NB Nord

Roads and Transportation Focus Area

Cost modeling approaches and latest news from the front

Proceedings from the Nordic-Baltic workshop

in Oslo 11–12 September 2018

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Introduction

NB Nord (Nordic-Baltic Network for Operational Research) is a networking project with partners from Finland, Denmark, Latvia, Norway, and Sweden. The network covers various themes in forestry research. The Roads & Transportation Focus Area focuses on research in logistics, transportation efficiency, transport infrastructure, and environmental impacts of transportation.

The Focus Area organized a workshop on "Cost modeling approaches and latest news from the front" in Oslo, Norway, on 11-12th September 2018. The workshop consisted of four sessions with themes including: 1) transport costing approaches, 2) development of system performance, 3) seasonality in transport and 4) forest and public road networks. The abstracts of the workshop presentations can be found in this document and the presentations can be found on the NB Nord website:
http://nordicforestresearch.org/nb-nord/

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Abstracts

1. Transport costing approaches

Principles of cost accounting for timber truck transports in Finland

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Background

Cost accounting for truck transports of timber follows the cost accounting principles recommended by the board of transport cost accounting (Ajoneuvojen… 2009). The board is organized by the Confederation of Finnish Industries and Finnish Transport and Logistics - SKAL. The studies of biomass transportation by trucks in Finland have mainly followed this cost accounting method. Here the cost factors and cost shares in timber trucking in Finland are presented.

Cost accounting method

The principles of cost accounting for trucking follow predominantly typical cost calculations of heavy vehicles and forest machines. Main exceptions are that price of tyres are excluded from the purchase price of new truck and trailer unit and that the price of new tyres and tyre coating costs are directed to variable costs and traffic costs (annual vehicle tax and inspection cost) are introduced in fixed costs. Main cost accounting factors are presented in Figure 1.

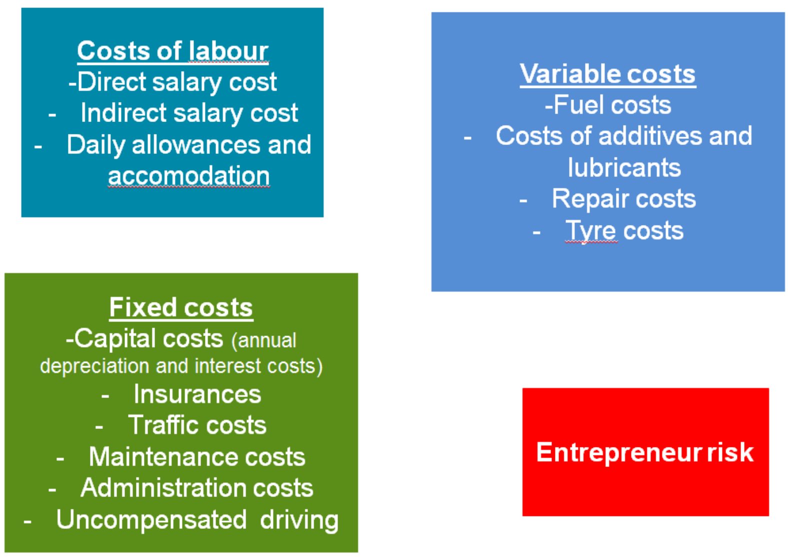

Figure 1. Cost factors in cost accounting of trucking (Ajoneuvojen… 2009).

Statistics Finland is acquiring and maintaining cost indexing for forest machines (harvester and forwarder), mobile chippers and timber trucks. Statistics of cost indexes offer information to negotiate during tendering and to monitor the influence of cost factor variation on total cost index and cost-effectiveness (Metsäalan… 2013). According to the Statistics Finland (2017) cost indexing of timber trucking, the dominant cost factor was salary cost of the drivers (salary + indirect salary) representing 37.8% share of trucking costs (August 2017). The share of fuel cost from the total was 29.5% (Figure 2).

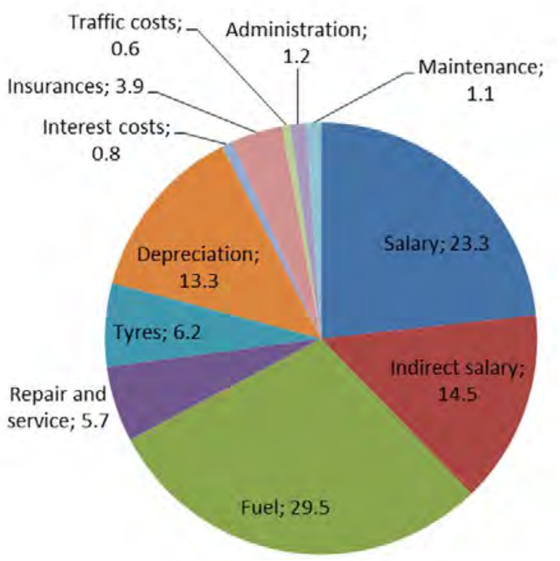

Figure 2. The share of cost factors in timber trucking in Finland (Source: Statistics Finland, August 2017).

Literature

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Cost calculations of waterborne and rail transport of wood in Finland

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Background

In Finland, rail transport covers 22,6 % and waterborne transport 2,2 % of all domestic wood transportation (Strandström 2018). However, the importance of rail and waterborne transport varies regionally. Transport costs are the major factor in national simulation models of wood transport flows. The national models are essential in estimations of regional wood flows in Finland. Transport statistics do not cover regional flows in detail and only models can be utilised when estimating the future development of flows. Transport flow models are important for national and regional transport authorities in transport network development and planning.

Material and Methods

Estimation of waterborne and rail transport costs in Finnish timber transport is difficult due to a limited number of transport service providers. Transport prices (annual and per unit) paid by Finnish forest sector companies is compiled in Metsäteho's yearly statistics (Strandström 2018).

Juronen (2017) compiled in her Master's Thesis information about the current costs and affecting factors in timber transport by vessels (Table 1). Since the sizes and types of vessels and other factors in the operative environment vary notably, the cost information should be considered solely indicative.

Table 1 Costs of vessel transport of timber as well as affecting factors (Juronen 2017)

Type of cost / cost factor	Unit	Average	Affecting factors
Ownership of the vessel	Year	15	Mostly bought second-hand
Volume of pulpwood	m^3 per load	1 647	
Volume of logwood	m^3 per load	1 788	
Transport volume	m^3 per year	78 663	Type of vessel, market situation
Operating hours (incl. empty)	h/a	1 986	Market situation
Fairway dues	€/a	28 000	Only maritime area (not IWW)
Port charges	€/a	29 044	Not if transported from islands
Capital costs (vessel)			
Acquisition cost (excl. tax)	€	348 714	
Financing costs	€/a	9 833	
Duration of use	a	16	
Depreciation	€/a	30 900	
Residual value	€	181 522	
Capital costs (vessel's loading equipment)			
Acquisition cost	€	290 000	
Duration of use	a	7	
Depreciation	€/a	57 000	
Time consumption			
Transport distance (loaded)	km	193	Area of operation
Travelling speed (empty)	km/h	12	Type of vessel
Travelling speed (loaded)	km/h	11	Type of vessel
Loading	min/m^3	0,55	Type of loading place
Other operations at the loading place	min/load	137	
Unloading	min/m^3	0,34	
Other operations at the unloading place	min/load	60	

Type of cost / cost factor	Unit	Average	Affecting factors
Personnel costs			
Labour work at the vessel	h/season	7 793	Vessel's size
Average wage	€/h	24	
Incentive earnings	€/a	6 716	
Non-wage labour costs	€/a	42 240	
Training	€/v	3 100	Area of operation
Fuel costs			
Fuel consumption	€/h	143	Area of operation, vessel type
Fuel price	€/l	0,62	
Other costs (excl. VAT)			
Insurance	€/a	14 013	Area of operation
Survey	€/a	863	Type of vessel
Maintenance	€/a	28 750	Vessel's age
Administration	€/a	7 067	
Other	€/a	1 000	

Even though freight rail transport market was opened to competition in Finland in 2007, there is still only one major operator in domestic rail freight services. For this reason, transport price information from Sweden has been applied in national transport studies (with some adjustments to Finnish price level). Transport prices have been applied in studies 1) estimating impacts of changes in wood demand on national transport flows (Iikkanen et al. 2010, Räsänen et al. 2016), 2) planning national network of timber terminals for rail transportation (Iikkanen & Lapp 2018), and 3) estimating impact of HCT vehicles on rail transportation of timber, chips, and other commodities (Lapp & Iikkanen 2017).

