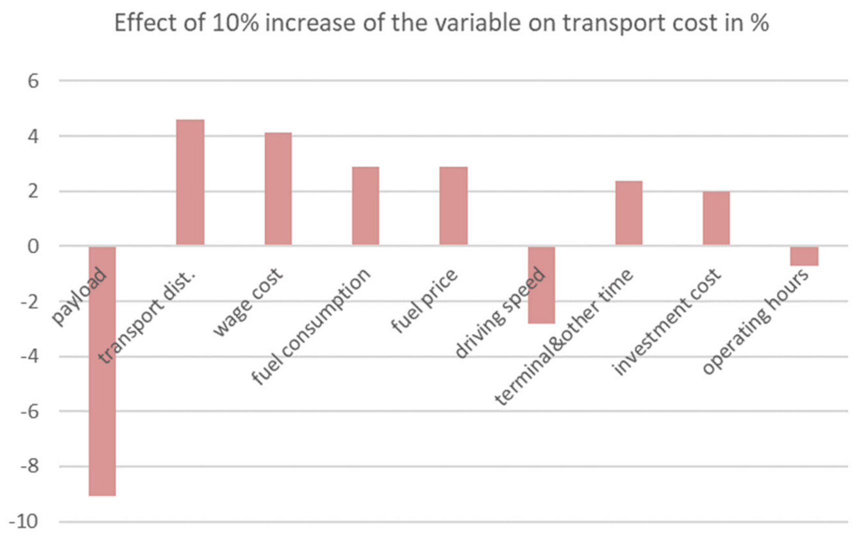

Figure 3. Effect of 10 percent increase of the respective cost factors (x-axis) on timber trucking cost (% of €/ton on y-axis).

The model provides the user with the opportunity to compare costs of alternative costing scenarios with variation in e.g. payload, fuel consumption, trucking speeds and distance distributions (Figure 4). Costing scenarios can also be compared to case-tariffs (market prices) so profit per loads, distance class and year can be estimated.

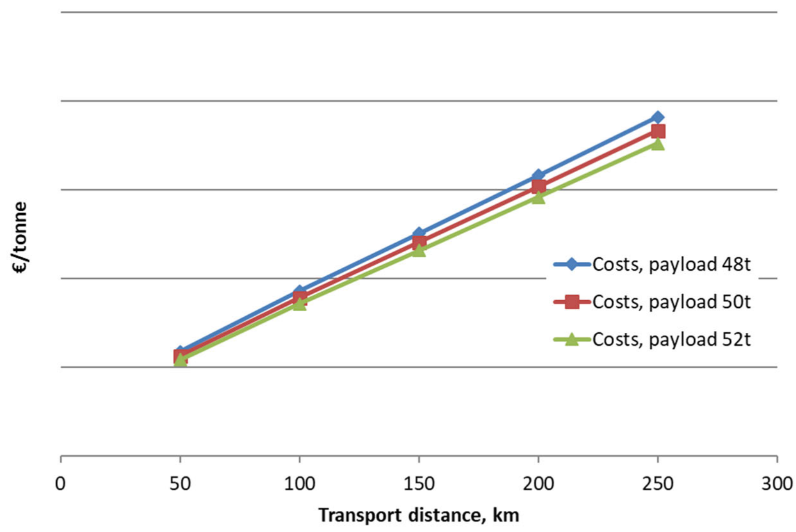

Figure 4. **Comparison of truck transport costs (€/t on y-axis) for three payload scenarios using the distance distribution-based costing model (km on x-axis).**

The traditional annual costing model was used to compare examples of average trucking costs between participants as a function of payload (Figure 5). The cost trend between the examples clearly follow the increasing payloads between Norway, Denmark, Sweden and Finland. An exception is Latvia, where the ton-kilometre cost is relatively low for the lowest payload. This is attributed to low cost levels especially for fuel and wage costs. Higher annual operating hours may also contribute to this deviation.

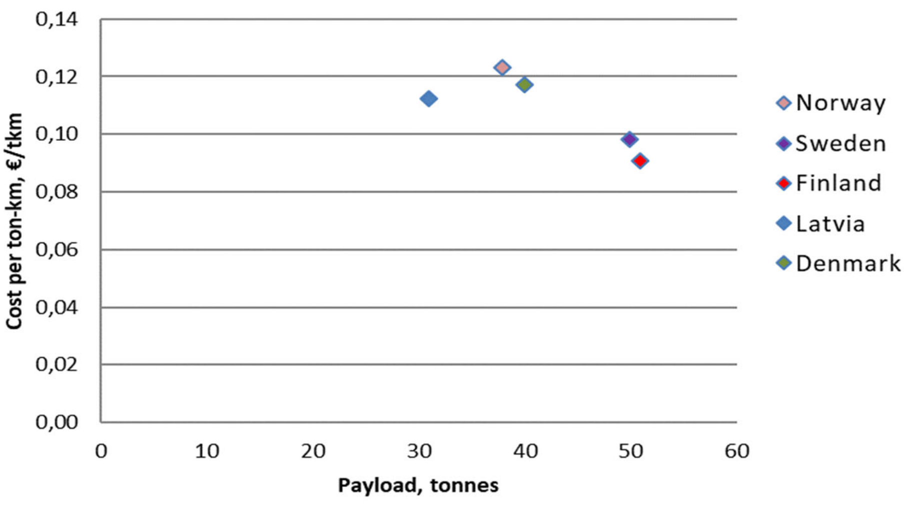

Figure 5. **Examples of timber trucking costs (€/tkm on y-axis) and payload (t on x-axis) for test cases calculated with the common framework.**

2.4 Sources for resource consumption and cost levels

Resource consumption	**Reference example**
Truck payload capacity	FIN https://hrcak.srce.hr/file/275057 SWE https://www.skogforsk.se/cd_20200225145603/contentassets/8e77fbbd07584d2fbbbdaec787996e6b/boberg_a_191121.pdf
Cycle times, driving speeds	Nurminen, T and Heinonen, J 2007. Characteristics and time consumption of timber trucking in Finland. Silva Fennica 41(3): 471-487. https://www.silvafennica.fi/pdf/article284.pdf Svenson, G and D Fjeld 2015. The impact of road geometry and surface roughness on fuel consumption of logging trucks. Scandinavian journal of forest research 31(5):526-536. https://www.tandfonline.com/doi/abs/10.1080/02827581.2016.1259426
Diesel consumption	FIN http://www.metsateho.fi/wp-content/uploads/2015/02/metsatehon_tuloskalvosarja_2004_01.pdf SWE Svenson, G and D Fjeld 2015. The impact of road geometry and surface roughness on fuel consumption of logging trucks. Scandinavian journal of forest research 31(5):526-536. https://www.tandfonline.com/doi/abs/10.1080/02827581.2015.1092574

Costs	**Reference**
Typical transport costs	FIN http://www.metsateho.fi/wp-content/uploads/Tuloskalvosarja_2019_17a_Puunkorjuu_ja_kaukokuljetus_vuonna_2018.pdf SWE https://www.skogforsk.se/kunskap/kunskapsbanken/2019/skogsbrukets-vagtransporter-2016/
Cost prices and indexes	FIN Collective labor agreement of trucking sector in Finland 2020-2023 https://www.akt.fi/site/assets/files/1683/kuorma-autoalan_tes_2020-2023_id_27758.pdf https://www.stat.fi/tup/kustannusindeksit/kustannustekijoiden-hintojen-kehitys.html#kuorma-auto SWE https://www.akeri.se/sv/transportekonomi/index https://spbi.se/statistik/priser/diesel/ https://www.transport.se/medlemskapet/kollektivavtal/kollektivavtalets-varde/ https://skr.se/ekonomijuridikstatistik/ekonomi/budgetochplanering/arbetsgivaravgifter.1290.html NOR https://www.ssb.no/statbank/table/12535/ https://www.ssb.no/statbank/table/12538/

3 Costing framework for rail transport

Pricing for rail transport of roundwood normally assumes a system solution with mill deliveries according to a regular weekly schedule. Pricing is generally set through a tendering process between rail operator companies. A typical pricing mechanism consists of both a fixed annual price component for holding the necessary capacity dedicated to the system, and a variable price component for the exact transport volume and output delivered.

The costing of rail system solutions becomes more complex than for road transport as the number of resources used increase. Investment levels are higher and equipment lifetimes longer so both capital costs (interest and depreciation) are defined as fixed costs. The costs for all resources (locomotives, wagons) are distributed over the system transport volume. High resource utilization is a key for low fixed costs per transported unit. The cost of traction current for electric locomotives and using the public rail network is set as a function of the transport output (gross tkm) and is therefore handled as a variable cost.

This chapter provides a simple calculation example for a fully electrified system running over a 22,5 t axle-weight infrastructure from three terminals (A, B, C) to the same mill. The 22,5 t axle weights enable total wagon weights of 45 and 95 t for single-axle and bogie-axle wagons, respectively. The calculation is done in three steps; 1) transport volumes and cycle scheduling, 2) annual fixed costs and 3) annual variable costs.

3.1 Step 1 – Specifying transport volumes and cycle scheduling

The example assumes an annual volume per terminal which is feasible for the specified distances to the mill. Fixed and variable costs are seen in relation to both the delivered tons and net transport output (tkm).

The first step in the calculation specifies the transport volumes, train set capacities and weekly scheduling. The example is based on 375 000 t/yr to be transported from three terminals to one mill with constant volumes per week.

	Annual volume (t/yr)	Distance (km)
Terminal A	75 000	350
Terminal B	150 000	250
Terminal C	150 000	150

Train set specifications

Train sets are generally configured to match locomotive drawing power and the maximum payload and length possible for the given topography and infrastructure. In this example:

1 electric locomotive (132 t)
24 wagons (tare weight 23 t, 60 t payload)
0,3 h/wagon loading, 0,1 h/wagon unloading, 2 h average delay before departure
Average speed 55 km/h (including delays)

The transported tonnage per cycle can then be calculated as follows

Train weight loaded = 132 t locomotive + 24 wagons (23t + 60t) = 2124 t

Train weight empty = 132 t locomotive + 24 wagons (23t) = 684 t

Payload = 24 wagons (60 t) = 1440 t

Cycle times and weekly/annual schedule

With the given payload (1 440 t) the annual tonnage is equivalent to 260 cycles per year (five mill deliveries/week). The equivalent number of cycles per year for terminals A, B and C are 52, 104 and 104, corresponding to 1, 2 and 2 departures per week, respectively.

The required time per cycle can be approximated as follows

$$\text{Cycle time} = \text{departure delay}_{mill} + \text{distance}_{mill\ to\ terminal\ x} / \text{speed}$$
$$+ \text{loading time per wagon (no. wagons)}$$
$$+ \text{departure delay}_{terminal\ x} + \text{distance}_{terminal\ x\ to\ mill} / \text{speed}$$
$$+ \text{unloading time per wagon (no. wagons)}$$

$$\text{Cycle time}_{mill\ to\ terminal\ B} = 2 + 250/55 + 0{,}3(24) + 2 + 250/55 + 0{,}1(24) = 22{,}7\ h$$

Terminal	Annual volume (t/yr)	Cycles/yr	Cycles/week	Cycle time (h)
A	75 000	52	1	26,3
B	150 000	104	2	22,7
C	150 000	104	2	19,1
Mill	375 000	260	5	Avg. = 22,7 h

Cycle times for terminal B and C are less than 24 hours. This enables regular terminal departures on a daily basis (e.g. C: Monday and Wednesday, B: Tuesday and Thursday). The cycle time for terminal A, however, requires more than 24 hours and regular departures can be scheduled every second day (eg. A: Saturday). Alternatively, tighter irregular scheduling can be accepted, or cycle times can be reduced by pre-loading wagons.

Terminal	Weekly schedule of terminal departures						
	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
A						1	
B		1		1			
C	1		1				

The cost calculation concerns the freight work alone. Additional costs for terminal infrastructure and handling must be added later. The freight costs are divided into fixed and variable costs. For a system rail solution with high utilization rates, annual fixed costs include capital costs (interest and depreciations) for all system resources as well as their regular maintenance programs. Annual variable costs are driven by operating hours, driven km and gross transport output (tkm). In the case of a larger rail operating company, locomotive engineers can be allocated to various systems, and are therefore defined as a variable cost.