Discussion

Challenges in forming detailed cost models for waterborne and rail transport of timber hinders creation of more realistic national transport models. Especially at regional level the models can not consider factors such as electrification of rail tracks or competitive situation between transport modes. However, transport models can still provide a good starting point when estimating impacts of major changes in the transport market or its operative environment. Modelling work should always be complemented with stakeholder interviews in order to identify possible drawbacks in the models.

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Cost calculation of road transport

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Delivery of roundwood or biofuel to the consumer is one of forest operations and it makes a relatively large share of production and supply prime costs. Increase of delivery distance and fuel price affects road transportation costs significantly, however detailed planning of supply chains can make it more effective. The cost calculation allows to compare different delivery scenarios. Depending on the type of prepared assortment, it is possible to use roundwood or biofuel delivery scenario using different transport options. Data about average productivity, load size, delivery distance and fuel consumption used in cost calculation are obtained in previous studies.

1. Background

The technological process of harvesting involves logging, off-road and road transport of round wood, harvesting residues and wood chips (Sarmulis & Saveļjevs, 2015; Uusitalo, 2010). Delivery of roundwood or biofuel to the consumer is one of the forest operations and it is related with specific productivity parameters, which have impact on prime cost. Detailed prime cost calculation allows to identify the impact of various factors on costs of the production unit (Alsiņa et al., 2011; Grīnfelds, 2004). Distance, fuel price and fuel consumption have a big impact to increasing prime cost, therefore, the choice of delivery scenarios is very important. Depending on the type of prepared assortment, it is possible to use roundwood or biofuel delivery scenario using different transport options. Aim of this study is to find more cost-efficient delivery scenarios to determine impact of changes in the system on the costs of production.

2. Material and Methods

Cost calculation base model elaborated within the scope of COST action FP0902 (Ackerman et al., 2014) is complemented with standard economic methods and adapted for the technological process of harvesting or any other forest operation including systems consisting from several machines. Different scenarios of delivery to the consumer were compared during this study (Figure 1).

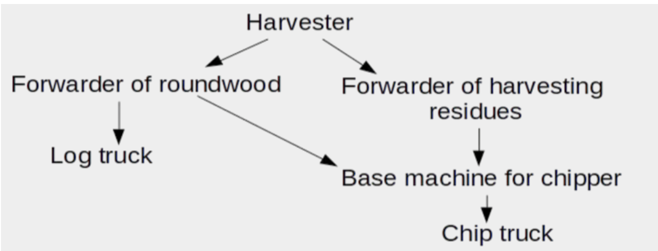

Figure 1 Potential delivery scenarios.

Data, which are used in cost calculations are summaries of information provided by contractors, service companies, dealers or obtained in previous studies (Kalēja, Brenčs, & Lazdiņš, 2014; Lazdiņš & Zimelis, 2015). To synchronize input data with service statistics from dealer centers, engine hours are used in calculation. The engine hours are also used to synchronize all time elements in the calculation, respectively, it is mandatory parameter, which should be obtained during time studies.

3. Results and discussion

Basic model version can be used to calculate and compare if it is cheaper to deliver forest biofuel as logs or chips (Table 1).

Table1 Example of output of cost calculation.

Calculation items	Harvester	Forwarder of round wood	Log truck	Forwarder of harvesting residues	Chipper	Chip truck
summary of costs, € per year						
investment costs	51 725	39 058	15 206	25 880	71 194	15 212
labour costs	62 637	62 637	72 692	62 637	60 765	72 692
operational costs	103 896	53 056	31 207	48 582	172 673	39 150
profit margin	10 913	7 738	5 955	6 855	15 232	6 353
total	229 171	162 488	125 060	143 955	319 864	133 406
productivity						
roundwood with bark, m^3 E_{15} h^{-1}	6.7	10.0	10.6	-	-	-
biofuel, LV m^3 E_{15} h^{-1}	-	-	-	37.5	96.5	23.9
amount of roundwood and biofuel produced per each unit of machinery per year						
total roundwood, m^3 per year	19 144	26 778	14 658	108 793	90 318	35 753
logs, m^3 under bark	15 955	24 125	13 205	-	-	-
biofuel (stem residues), m^3 per year	1434	-	-	-	-	-
biofuel (logging residues), m^3 per year	-	-	-	108 793	-	-
bark and other residues, m^3 per year	1 755	2 654	1 453	-	-	-
biofuel (wood chips), LVm^3 per year	3 443	-	-	261 103	216 762	85 807
output						
logs under bark, € per m^3	14.4	6.7	9.5			
biofuel, € per LV m^3				0.6	1.5	1.6

Sensitivity analysis can be used to determine, how road transport distance affects costs of production and to find threshold values for these parameters. Built in spreadsheet linear optimization functions can be used to determine the threshold values. Similar conclusions are also available in other studies (Väätäinen, Liiri, & Röser, 2006; Harrill & Han, 2012).

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Approaches for transport costing in Sweden

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There are several models available for costing of all transport modes. Official statistics of transport costs from an operators perspective are difficult to find, hence our calculations depend on input data from, commonly, a few companies within the sector.

Knowing the transport distance is key in transport costing and generally a parameter in pricing together with loaded weight. Calibrated Route Finder (CRF), the online route generation system, are used as a standard and the system is continuously developed. Recently, a project has received financing for an inventory of all roads in Southern Sweden. Possibilities for transport payment according to resistance in CRF, instead of only distance, are under development and so are an expansion of the network of nodes in CRF in order to improve accuracy of pathways through traffic circles as well as entrances and exits from highways.

For truck transport, the Excel extension SÅcalc is openly available and continuously maintained by The Swedish Association of Road Transport Companies. However, SÅcalc is not developed for the purpose of comparing different vehicle sizes, which have been an important task in the latest years. To better address this problem a new model has been developed by Skogforsk, called HCT-kalkyl. This tool has the ambition of merging the abilities from SÅcalc and two other commonly used Excel tools.

In contradiction to transport allowance, we know that the actual transport costs are not caused by loaded weight and distance only. So if we want to analyze the effect of logistical strategies we would must also add the amount of driving without load, the terminal times and perhaps model shifts and schedules in order to analyze the system performance. For these applications, simulation tools are preferable. Many interesting simulation analyzes has been done on the transportation system for forest fuel.

For other transportation modes, and for the combination of transport modes we have open access to the Samgods tool. It is used to perform analyzes, estimates and forecasts for freight traffic by road, rail, aviation and shipping. It models freight traffic at national level, with the ambition of modeling regional levels in the future. The model includes transport costs, but it is customized for forecasting and analyzing on a national economic level, not to calculate costs for individual flows from an operator perspective.

A model for rail transport costing needs to be complex in order to capture the big variety of transport systems and parameters. The most updated and detailed model today is EVA-Rail (described by G. Troche 2015). It is an Activity-Based Rail Freight Costing model for calculating transport costs in different production systems.

Roundwood transport pricing and cost modelling approaches – examples from Norway

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Truck pricing practices

Forest owner associations in Norway often sell wood at roadside to local sawmills and at terminal for multimodal deliveries ($DAT_{terminal}$, FAS_{PoL}). Consequently, both suppliers and mill customers have transport service buyer roles for road transport. The public road network in Norway has considerable variation in truck maximum axle loads and GVWs (up to 60 t for logging trucks, BK). Truck transport tariffs are therefore BK-specific with regional adjustment for transport conditions. All tariffs specify the BK-specific price for service payment per cubic meter (NOK/m3fub) with a fixed component (NOK/m3) and variable component (NOK/m3km). Transport distances for payment are set in the national routing tool (Skog-Data TRProd) which chooses the lowest cost route based on the combinations of route distances per BK.