3.2 Step 2 - Annual fixed costs

a) Interest

Average annual interest costs can be quite simply calculated as the average capital value over the resource's lifetime multiplied with the interest rate. The average capital value can be estimated as the average of purchase price and residual value as shown in the example below.

	Investment (€)	Life (yrs)	Residual value (%)	Annual maintenance (€/unit/yr)
locomotive	3 500 000	30	5	50 000
wagon	90 000	20	5	3 000

Annual interest = r ((investment + residual value)/2)   where r = interest rate for bound capital value

Locomotive   interest/yr = 0,125 (3 500 000 + 0,05 (3 500 000))/2 = 229 688 €

Wagon   interest/yr = 0,125 (90 000 + 0,05 (90 000))/2 = 5 906 €

b) Depreciation

In a similar way the average annual depreciation can be estimated as the difference between purchase price and residual value, divided by the lifetime in years.

Depreciation = (investment – residual value)/lifetime

Locomotive   depreciation/yr = (3 500 000 – 0,05 (3 500 000)) / 30 = 110 833 €/yr

Wagon   depreciation/yr = (90 000 – 0,05 (90 000)) /20 = 4 275 €/yr

c) Sum annual fixed costs

The annual fixed costs then consist of the sum of interest, depreciation and maintenance multiplied by the number of resources required (1 locomotive and 24 wagons).

Annual fixed costs = 1 (229 688 + 110 833 + 50 000) + 24 (5 906 + 4 275 + 3 000)

= 706 871 €/yr

While planned maintenance is included in the fixed costs, there are generally a number of units unavailable due to repairs and mainenance. The necessary number of resource units (and annual fixed costs) should be increased proportionally to account for this. In the example above a 10 percent increase is used. As utilization increases (>5 000 hrs/yr) so should the proportion of extra units.

Adjusted fixed costs = 706 871 (110 %) = 777 558 €/yr

3.3 Step 3 - Annual variable costs

The variable costs include a) hourly-based costs for labour, b) km-based costs for accident insurance, and c) gross tkm-based costs for rail fees and traction current.

a) Hour-based costs

The sum of system hours are the product of terminal cycle times and their respective cycles per year where e.g.

Hours per year $_{\text{terminal B}}$ *= 22,7 (104) = 2 360 h/yr*

In this case the system hours sum to 5 711 h.

	Cycles/yr	Cycle time (h)	h/yr
Terminal A	52	26,3	1 369
Terminal B	104	22,7	2 360
Terminal C	104	19,1	1 982
			5 711

Because the hourly cost for locomotive engineers (80 €/h incl. travel to meeting points) is per total work hour, the cost per effective hour is slightly higher (assuming 90 percent utilization of working hours). The total hourly cost can then be calculated as

Hourly-based costs per year = 5 711 h (80 € per h /90 %) = 507 604 €/yr

b) Km-based costs

The total distance driven is given by the product of the two-way distance to each terminal and the respective cycles per year.

	Cycles/yr	km (two-way)	km/yr
Terminal A	52	700	36 400
Terminal B	104	500	52 000
Terminal C	104	300	31 200
			119 600

The sum annual distance (119 600 km) is then multiplied with the km-based costs for accident risk insurance (0,2 *€/km)*

Km-based costs per year = 119 600 (0,2) = 23 290 €/yr

c) Gross tkm-based costs

The gross tkm per year can be calculated as the product of average train weight and total driven distance (1404 t * 119 600 km = 152 131 200 gross tkm). The sum of the annual gross tkm is then multiplied with the gross tkm-based costs such as rail fee (0,0010 €/gross tkm) and traction current (0,0015 €/gross tkm).

Gross tkm-based costs per year = 152 131 200 (0,0010 + 0,0015) = 380 328 €/yr

d) Total annual variable costs

The sum of hourly-, km- and gross tkm-driven costs is then

Annual variable costs = 507 604 + 23 920 + 380 328 = 911 852 €/yr

Distributing annual costs on transported units

The annual sum of fixed and variable operating costs is more tangible when presented per delivered ton (375 000 t/yr) or net tkm of transport output (86 250 000 tkm). The net tkm is calculated as the sum of products of tonnage and loaded distance for the respective terminals.

Net tkm per year = 75 000 t (350 km) + 150 000 t (250 km) + 150 000 t (150 km)

= 86 250 000 tkm/yr

	Fixed cost	variable cost	Sum cost
€/yr	777 558	911 852	1 689 410
€/t	2,07	2,43	4,51
€/net tkm	0,0090	0,0106	0,0196

Given an average roundwood density of 0,91 t/m^3, the equivalent cost per delivered m^3 is 4,10 €/m^{3}sub. For the example above, a sensitivity analysis is shown below comparing the effect of a 10 percent increase in the respective factors on the calculated cost per m^3. The comparison concerns single factors only (e.g. wagon payload, irrespective of eventual limitations and interactions with other factors). The single most important factors are payload capacity and operator costs.

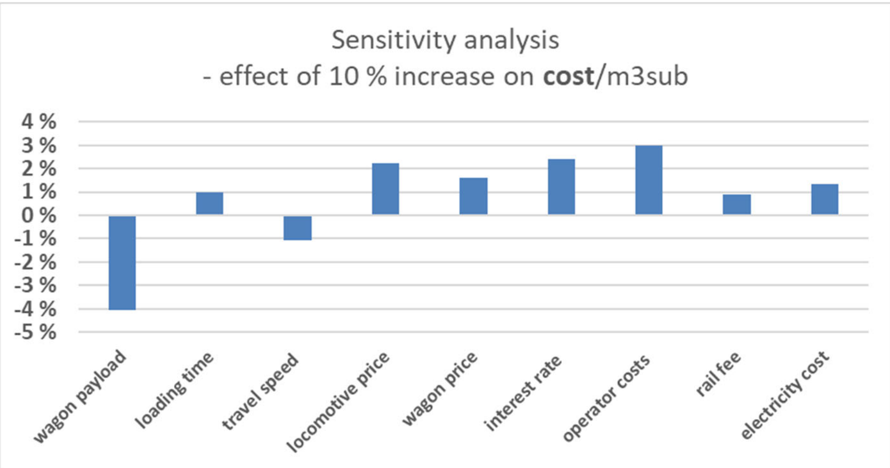

Figure 6. Sensitivity analysis for effect of 10 percent increase of cost factors (x-axis) on rail transport cost (% of €/m3sub on y-axis).

Depending on pricing mechanism agreed in the tender, the tables above provide a cost base for pricing before the profit/risk margin has been added. Typically the periodic billings include the fixed price for holding the dedicated resources and the variable price for actual tonnage moved per period from the respective terminals. Terminal and handling costs at each end of the cycle must be added before the system cost is complete.

3.4 Sources for resource consumption and cost levels

Resource consumption	**Reference example**
Electricity	NOK/km = gross weight (NOK/kWh)1,2 (gross weight) $^{-0.62}$ Grønland (2018) Kostnadsmodeller for transport og logistikk - basisår 2016. TØI rapport 1638/2018
Diesel	NOK/km = gross weight *0,458*(NOK/l)(gross weight) $^{-0.62}$ Grønland (2018) Kostnadsmodeller for transport og logistikk - basisår 2016. TØI rapport 1638/2018

Cost	**Reference**
Rail fees, traction current pricing, etc.	FI https://julkaisut.vayla.fi/pdf8/lv_2018-03_vs2020eng_web.pdf SE https://www.trafikverket.se/contentassets/b62bebabc75e42b2ac3f7f8c4c1061b2/network_statement_2020_ver2.pdf NO http://networkstatement.jbv.no/doku.php?id=2020

4 Costing framework for short-sea shipping

Pricing for short-sea shipping of roundwood is typically contracted in two ways; contract of affreightment (COA) or SPOT (individual voyages). COA pricing is most common and regulates an agreed volume per assortments between specified ports of loading (PoL) and -discharge (PoD). The freight rate (€/transported unit) is agreed between the charterer and the Owner/Operator (based on transport and loading conditions specified in the charter party with mutually agreed terms/conditions) with adjustment according to bunker price clauses and freight indexes for multiple years' contracts.

Mini-bulk vessels (length 70-120 m, beam 12-17 m, draft 5-7 m) are commonly used for short-sea shipping of roundwood in the sheltered coastal waters of northern Europe. These vessels typically carry cargoes of 2 000 – 6 000 m^3sub over distances of 100-1 000 nm (nautical miles). The vessel capacity used (< 10 000 dwt) varies between regions distances and seasons. For roundwood transport, maximum volume is generally reached before deadweight carrying capacity (dwt). Solid volume factors (m^3sub/hold volume) are therefore more convenient for calculating cargo volumes than stowage factors (hold volume/t). During typical summer conditions shallow draft/wide beam vessels allow access to shallow harbours and larger deck loads (extra 20-30 % on deck). For longer winter voyages larger ice-classed (SF1a) vessels are often used to provide more stable deliveries, but with reduced deck loads.

COA freight rates (€/m^3) can be estimated using a time charter (TC) approach. Time charter rates specify the given price (TC_{hire}) for a charterer's use of a vessel including crew and maintenance work (normal wear and tear). This bypasses the need for calculating capital costs, and links directly to actual market prices which fluctuate with available capacity. The total voyage cost includes the vessel cost plus bunker fuel, port and canal costs. Bunker prices constitute a large proportion of voyage costs and are also subject to market fluctuations. In practice, freight rates also depend on the availability of alternative cargo flows in the region to reduce the distance without cargo (ballast) from PoD to the next PoL. A general overview of the most common shipping terminology is provided in Table 8.

Table 8. Common shipping terms or abbreviations

Term/abbreviation	Description
Owner/Operator	Owner/operator of vessel, service provider
Charterer	Cargo owner, service buyer
CP	Charter party contract (CerteParti) regulating agreement between service provider and buyer
Freight rate	Agreed payment rate for delivery per cargo unit
PoO	Port of origin
PoL	Port of lading (loading)
PoD	Port of discharge (unloading)
DWT	Dead weight tons of carrying capacity (total mass for cargo, fuel, crew etc)
TC_{hire}	Total daily price for vessel, crew and regular maintenance
SF1a	Required vessel classification for ice-breaker assistance (Finland, Sweden)
Ballast	Steaming without cargo
Turn time to berth	Time from arrival to loading/discharge
Bunker	Vessel fuel (see resource consumption table)
mt	Metric tons (bunker)
nm	Nautical mile (1 nm = 1,852 km)
kn	knots; nautical mile per hour
FAS	Free alongside ship; price paid by receiver for cargo delivered to specified PoL (within vessel loader reach)
FOB	Free on board; price paid by receiver for cargo delivered to specified PoL, including stowage on board
CIF	Cost, insurance freight, price paid by receiver for cargo delivered to specified PoD, including freight and cargo insurance

This chapter provides a simple 3-step example of TC-cost calculation for a typical voyage in the Nordic-Baltic geography. The steps include 1) vessel cargo capacity, 2) voyage time and 3) voyage cost estimation.

4.1 Step 1 - Vessel cargo capacity

The calculations start with the specification of vessel cargo capacity. For roundwood transport, vessels required boxed holds (rectangular openings) where hold capacity is often specified in ft^3 (bale measure). After conversion to m^3, a solid volume factor (45-55 % for deciduous and coniferous pulpwood) is used to estimate the roundwood volume (m^3sub) stowed under deck. The proportion of extra volume possible to load on deck (15-30 %) is set by vessel stability. This will vary with seasonal variation in log weight and wave height as well as stowage practices.

Below, a calulation example is provided for a vessel with two boxed holds (102 000 ft^3 and 124 000 ft^3).

Hold volume = (102 000 ft^3 + 124 000 ft^3) / 35,3 ft^3 per m^3 = 6 402 m^3

Solid volume capacity in holds = 6 402 m^3 (53 % solid volume factor) = 3 393 m^3sub

Assuming that an extra 20 % is possible to load on deck, the total roundwood cargo is:

Solid volume capacity with deck load = 3 393 m^3sub (120 %) = 4 072 m^3sub

4.2 Step 2 - Voyage times

The voyage can be divided into four main elements;

- ballast steaming (without cargo) from Port-of-Origin (PoO) to PoL
- turn time to berth and loading
- steaming with cargo from PoL to PoD
- turn time to berth and discharge

These may be further simplified to two main elements; steaming and port times with corresponding levels of bunker consumptions. An example for a 432 nm voyage is shown below.