Table 1. Variation in stipulated tariffs with increasing GVW (interior zone).

	BK 4 – 50 t	**BK5 – 56 t**	**BK6 – 60 t**
Tariff (NOK/m3fub)	26 + 0,72 (km)	24 + 0,67 (km)	22 + 0,62 (km)

A recent review of pricing practices between regional transport organizations revealed some variation. Breakpoints for the variable price component are used in a few cases, where longer distances occur. In the interior a single service provider could have 1-5 tariffs per service buyer (and BK), varying between assortments and topography/road network. In the coastal region a single sawmill could use a single tariff (common for pine and spruce) because of the small supply areas, while a pulpmill may have up to 10 tariffs. A typical range for 60t tariffs is shown below.

Table 2. Variation in BK6 (60t) tariffs between topographies (coastal zone).

BK6 – 60 t	Fixed component (kr/m3)	Variable component (kr/m3km)
Even topography	25	0,60
Varied topography	28-28,5	0,75-0,80

For a supply organization contracting transport services in both the coastal and interior zones, two different levels of tariff were used; one for loads following valleys to lowland mills and another for loads travelling over passes to mills in adjacent valleys. In this case, transport services were contracted via multiple service provider organizations and tariff structures were simplified to a single tariff per assortment and species.

Tariff "extras" were common for all three organizations. These include additions for 1) unassisted unloading at mill site, 2) "forwarding" stacks (truck only) out to the nearest road approved for both truck and trailer, 3) other difficult landing conditions 4) volumes less than a full stack (15 m^3) and 5) truck-operator scaling at isolated shipping terminals. 10 % payment reductions for backhauling (both reductions) are implemented per transport order by either the transport manager or the service provider. Adjustment of tariffs according to changing diesel costs are implemented per quarter when price variation exceeded specified limits. All organizations had annual tariff negotiations. The current tariffs levels are based on historical developments with annual adjustment according to logging truck cost indexes (SSB). In the case of disagreement, costs for single route scenarios are analyzed. It was noted that tariff curves could often be flatter than the underlying cost curves so that profitability on long tours (> 150 km) is reduced when backhauling potentials are not exploited. At the same time two organizations noted that particularly short tours (high proportion of forest roads with urban congestion or terminal queuing) could frequently have low profitability.

Truck cost calculation method

Although it is argued that tariffs must provide profitable operations for average distances and typical conditions, cost calculation methods should adequately reflect the costs of a specific operating environment. The presentation shows a simplified calculation approach for truck costing. The model calculates the costs per tour (subsequently per transported unit) using three cost components: fixed hourly costs (F_{hr}), variable costs per km (V_{km}) and variable costs per material handling (V_{mh}). In this context capital costs are driven by the average value bound over the respective lifetimes of the 3 respective components (truck, trailer, loader). Average interest is handled as a fixed annual cost under F_{hr} (NOK/hr) while average depreciation is treated as a variable cost as a function of actual wear of the truck and trailer in V_{km} (NOK/km) and of the wear on the loader in V_{ha} (NOK/load handling). The approach lends itself well to costing for varying transport environments with the various extra features needed for estimating tariffs in practice. This framework was adapted to segment specific cost modeling for a Norwegian calibration of the Swedish calibrate route finder (CRF). Combining the two approaches made it possible to calculate the operating margin (%) as a function of distance and transport environment (example with respect to road curvature is shown below left).

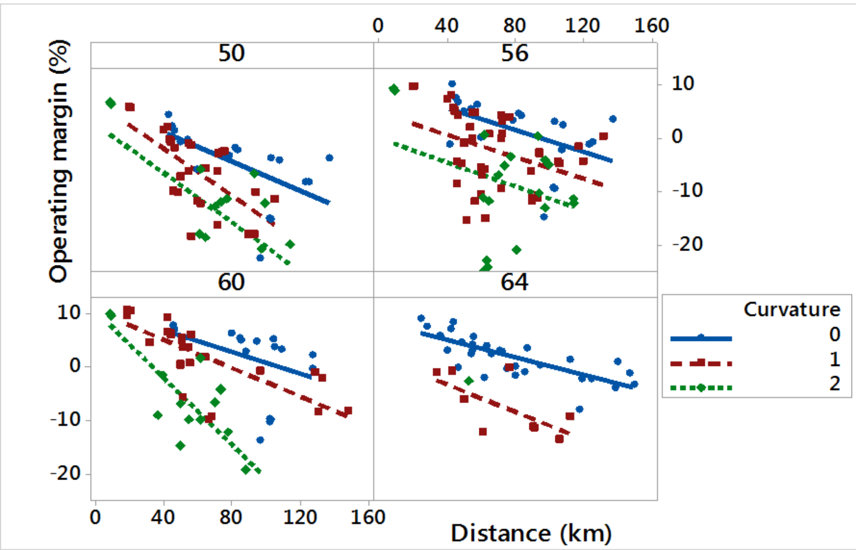

Figure 1. Calculated truck operating margins (% of income during individual deliveries) for varying GVWs (50-64t) and transport environments. After Fjeld et al.

Pricing and cost calculation for multimodal transport

Because of the high road transport costs, multimodal systems are competitive options in Norway. System rail solutions are used for both domestic and export destinations, with 800-1750 m3 per delivery. Pricing is regulated by multi-year contracts with commercial rail service operators after tendering. Where volumes are collected from multiple terminals, pricing can be divided into a fixed price per period for holding capacity and a variable pricing according to delivered volumes per terminal during the period. The general method is presented which has been used for studies in southeast Norway (Fig. 2).

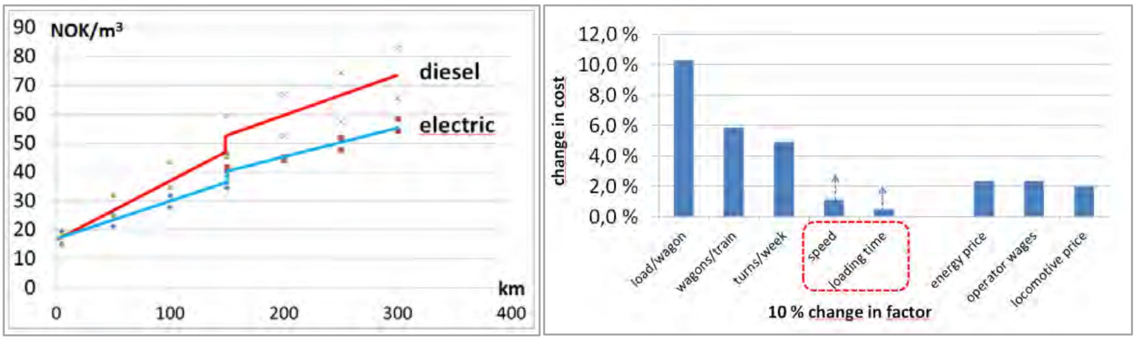

Figure 2. Rail transport cost curves (NOK/m3) over varying distances (km) for diesel (red) and electric locomotives (blue) with sensitivity analysis on right. After Fjeld & Skjølaas (2016).

Short-sea shipping with mini-bulker (coaster) vessels is used for both domestic and export deliveries. Full cargo volumes for domestic deliveries can range from 2000-3000 m^3 while cargoes for export are typically 4000-5000 m^3. Wood for key domestic customers can be sold at mill port-of-discharge (CIFPoD) and in this case the supply organization is the service buyer and vessel freight rates are agreed under contract-of-affreightment terms (COA). Because of the limited volumes per port-of-lading, a full cargo is often collected at 2-3 designated wood terminals. Annual pricing agreements take into consideration the expected distribution of volumes per port-of-lading as well as the availability of other cargoes to reduce ballast distances. The general time charter (TC) method is presented which was used for studies in the mid-coast region.

Such cost calculation approaches represent simplifications of reality and further development is possible to better reflect cost-drivers for pricing.

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2. Development of transport system performance

The effect of truck size and transport distance on timber trucking performance – case study in Central Finland

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Background

Higher gross vehicle weights (GVW) in trucking have been witnessed in Finland and Sweden during the recent years. The need to decrease transport costs as well as to decrease emissions are the main reasons for the increased vehicle weights. In Finland, GVWs of 60, 68 and 76 tons are legal for roads, whereas heavier transport units up to 104 tons are operating with special permits in predefined routes. Predominantly truck-trailer units with GVWs of 68 tonne (3+5 axles) and 76 tonne (4+5 axles) are trucking timber from roadside (RS) storages in Finland, 76 tonne trucks being the most typical transport unit at the moment. With a special permission for trafficking a 84 tonne truck-trailer unit (5+5 axles) is trucking timber from RS storages to delivery places in predetermined routes in Northern Finland. According to recent study of Palander & Kärhä (2017) and feedback from the trucking operators, there are sometimes difficulties to achieve maximum filling decrees especially by 76 tonne truck-trailer unit depending on the dimensions and fresh density weight of timber. Today, multiple wood assortments with varying lengths are harvested and transported from logging sites to delivery places. This poses a challenge not only to logging operations but also to timber trucking.

Main objective of the study was to evaluate timber trucking performance in function of transport distance and the size of a truck-trailer unit in a procurement area of one timber supplier in Central-Finland.

Material & Methods

Study was carried out by discrete-event simulation method. Simulation environment was compiled corresponding practical operations of one timber supplier in Central Finland with certain simplifications. Simulation model consisted of 4 timber truck-trailer units, 12 delivery places, active RS storage matrix, monthly demands of timber assortments of each delivery place, road network, ruling for the selection of timber, delivery place selection and routing as well as work shifts and time-element functions for trucking. Authentic RS storage data representing the operating area of supplier was used. Digiroad-data of road network was used to define shortest routes between RS storages and delivery places. Timber demands of delivery places for each truck option were rescaled to meet the trucking capacity of each truck size. Each scenario was replicated 5 times representing one year supply of timber. Truck sizes with GVWs of 68, 76 and 84 tonnes together with the road distances of -15km of the prevailing distance (PD), PD, +15km of PD and +30km of PD from roadside storages to delivery places were simulated. For the each truck size, truck load and timber assortment the maximum loading volume were calculated. In total, 25 wood assortments were included in the study. For the timber trucking from RS storages to delivery places, time element functions of Nurminen & Heinonen (2007) was used. For the cost accounting, cost factors and values were obtained from the Finnish Transports and Logistics SKAL and the truck dealers.

Results & Discussion

The average loads for truck sizes of 68, 76 and 84 tonne truck-trailer units were 51.3m³, 55.6m³ and 63.7m³. Biggest truck-trailer unit had bigger frame and weight capacity in tractor's load space to utilize especially for the timber lengths which were able to load as two bunches in a line due to the longer load space (approx. 2 m longer). Annual trucking performance was increased by 4.5% and 14.2% while comparing 68 tonne trucking unit to 76 and 84 tonne units in BAU. Of annual working hours more time was spent in loading, driving between RS piles and unloading when compared bigger truck-trailer unit to smaller ones. On the contrary, time for driving unloaded and loaded decreased (Figure 1).

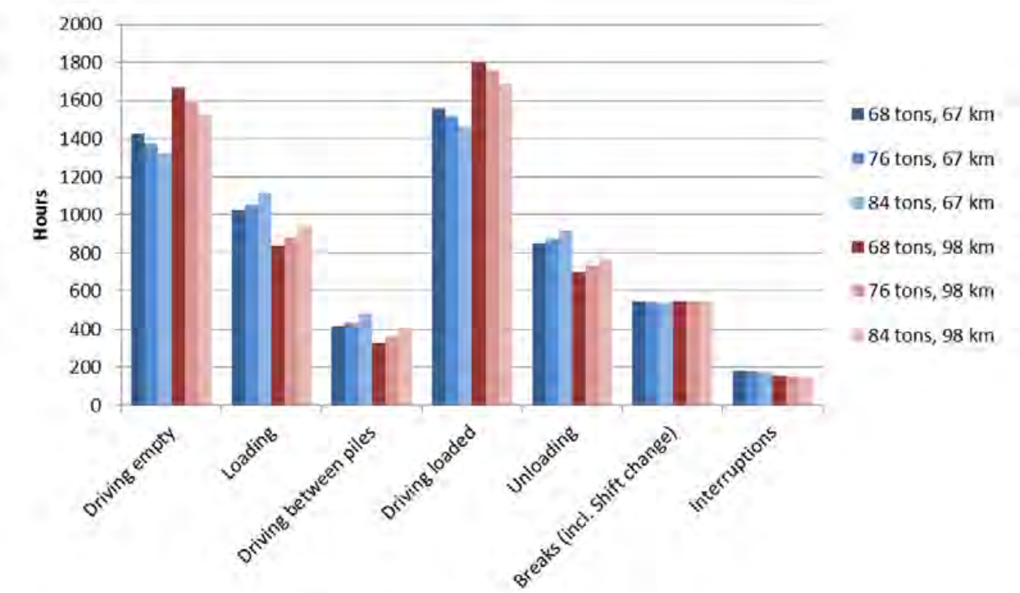

Figure 1. Work element distribution within 68t, 76t an 84t trucking units and two different average transport distance (67km and 98km). Average transport distance represents half of the hauling cycle.

Finally, cost accounting for each truck-trailer concept resulted unit costs in euros per transported cubic meter. While comparing 68 tonne trucking unit to 76 and 84 tonne units, timber transport costs from RS storages decreased by 2.0% and 8.1% in average transport distance of 68km, whereas in distance of 98km decrease was 3.3% and 9.6%, respectively.

While discussing the validity of the results to practice one has to address some remarks of the study. In the simulations, trucks were in full use (July off-shift) having approximately 5,470 operating hours per annum. Loads were collected always from the RS storages, without using intermediate storages or terminals, which belong to the normal trucking procedure. Moreover, all RS storages were next to always trafficable roads and there were no bridge or route constraints in use. Same work element functions and trucking speeds were used for all truck sizes due to the inexistence of the data from the truck sizes of interest. In addition, load sizes were calculated by fixed values of average winter fresh densities of wood assortments and having a loader always attached in trucking units. Unloading was always carried out by the truck's loader. However, results are valid within a given case specifications. Moreover, the first effort of modeling timber trucking guides the development of the model to match closer to the trucking operations in practice in the future.

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Modeling timber truck speed and fuel consumption in Finland based on CAN bus data

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1. Background

Information on timber truck speed and fuel consumption in varying conditions is needed for route optimization. Data on timber truck speed and fuel consumption can be extracted from the CAN bus of a truck. Additional data can be spatially joined with the CAN bus data and used as explanatory variables in modeling driving speed and fuel consumption.

2. Material and Methods

A follow-up study was started in April 2018 with three timber truck entrepreneurs. Entrepreneur A operating in Northern Finland has 8 trucks whereas entrepreneurs B (3 trucks) and C (2 trucks) are operating in Southern Finland. All vehicles are made by Scania and have a maximum gross weight of 76 tonnes. Scania Fleet Management System is operative in all the trucks. Driving speed and fuel consumption are recorded at 10-minute interval. Data can be retrieved via REST interface maximum 3 months back. The dataset here is from April to June.

Digiroad is the Finnish national road and street database, which contains both road geometry and road attribute data. One of the attributes is functional class, which describes the importance of a route for traffic.