Ballast steaming PoO-PoL	= 432 nm / 12 kn = 36,0 h	= 36 h
Turn time to berth + loading at PoL	= 2 h + 4072 m^3 / 170 m^3 per h = 27,9 h	= 26 h
Steaming with cargo PoL-PoD	= 432 nm / 12 kn = 36 h	= 36 h
Turn time to berth + unloading at PoD	= 2 h + 4072 m^3 / 200 m^3 per h = 24,0 h	= 22,4 h
Sum voyage time	= 36 + 26 + 36 + 22,4 h	= 120,3 h = 5,01 days
Sum time steaming	=36 + 36 h	= 72 h = 3,00 days
Sum time in port	= 26 + 22,4 h	= 48,3 h = 2,01 days

4.3 Step 3 – Voyage cost estimation

An example of vessel cost can be calculated using the voyage time above (5,01 days) and a TC_{hire} rate of 3 500 €/day. The time steaming and in port are multiplied with the respective bunker consumptions (11,5 and 1 mt/day for steaming and in port, respectively) and bunker prices (450 and 550 €/mt) to give bunker costs. After this, port costs (PoL and PoD) are added to give the total voyage cost.

Vessel hire	= 5,01 days * 3 500 €/day	= 17 545
Main bunker (steaming)	= 3,00 days * 11,5 mt/day * 450 €/mt	= 15 525
Aux. bunker (in port)	= 2,01 days *1 mt/day * 550 €/mt	= 1 107
Port costs (PoL and PoD)	= 4 000 + 4 000 €	= 8 000
Sum voyage cost	=	= 42 178 €

Dividing the total voyage cost (42 178 €) with the estimated cargo volume (4 072 m^3) gives a basic freight cost of 10,72 €/m^3.

Basic freight cost = 42 178 € / 4 072 m^3sub = 10,36 € / m^3sub

Given that 432 nm is 800 km the basic cost per net m^3km would be 0,0129 €/m^3km. The equivalent cost per net tkm (assuming 0,910 t/m^3) is 0,0142 €/tkm.

For the above example (432 nm) a sensitivity analysis is shown below comparing the effect of a 10 % increase in the respective factors on the cost per m3. The comparison concerns single factors only (e.g. cargo volume, irrespective of effect on speed and bunker consumption). The single most important factors are related to cargo capacity (e.g. high solid volume factor).

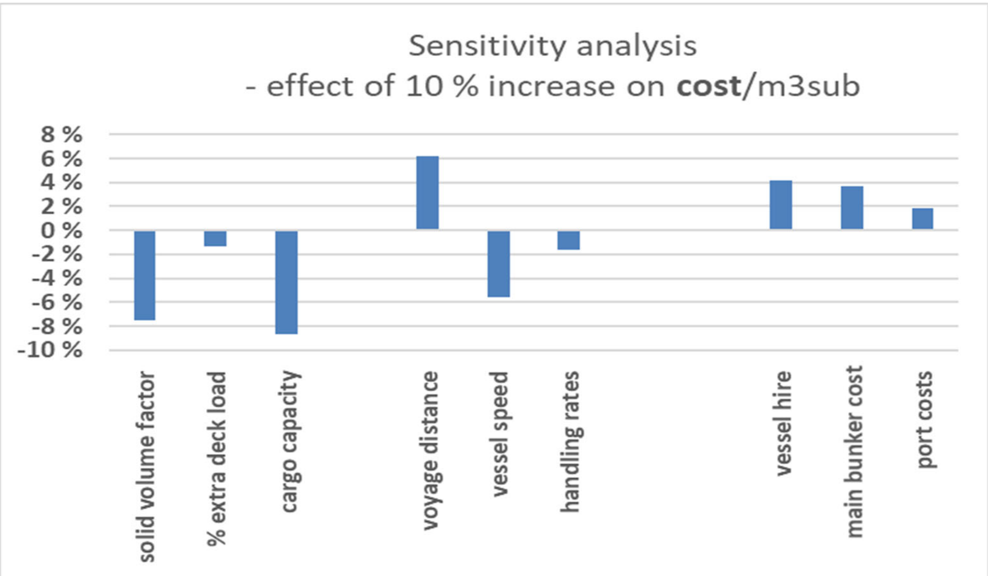

Figure 7. Sensetivity analysis for effect of 10 percent increase of the respective variables (x-axis) on rail transport cost (% of €/m^3sub on y-axis).

The operating margin and any ship broker fees must also be included before the Owners/Operator can complete an offer to the charterer. The final freight rate offered is given on the terms specified in the charter party (CP) agreement, including demurrage rates payable to the shipper for delays at PoL or PoD.

The agreed freight rate concerns only the Owners/Operator transport. Loading and unloading charges will often amount to approx 2 €/m^3 at each end of the voyage. Responsibility for these different costs is regulated by the INCO-terms used in the wood sales agreement. FAS_{PoL} (free alongside ship at the specified PoL) means that the wood is priced at shipside. In this case, the seller bears responsibility for all costs to this point, where the receiver takes over as charterer to the PoD. CIF_{PoD} (cost, insurance, freight) means that the wood is priced at the receivers PoD. In this case, the seller has the role of charterer and bears responsibility for all costs to this point.

4.4 Sources for resource consumption and cost levels

Resource consumption	**Reference**
Port distances	https://sea-distances.org/
Voyage times, delays	Fjeld, D and B Talbot 2016. Time of arrival variations for short-sea shipping of roundwood and chips within the Baltic Sea. Proceedings FORMEC 2016 From theory to practice: challenges for forest engineering: 45-48.
Bunker types	Bunker fuel quality varies from the least refined fuel types (heavy fuel oil; HFO) to cleaner variants (marine gas oil; MGO) and others fulfilling the maximum sulphur limits in SECA-defined areas (see bunker regulations https://www.dnvgl.com/maritime/global-sulphur-cap/FAQ.html).
Average bunker consumption	Example for mini-bulkers freighting roundwood/chips in the Baltic Sea area; 10-13 mt/day, depending on vessel displacement, weather and speed

Cost	**Reference**
Bunker prices	https://www.bunkerworld.com/prices/
Port, fairway costs	Port-specific, including fairways, pilotage and harbour fees (vary with vessel capacity)
TC_{hire} rates	Example for mini-bulkers freighting roundwood/chips in the Baltic Sea area; 2500-4500 €/day, depending on cargo capacity and market situation

References

Fjeld, D and B Dahlin (2017). Nordic logistics handbook – forest operations in wood supply. SLU/U.Helsinki.