2. Results and Discussion

Functional road class seems to explain some of the variation on driving speed and fuel consumption as the speed is lower and consumption higher the lower is the level of a road (Figure 1, Figure 2). The average speed was highest on Class I main roads (77 km/h) and lowest on Class II private roads (28 km/h). Correspondingly, the lowest fuel consumption was reached on Class I main roads (51 l/100 km) and highest on Class II private roads (89 l/100 km).

However, there is still plenty of unexplained variation left which could potentially be explained by introducing additional explanatory variables. The highest fuel consumption observations may result from driving when loading, because they were measured when there was only a small movement during the 10-minute interval.

In addition to continuing CAN bus data collection – preferably with 1-minute interval – additional data needs to be collected and analyzed. Especially fuel consumption is strongly affected by vehicle weight. Discussions with forest industries are currently ongoing to obtain mill gate measurement data. Additional explanatory variables describing road geometry and slope will be calculated based on road data and digital elevation models.

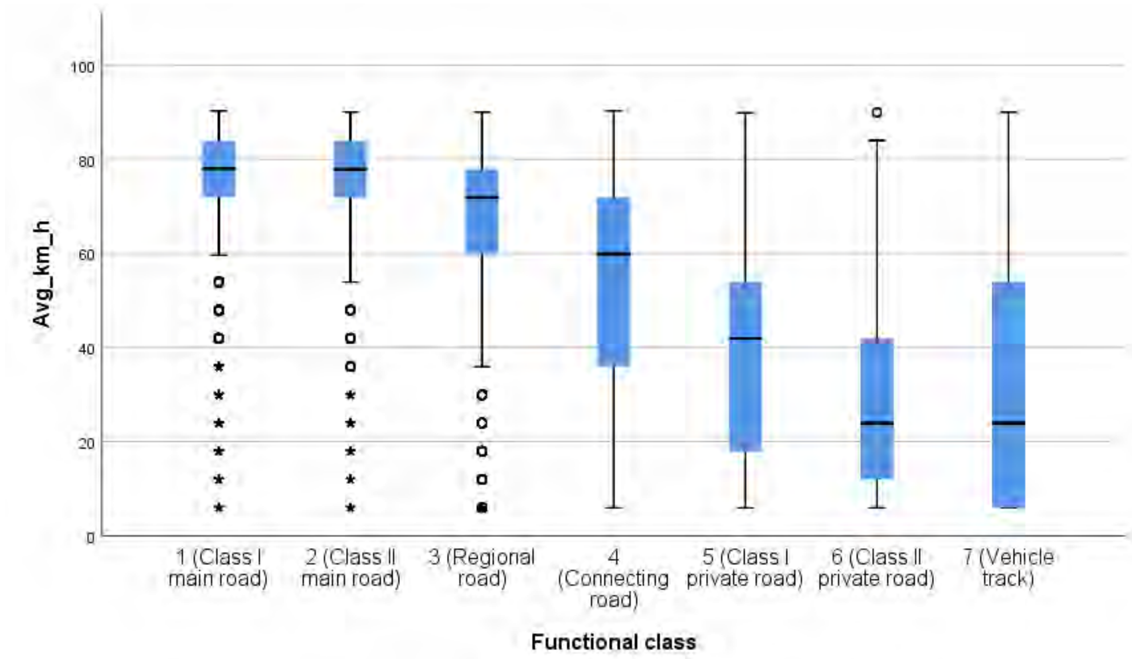

Figure 1. Average speed on a 10-min interval by functional class.

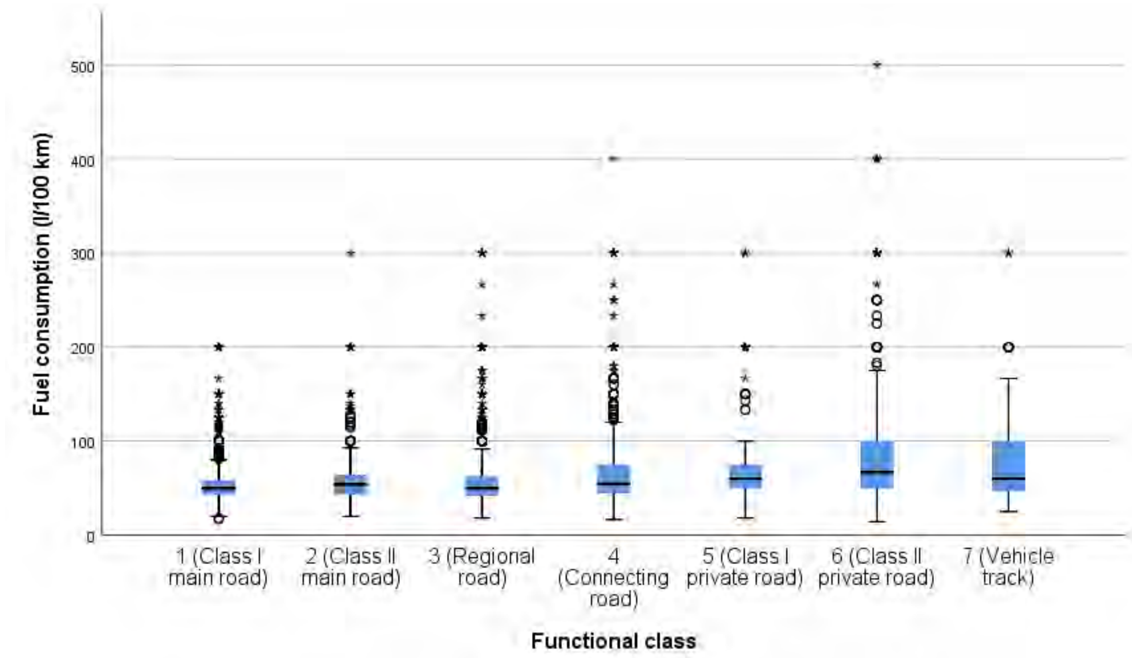

Figure 2. Average fuel consumption on a 10-min interval by functional class.

An overview of the latest transport development studies from Sweden

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BK4 (Load Class 4) is now implemented on a limited road net. Almost 10 % of the national road net is allowed, and so far, only a very few kilometers of local roads. Still there are several private roads as well as local ones that need to be upgraded to BK4 before traffic from forests will be feasible. The problem is that many industries are not situated directly on a national road. As from 2019-06-30 all special permissions for 74 tonnes will expire. New permits for longer HCTs is still possible and even desired. This is greatly simplified by a new solution for giving permissions so that the lead time has been reduced from around six years to less than six months.

An updated "HCT roadmap" has been compiled and is currently finalized to be printed during October. The main goal for this work has been to identify haw far we want HCT development to have come by 2030 and what steps must be taken by 2020 and 2025 to get there. The work group behind the roadmap are from the authorities as well as from vehicle manufacturers and researchers within various relevant disciplines.

Skogforsk has recently received funding for participation in a large research approach called Triple F (Fossil Free Freight) where we will play some part looking after forestry demands. The main goal of the research programme is to reduce GHG with 70% by 2030. Budget is set to at least m€ 30 over 12 years and 53 consortium participants where Lindholmen Science Park/CLOSER, RISE (Research institutes of Sweden) and VTI (Swedish Road and Transport Research Institute) are the leading ones.

ETTpush – tests of auxiliary hydraulic hybrid drive on large timber trucks

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Transport capacity and maximum gross vehicle weights (GVW) have increased in Sweden. From 1985, the steps in this development has been from 51,4 to 56/60 (1995) and 60 tonnes (2005) to 64 tonnes (2015) and 74 tonnes (2018). This development, yielding both economic and environmental benefits, has to a large extent been driven by Swedish forestry through Skogforsk.

Increasing GVW has made it necessary to add axels to the road-train, to avoid excessive axle and axle-group loads. As a result, maximum axle loads have been reduced by almost a tonne, while weight and starting resistance have increased. This means that the larger trucks' ability to start under unfavourable conditions, such as uphill slope, muddy or icy roads, has become a critical factor. In a concept development project, Skogforsk studied a 74-tonne timber truck with auxiliary hydraulic hybrid drive on an axle on the link, for extra traction from start up to 30 km/h.