Venäläinen, P and D Fjeld (2018). Cost modelling approaches and latest news from the front. Proceedings from the Nordic-Baltic workshop in Oslo 11-12 Sept, 2018. NB Nord Roads and Transportation Group. https://nordicforestresearch.org/wp-content/uploads/2018/10/NBNord_OsloWorkshop_Proceedings.pdf

Väätäinen, K and D Fjeld (2020). Transport costing models – a common Nordic-Baltic Framework. In: Björheden, R and I Callesen (eds) Proceedings from NB Nord conference Forest Operations for the future. Helsinore 22-24 Sept, 2020. https://nordicforestresearch.org/wp-content/uploads/2020/11/arbetsrapport-1061-2020_.pdf. http://dansoil.dk/NBNord2020/1_5_VaatainenFjeld.mp4

Fjeld, D, Väätäinen, K, von Hofsten, H, Noreland, D, Callesen, I, Lazdins, A (2021). Costing models for road, rail and sea transport of roundwood (MS Excel). http://urn.fi/URN:NBN:fi-fe202101151893.

Appendix A – Overview of truck costing spreadsheet

A. Cost calculation model for road transport of roundwood by timber truck - average distance model

	AREAS COLOURED BY BLUE ARE USER DEFINED
Input parameters	AREAS COLOURED BY GREEN INCLUDE FORMULAS
	NB Nord countries (average)
1. VEHICLE AND LOAD CYCLE SPECIFIC FACTORS	
a. Gross vehicle weight and average payload	
a1. Gross vehicle weight, t	65
a2. Average payload, t	42
b. Distance specific factors	
b1. Average transport distance, km	**84,7**
b2. Average distance of driving between decks, km	6,5
b3. Average distance of fully loaded, km	*78,2*
b4. Average distance of driving unloaded, km *Note: define backhauling here!!*)	80,0
b5. Average load cycle distance, km	***164,7***
b6. Uncompensated driving per year, km	
c. Shares of road classes	
c1. Share of public paved roads, %	88,2
c2. Share of public gravel roads, %	8,4
c3. Share of private roads (e.g. forest roads), %	3,4
d. Average speeds	
d1. public paved roads, km/h	70,0
d2. public gravel roads, km/h	36,0
d3. private roads, km/h	17,8
d4. Speed correction factor for driving as loaded	0,95
e. Duration of time element per load cycle	
e1. Loading, h	0,8
e2. Unloading, h	0,4
e3. Other time, h	0,5
e4. Driving fully loaded, h	*1,39*
e5. Driving unloaded, h	*1,35*
e6. Driving between decks, h	*0,2*
e7. Load cycle time, h	***4,6***
e8. Additional work time for drivers, % of the operating hours	*3*
f. Average fuel consumption, l/100km	
f1. During fully loaded, l/100km	58,6
f2. During between decks, l/100km	77,0
f3. During unloaded, l/100km	41,3
f4. During crane work, l/h	8,0
g. Annual operating hours, h	**3 557,4**
h. Performance indicators	**NB Nord countries (average)**
h1. Transport distance (as loaded), km	***84,7***
h2. Average load cycle distance, km	***164,7***
h3. Average cycle time, h	***4,6***
h4. Average driving speed, km/h	***56,5***
h5. Average fuel consumption, l/100km	***56,7***
h6. Average fuel consumption, l/tkm	***0,014***
h7. Annual fuel consumption, l	***72 366,1***
h8. Annual operating hours, h (associated to load cycle operation)	***3 557,4***
h9. Annual working hours, h	***3 664,1***
h10. Loads per year	***774,8***
h11. Transported tons per year, ton	***32 540,7***
h12. Annual driving, km	***127 605,9***
EMPTY RUNNING %	**48,6**
2. COST FACTORS	**NB Nord countries (average)**
a. Investment; purchase price	
a1. Truck, €	180 107
a2. Trailer, €	60 554
a3. Self loader, €	57 832
b. Lifetime	
b1. Truck, km	821 320
b2. Trailer, km	1 211 320
b3. Self loader, loads	5 360
c. Rest value percent	
c1. Truck, %	20,4
c2. Trailer, %	11,8
c3. Self loader, %	10,8
c3.1 Share of self loader use during unloading, %	50,0
d. Tire cost, €/km (Option 1)	0,1
d. Tires (Option 2; *method Finland*)	
d1. price for truck, €/tire	
d2. price for trailer, €/tire	
d3. number of tires in truck	
d4. number of tires in trailer	
d5. price for truck, €	
d6. price for trailer, €	
d7. lifetime of tires, km	
e. Taxes, traffic costs and insurances, €	6 915
f. Administration and maintenance, €	8 035
g1. Diesel price, €/l	1,0
g2. Price of AdBlue, €/l	0,6
g3. Consumption of adBlue, l/100km	2,0
h1. Repair and service (Option 1), € (incl. oils)	
h2a. Repair and service for truck and trailer (Option 2), €/km	0,21
h2b. Repair and service for self loader (Option 2), €/load	
i. coating of tires, €/tire (case Finland)	
j. Interest rate, %	4,1
k. Driver's wage cost, €/hour	24,5
l. Indirect wage cost, %	30,9
m. Sum of allowances for the year, €	
m. Profit margin, %	3,0
Costs and cost formulas	
3. FIXED ANNUAL COSTS	**NB Nord countries (average)**
a. Interest of truck, €/year	4 445,4
b. Interest of trailer, €/year	1 387,8
c. Interest of self loader €/year	1 313,6
d. Taxes, traffic costs and insurances, €/year	6 915,3
e. Administration and maintenance, €/year	8 035,4
f. Wages (and allowances), €/year	117 495,9
g. Fixed annual costs, €/year	**139 593,4**
4. VARIABLE COSTS	
a. Depreciation of truck, €/km	0,175
b. Depreciation of trailer, €/km	0,044
c. Depreciation of self loader, €/load	9,624
d. Tires, €/km	0,073
f. Repairs and service, €/km	0,206
f1. Repair and service for loader, €/load	
e. Diesel and AdBlue	
e1. driving loaded and driving between decks, €/km	0,638
e2. Driving empty and other driving, €/km	0,443
e3. Crane work, €/load	8,116
e4. driving loaded and driving between decks, €/load	54,0
e5. Driving empty and other driving, €/load	35,5
5. RESULTS	
a. Cost per load	**NB Nord countries (average)**
a1. loader depended variable costs, €/load	17,7
a2. distance depended costs, €/load	171,5
a3. fixed costs, €/load	180,2
a4. Cost per load, €/load	369,4
a5. Profit margin, €/load	11,1
Key performance indicators	
a. Cost per load, €/load	***380,5***
b. Cost per tkm, €/tkm	***0,107***
c. Cost per tonne, €/t	***9,060***
d. Cost per operating hour, €/h	***82,9***
e1. Cost per kilometre (load cycle), €/km	***2,31***
e2. Cost per kilometre (transport distance), €/km	***4,49***
f. Costs of the vehicle, €/year	***294 817***
Vehicle costs (Profit margin excluded)	**286 230**