Figure 1. The ETTpush vehicle with the drive and auxiliary drive axles indicated in yellow

The results of the tests are that the geometry of the push-vehicle allowed road access to the same extent as for standard vehicles. Roadholding ability, under poor road conditions, was improved. Traction measurements (Fig 2). showed that the average tractive force was improved by 34 % on gravel, by 25 % on asphalt and by 26 % on "wet dirt", a mixture of wet soil, bark and sawdust.

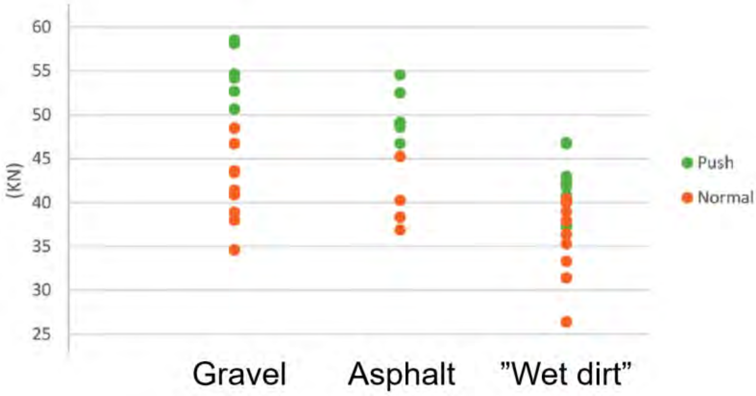

Figure 2. Readings from the traction tests using a load link dynamometer.

The experiences from the project include suggestions for improved design of the push-function, that can be incorporated in renewed experiments with auxiliary drive axles.

Variation in wagon payloads for rail deliveries of pulpwood

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1. Introduction

Recent years have seen increasing deliveries of roundwood by rail. For the Norwegian rail network earlier studies have showed the influence of wagon load profiles and their utilization on transport costs. The goal of this study was to quantify the variation in roundwood volume per wagon on sgnss timber wagons (JBV-L profile), and the effect of driving factors on this variation.

The study was focused on a rail solution delivering approx. 1,7 million m3 of pulpwood annually with three deliveries per day. The study material consists of a sample of 180 fmb-scaled wagon loads from selected departure terminals supplemented by a one-year register of estimated wagon volumes at the receiving mills.

Figure 1. 9-bunk SGNSS timber wagon with 3 stacks.

2. Results

Regarding the fmb-scaled sample at departure terminals, 58 % of the variation in m3 per wagon was driven by the sum of the average stack lengths per wagon (dm), 13 % was driven by average stack height (dm), and 12 % by average stack density (fm %). 37 % of the variation in volume per wagon could be estimated by the number of stacks per wagon, alone.

Table 1. Effect of various loading dimensions on wagon payload.

Factor	Regression	R^2	p-value
Sum stack length per wagon (dm)	9,76 + 0,4030 (dm)	57,6%	P < 0,000
No. stacks	51,6 + 4,213 (no.)	35,7%	P < 0,000
Average height (dm)	-5,6 + 2,864 (dm)	12,8%	P < 0,000
Average FM%	24,79 + 69,2 (%)	12,1%	P < 0,000

The key factor for achieving full utilization was the distribution of sum stack lengths (Fig. 2). For 5 stacks of 3 m pulpwood the average wagon volume was 76,3 m3. The corresponding figures for 4 and 3 stacks with mixed lengths were 66,4 and 64,8 m3.

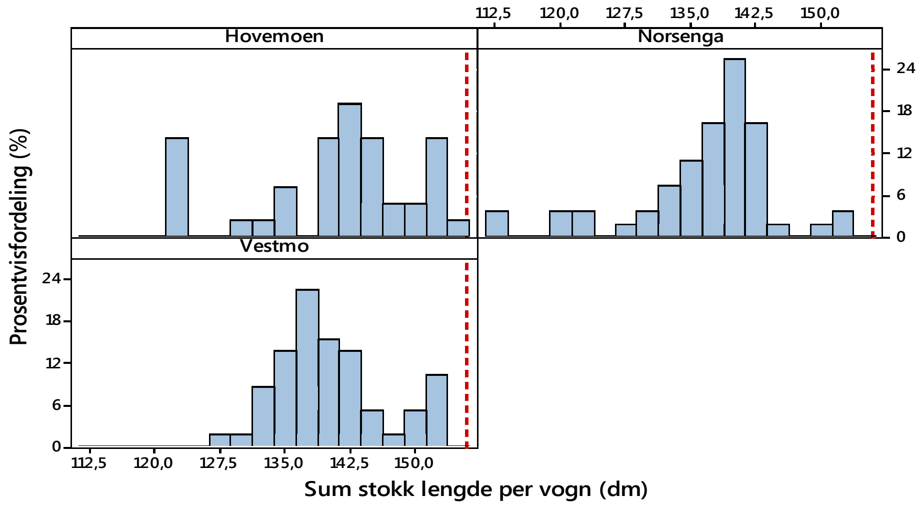

Figure 2. Distributions (%) of sum stack length per wagon (sum stokk lengde in dm) per wagon for respective terminals.

3. Discussion

Some differences were observed between the departure terminals, but most of these variations were a result of the log lengths and dimensions received. Terminals using excavator-based loaders with elevated operator cabins had slightly higher average load heights than the terminal using front-end loaders. Otherwise, the highest stack density (fm %) was achieved at the terminal with the longest available time frame for loading (0,87 h/wagon). The lowest wagon volumes found in the data from the receiving mills came from the terminal with the shortest available time frame for loading (0,11 h/wagon).

3. Seasonality in transport

Costs impacts of seasonal variation and potential actions

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Background

Wood production demands for constant supply of wood, but problems with bearing capacity of soil and roads causes seasonal variation in wood supply. This variation causes additional costs with personnel, equipment, and storage in wood supply chains. The growth in the Finnish forest sector production increases need to harvest also in areas with weaker bearing capacity. On the other hand, the climate change is expected to increase risks of growing seasonal variation.

Material and methods

A study by Metsäteho Oy (Venäläinen et al. 2017) estimated the costs of seasonal variation on timber supply chains and identified potential actions to be taken to decrease the costs in the future. The costs were calculated based on available statistics on machinery use and thawing periods as well as a questionnaire sent to forest companies. The potential actions to reduce impacts of seasonal variation were identified and described with help of available research and pilot projects as well as work shop discussions with forest companies.

Results and discussion

Seasonal variation causes annually 70 MEUR additional wood harvesting, transportation, and storage costs in Finland. The additional costs are mainly caused by thawing periods, other bearing capacity restrictions on roads, restrictions in soil trafficability in forests, and variations in wood demand at forest sector production facilities. The major share of additional costs is composed of 1) capital costs of excess harvesting machinery capacity (59 % of annual costs), 2) decrease in processing value of wood during seasonal warehousing (13 %), and 3) renovation, and winter maintenance costs of private roads (10 %) (Figure 1).

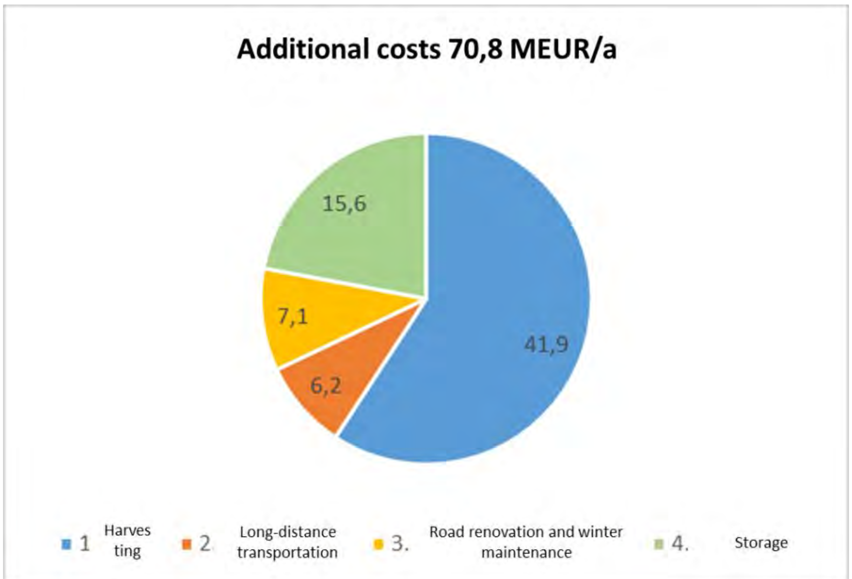

Figure 1. Additional costs in wood supply chains caused by seasonal variation (Venäläinen et al. 2017)

In this study, 19 potential actions to decrease seasonal variation and related impacts are described. These actions are categorised as actions related to Data, Planning, Improved bearing capacity, or Development of Equipment (see actions for roads and long-distance transportation in the Table 1). In a short term, the following actions are valued as the most potential ones: 1) Utilisation of the soil trafficability map, 2) Development of trafficability classification for private roads, 3) Improving the bearing capacity of private roads by developing competence of road cooperatives, 4) Advancing the utilisation of new solutions in harvesters, and 5) Improving the acceptability of summer harvesting.

Table 1. Actions for roads and long-distance transportation.

Data	
Development of a tool for estimating trafficability on private roads	Improved availability of up-to-date information on thawing period
Planning	
National database on timber terminals	
Bearing capacity	
Improved planning of private roads (by increasing competence and tools)	Improving bearing capacity of private roads (ash roads, compaction, etc)
Increased need for roads on drained peatlands, database on already available roads needed	
Equipment	
CTI in long-distance transportation	New type of tyre solution for timber trucks

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User experiences of Central Tire Inflation Systems of timber trucks in Finland

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Introduction

Seasonal limitations in bearing capacity hamper the year-around wood procurement. According to Rieppo (2006), seasonal bearing capacity problems causes an additional cost of about EUR 100 million per year for the Finnish forest industry, of which about 65 million is due frost heave. Suitable tire pressure is important to ensure the safety and reliability of transport and to maximize the benefits of the vehicle for heavy vehicles.

With the Central Tire Inflation (CTI) system, the driver can change the tire pressure on the vehicle while driving to match the prevailing road conditions and the load situation. The benefits of operating with this CTIS technology mentioned in the literature include: (*i*) reduced road surfacing and/or base course requirements, (*ii*) reduced road maintenance, (*iii*) reduced driver fatigue and medical complaints, (*iv*) lower vehicle operation costs, (*v*) increased vehicle mobility, (*vi*) extended haul seasons (Ghaffariyan 2017).

The aim of the study was to find out the user experiences of CTI from timber transportation entrepreneurs' through interviews with a questionnaire. The study also investigated entrepreneurs' perceptions of the benefits of the system among the various stakeholders and how the costs of using the system should be financed by entrepreneurs.

Material and methods

The study material was collected by telephone interviews from entrepreneurs owning a timber truck or trucks with CTI system. A list of vehicles and entrepreneurs was obtained from Metsähallitus, a state-owned enterprise that runs business activities in Finnish forests, and 16 of the 21 entrepreneurs in the list answered the questionnaire.

All enterprises had a TIREBOSS-system, and in addition, one enterprise also had Syegon's system. Most of the vehicle combinations with the CTI consisted of a four-axle truck and a five-axle trailer, but other combinations of three or four axle trucks and four or five axle trailers were used as well. In all cases, the system was installed on all axles of the trailer, but there was variation in the number of axles in truck.

Results and discussion

Entrepreneurs were asked whether higher transported volume was possible by CTI than by a timber truck without CTI, and according to the responses, the volume of transport was only slightly higher for all types of seasonal bottlenecks, with average values ranging from 2.00 (SD = 1.06) for surface weakening due to autumn rainfall to 2.31 (SD = 1.16) for surface spring thaw weakening (Figure 1). According to five entrepreneurs, when driving on a CTI truck, the length of the transport season was no difference compared to the normal timber truck, and according to two entrepreneurs, the difference was only a few days apart. According to four entrepreneurs, the transport season was extended from two weeks to two months per year, and in the best case, there were no restrictions at all.

Under difficult circumstances, the system was considered to be the most useful in snowy conditions and hills, but in all of the conditions mentioned in the survey, the system was found to be on average only a little help. CTI was found to help in a number of other situations, such as driving on a wet surface in the summer, driving on a soft and very fine sand, driving in a condition where hard ridge of snow is breaking under the tires or where forest machine has broken the road and driving on a coarse aggregate. According to one entrepreneur, spring-levelled roads are always driven first with lower tire pressures preventing the sharp stones on the surface causing tire crunches as the tire stretches, leading to savings in tire expenses. According to average responses, CTI did not have clear effect on tire expenses or fuel consumption (Figure 2).

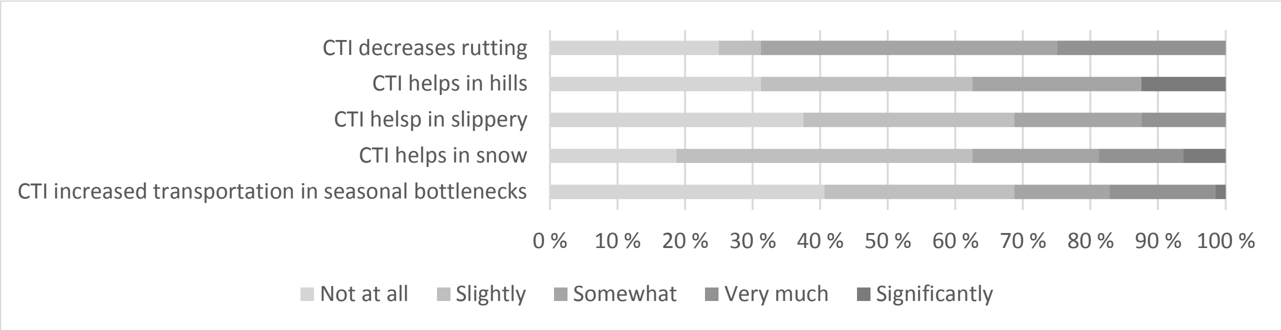

Figure 1. The effect of CTI system on trafficability.

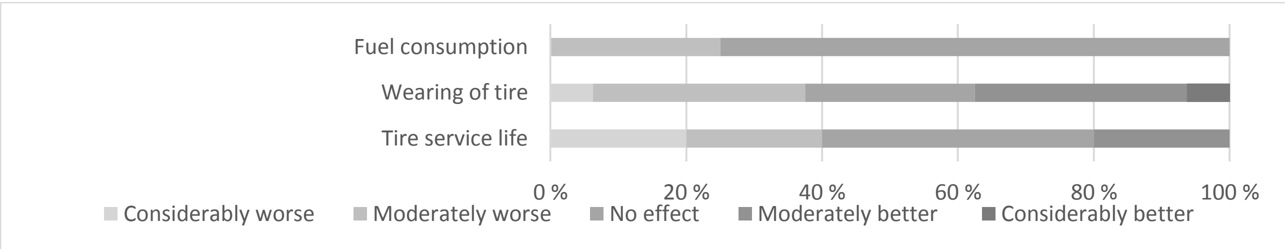

Figure 2. The effect of CTI systems on tires and fuel consumption.

Based on these results, the entrepreneurs' experience of CTI differs from previous literature in that the benefits of the system are not as unambiguous and significant as expected. The expensive initial investment and the non-existent or low impact on the fee, together with the risk of breakdowns caused by the device, make the CTI as an investment unprofitable from the entrepreneur's point of view. In order to improve the cost-effectiveness of CTI trucks, the entire wood procurement chain should consider the trucks equipped with the CTI in planning, so that the benefits of the CTI can be utilized as fully as possible. Adequate number of CTI allocated roads is a prerequisite for the cost-effectiveness of the CTI system.