Appendix B – Overview of rail costing spreadsheet

2. Cost Calculation model for rail transport of roundwood

System example: single electric train set feeding 1 mill from 3 terminals

input cells
key output cells

Calculations		Input instructions
1. TRAIN SET SPECIFICATIONS		
no. train sets	1	1.1 Enter no. of complete train sets required to fufill the scheduled cycles/yr
		(Note; fixed costs for all resources specified here are allocated to the specified transport tonnage)
locomotives/set		
no.locomotives	1	1.2 Enter no. of locomotives required to draw full wagon set
locomotive weight (t)	132	1.3 Enter locomotive weight
wagons/set		
no. wagons	24	1.4 Enter no. of wagons required to deliver tonnage/cycle
wagone tare weight (t)	23	1.5 Enter empty wagon weight
payload/wagon (t)	60	1.6 Enter actual payload for the given wagon profile
sum weight unloaded wagons (t)	552	
sum weight loaded wagons (t)	1992	
sum weight payload (t)	1440	
weight/train set		2.1 Enter cycle time parameters (below left)
total weight empty	684	2.2 Enter terminal and transport data for scheduling (below right)
total weight loaded	2124	
2. CYCLE TIME PARAMETERS		
cycle time parameters		
loading time/wagon (hrs/wagon)	0,3	
unloading time/wagon (hrs/wagon)	0,1	
departure delay (average hrs waiting for scheduled departure)	2	
average travel speed (incl. delays underways)	55	
3. COST CALCULATIONS		
Investments (€)		
per locomotive	3 500 000	3.1 Enter purchase prices
per wagon	90 000	
rest value (%)		
locomotive	5 %	3.2 Specify residual values after assumed life time (% of purchase price)
wagon	5 %	
lifetime (yrs)		
locomotive	30	3.3 Enter expected lifetimes under normal operations
wagon	20	
maintenance (€/unit/yr)		
per locomotive	50 000	3.4 Enter annual costs of annual maintenance program
per wagon	3 000	
3a. Annual fixed costs		
average bound capital over lifetime = (investment+rest value)/2		
all locomotives	1 837 500	
all wagons	1 134 000	
average interest/yr		
interest rate on capital bound in system resources (%)	12,5 %	3.5 Enter required interest rate for capital
locomotive	229 688	
all wagons	141 750	
sum interest (€/yr)	371 438	
average depreciation/yr		
all locomotives	110 833	
all wagons	102 600	
sum depreciation (€/yr)	213 433	
maintainence/yr		
all locomotives	50 000	
all wagons	72 000	
sum maintenance (€/yr)	122 000	
fixed costs/yr	706 871	
% extra resources (req'd during breakdown/maintenance)	10 %	
Sum annual fixed costs (€/yr)	**777 558**	
3b. Annual variable costs		
sum system hrs/yr	5 711	
operator costs €/hr	80	3.6 Enter total wage costs per paid work hour including travel, breaks, etc.
expected utilization rate (% active in cycle/annual working time)	90 %	3.7 Enter proportion of paid working time in operation (%)
sum hourly costs (€/yr)	507 604	
sum system km/yr	119 600	
insurance costs/km	0,20	3.8 See rates from national network statememt
sum km-driven costs (€/yr)	23 920	
sum system gross tkm/yr	152 131 200	
rail fee/gross tkm	0,0010	3.9 See rates from national network statement
electricity cost/gross tkm*	0,0015	3.10 See rates from national network statement (example in Appendix A)
sum gross tkm-driven costs (€/yr)	380 328	
Sum annual variable costs (€/yr)	**911 852**	
3c. Sum annual costs per transported unit		
annual variable costs	911 852	
annual fixed cost	777 558	
sum annual costs (€/yr)	**1 689 410**	
sum annual tonnage	375 000	
variable costs/t	2,43	
fixed cost/t	2,07	
sum costs (€/t)	**4,51**	
Conversion factor; ton per m3sub	0,91	3.11 Enter roundwood weight (tons per m3) to get transport cost per m3
sum costs €/m3	4,10	
sum annual (net) transport output	86 250 000	
annual variable costs/tkm	0,0106	
annual fixed cost/tkm	0,0090	
sum costs (€/tkm)	**0,020**	
sum costs €/m3 km	0,018	

Terminal and transport data for scheduling and costs	Terminal A	Terminal B	Terminal C	Terminal D	Terminal E	Terminal F	Sum	
one-way distance (km)	350	250	150					
annual transport tonnage (tons/yr)	75 000	150 000	150 000				375 000	tons/yr
annual transport output (net t km/yr)	26 250 000	37 500 000	22 500 000				86 250 000	net t km/yr
cycles per year	52	104	104				260	
hours/cycle (hrs mill-terminal-mill)	26,3	22,7	19,1					
required calender days per cycle	2	1	1					
required calender days for regular scheduled operation	104	104	104				312	scheduled calender days/yr
annual resource utilization (operation hrs)	1 369	2 360	1 982				5 711	operating hrs/yr
annual km (total driven distance)	36 400	52 000	31 200				119 600	km/yr
annual gross tkm (tkm loaded and unloaded)	46 300 800	66 144 000	39 686 400				152 131 200	gross t km/yr

Terminal	cycles/week	days/cycle
A	1	2
B	2	1
C	2	1

Scheduling explanations

230	(km) average loaded transport distance
22	Average cycle time (hrs). **To convert terminal-specific cycle times (hours) to calender days for regular scheduling:**
	< 12 hrs = 0,5 days/cycles; < 24 hrs = 1 day/cycle; > 24 hrs r= 2 days/cycle
	> 364 scheduled days/yr requires more than 1 train set (input instruction 1.1, cell B9)
114 %	% of capacity utilization (typical locomotive utilization in practice = 5000 hr/yr, max theoretical hrs/yr = 365*24 = 8769)

		Weekly scheduling of terminal departures to mill							
Train set	Terminal	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	Sum cycles/week
	A						1		1
1	B		1		1				2
	C	1		1					2

Appendix C – Overview of vessel costing spreadsheet

3. Cost calculation model for short-sea shipping of roundwood

Time Charter-based for Contract of affreightment (COA) between PoL-PoD

input parameters			
main output			
Calculations		**Input intructions**	**Typical input range**
1. CARGO CAPACITY			
Cargo hold volumes			
First cargo hold (ft3)	102000	1.1 Enter hold volumes in cubic feet (ft3)	See vessel specification (ft3 bale)
Second cargo hold (ft3)	124000		
Sum hold capacity in ft3	226000		
Sum hold capacity in m3 (35,3 ft3/m3)	6402		
solid volume factor (svf %)	53 %	1.2 Convert vessel hold volume to corresponding m3sub of roundwood	for pulpwood: ranging from 45 % (deciduous) to 55 % (coniferous)
hold capacity (m3sub)	3393		
% extra load on deck	20 %	1.3 Add additional load on deck (% of volume under deck)	15-30 %, depending on required stability (seasonal wave height and hull width/depth)
Vessel cargo capacity (m3sub in hold + on deck)	**4072**		
2. VOYAGE TIMES			
Distances*, steaming speeds, terminal handling rates			
ballast distance (from PoO to PoL in nm)	432	2.1 Enter ballast distance to PoL (nm)	varies from 75 % of laden distance (shuttle routes < 200 nm with limited backhauling) to 25 % (longer routes > 600 nm with cargo backhaul flow)
voyage distance (PoL to PoD in nm)	432	2.2 Enter voyage distance for cargo from PoL to PoD (nm)	see https://sea-distances.org/
ballast speed (11-13 kn)	12		10-12 kn, depending on vessel, weather and possibility to reduce bunker consumption
turn time at PoL (hrs)	2		2 hr standard time
loading rate at PoL (m3sub/hr)	170	2.3 Enter standard loading rate at PoL	150-250 m3/hr, see port specifications
loaded speed (kn)	12	2.4 Enter vessel speed (kn)	
turn time at PoD (hrs)	2	2.5 Enter turn time from arrival in port to loading/unloading	
discharge rate at PoD (m3sub/hr)	200	2.6 Enter standard discharge rate at PoD	150-250 m3/hr, see port specifications
General delay time (hr)	0	2.7 Enter expected delay times (hrs)	for example 24 hours, often after loading at PoL or while steaming laden, in order to meet agreed time-of-arrival at PoD
Voyage times (hrs)			
ballast voyage	36,0		
turn+loading	26,0		
loaded voyage	36,0		
turn+discharge	22,4		
Sum voyage time (hrs)	**120,3**		
sum TC-time for voyage (days)	5,013		
days steaming	3,00		
days in port	2,01		
3. COST CALCULATIONS			
Cost parameters			
Vessel hire (TC_{hire} euro/day)	3500	3.1 Enter vessel hire rate (euro/day)	Rate varies from 2500-4500 euro/day, depending on vessel capacity and market conditions
main bunker cost (euro/mt)	450	3.2 Enter main bunker cost (euro/mt)	10-13 mt/daty, varying with fuel type, for market variation see www.bunkerworld.com (covered by retroactive bunker clauses in CP)
auxiliary bunker cost (euro/mt)	550	3.3 Enter auxliary bunker cost (euro/mt) while in port	1 mt/day
Port charges PoL (euro)	4000	3.4 Enter sum port costs (pilotage, fairway and harbour fees)	Details provided by each individual port
Port charges PoD (euro)	4000		
Main bunker consumption while steaming (mt/day)	11,5	3.5 Enter main bunker consumption while steaming with cargo (mt/day)	10-13 mt/day depending on fuel type, vessel displacement and speed
Aux. bunker consumption in port (mt/day)	1		
Voyage costs			
TC-hire (sum days *dayrate)	17 545		
Bunker main	15 525		
Bunker aux	1 107		
Port costs	8 000		
Sum costs/voyage (euro)	**42 178**		
Sum cost/m3 (euro/m3)	**10,36**	**Estimated freight cost per m3sub (excluding broker fees, VAT, etc.)**	
sum cost euro/m3/km	0,0129		
conversion factor; ton per m3sub	0,91		
sum cost euro/t/km	0,0142		

NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

Norsk institutt for bioøkonomi (NIBIO) ble opprettet 1. juli 2015 som en fusjon av Bioforsk, Norsk institutt for landbruksøkonomisk forskning (NILF) og Norsk institutt for skog og landskap.

Bioøkonomi baserer seg på utnyttelse og forvaltning av biologiske ressurser fra jord og hav, fremfor en fossil økonomi som er basert på kull, olje og gass. NIBIO skal være nasjonalt ledende for utvikling av kunnskap om bioøkonomi.

Gjennom forskning og kunnskapsproduksjon skal instituttet bidra til matsikkerhet, bærekraftig ressursforvaltning, innovasjon og verdiskaping innenfor verdikjedene for mat, skog og andre biobaserte næringer. Instituttet skal levere forskning, forvaltningsstøtte og kunnskap til anvendelse i nasjonal beredskap, forvaltning, næringsliv og samfunnet for øvrig.

NIBIO er eid av Landbruks- og matdepartementet som et forvaltningsorgan med særskilte fullmakter og eget styre. Hovedkontoret er på Ås. Instituttet har flere regionale enheter og et avdelingskontor i Oslo.

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