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Seasonality of truck transport and transport lead-times in coastal Norway

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1. Introduction

This goal of this study was to quantify seasonal variation in production and harvesting for a forest owner association in coastal Norway. The study is a part of the Norwegian contribution to Era-Net MultiStrat (Fjeld et al. 2017, Westerlund et al. 2018).

The study started with a general mapping of demand and supply risks together with wood supply management processes. After this introduction, the work continued with analysis of three years of production and transport reports (2014-2016). The accumulated weekly production and transport volumes were used to calculate a weekly pace relative to the annual average (percent). Weekly roadside stocks were calculated as the accumulated production minus the accumulated transport. For each harvesting contract transport lead times per assortment were calculated by two methods; from first production report to last transport report (LTstart) and from last production report to last transport report (LTfinish). Daily weather records during the study period included temperature, precipitation, and snowpack from surrounding weather stations at varying elevations. Analysis methods used for the results presented are limited to regression analysis.

2. Results

For coastal Norway, the seasonal supply patterns are characterized by a mid-winter high season and lower summer/autumn season. Given that mill demand is relatively constant, transport managers seek to maintain an equivalent transport pace (m^3) without exceeding transport capacity limitations (m^3km). The resulting variation in production pace is therefore greater than variation in transport pace (Fig 1).

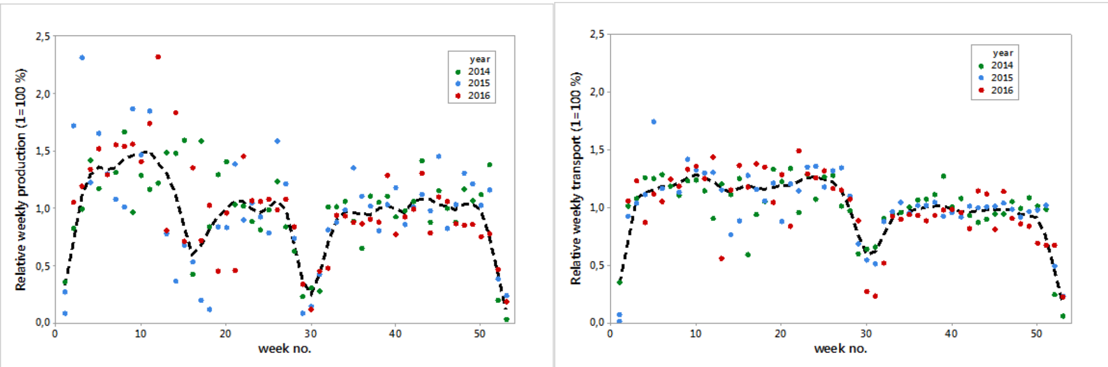
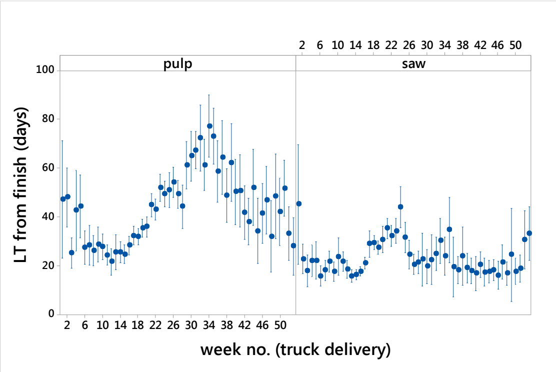


Figure 1. Seasonal variation in weekly production pace to roadside (left) and weekly truck transport pace from roadside (right)

This leads to a corresponding seasonal variation in transport lead times. For sawlogs, lead times peaked both just before summer holidays. For pulpwood, the peak coincided with the transition to the autumn low supply season (Fig. 2). Typical lead times varied between 10 and 45 days, depending on assortment and calculation method.



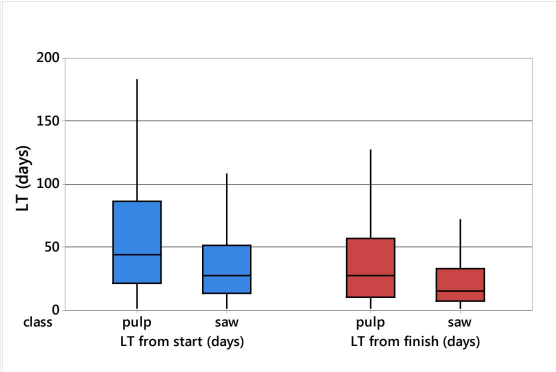


Figure 2. Seasonal variation in transport lead time (left) and box-plots for lead times per assortment (right)

Given the considerable variation in production pace, these were checked against weather data. A simple plot of production pace and temperature (summer and Christmas holidays excluded) shows the highest production at sub-zero temperatures, decreasing to a minimum production between 5 and 10 degrees, increasing slightly thereafter as temperatures rose towards 15 degrees. Structured interactions between temperature, precipitation and snowpack were significant ($p<0{,}001$) and together explained thirty percent of variation in weekly production pace. The individual effects of temperature, precipitation and snowpack alone were not statistically significant. The interactions are structured to follow a simple logic regarding their effect on bearing capacity and site availability where: 1) precipitation during sub-zero temperatures contributes to the snowpack enabling access to mire sites at medium and high elevations (winter), 2) low precipitation during higher temperatures provide periodic drying and access to silt and clay areas at low elevations (spring/summer) and 3) rainfall at low temperatures constitutes the worst case scenario with reduced bearing capacity on most site types during periods with limited evaporation and drying (autumn).

Variations in transport pace were limited due to mill demand, but were also checked against weather data. Within both high- and low seasons, a linear reduction of weekly transport pace was observed with increasing precipitation. However, average truck transport distances also increased during periods of low production pace. Forty-five percent of the weekly variation in transport distance was correlated with the variation in road-side stocks.

3. Discussion

In summary, the study provides a quantitative mapping of seasonal variation in production- and transport pace typical for a boreal coastal region. Decoupling production- and transport at roadside stocks enables a relatively even supply pace to customer mills, with the observed consequences for variation in roadside stocks and transport lead times. As reduced roadside stocks during low production periods were also associated with increased average transport distance to mills and terminals, these trends can reflect both transport policy and site availability restrictions. However, the particularly long transport distances during periods of low roadside stocks are more related to accessing sufficient wood for maintaining supply flows.

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4. Forest and public road networks

Bearing capacity on forest roads – ongoing empirical studies in Norway

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The majority of Norway's forest road network was built during a period of lower axle loads, truck lengths and GVWs than are standard for current logging trucks (24 m/60 t). At the same time, ambitions for more even wood supply year-round requires that the seasonal selection of harvesting sites must be better matched to their respective bearing capacities. Current Nordic classifications of terrain bearing capacity use between 3 to 5 classes. Corresponding classification of road bearing capacity (seasonal availability) vary between 2 to 4 classes.

The goal of the ongoing studies is to develop a simple classification scheme for forest road bearing capacity, with prediction of strength and rutting according to current or expected weather conditions. The work is a cooperative effort between the Norwegian Federation of Forest Owner Associations, Norskog, Skogkurs, NIBIO and all 7 forest owners associations.

Based on ongoing harvesting contracts from the forest owners' associations, roads are selected to provide variation in transport volume, parent materials and road construction. On each road, 3 to 5 road cross sections are selected for pre- and post-transport registrations. The registrations aim to quantify the effect of transport volume on road rutting and deformation during varying weather conditions. The cross-sections are measured before and after transport with laser-profilometers. Soil water content is measured in the substrate and road layers. Substrate and road bearing capacity is measured with Zorn light-weight deflectometers. Weather data during the relevant transport interval is logged from local weather stations.

The field registrations will be ongoing throughout 2018 and 2019 in southeast-, west-, and mid-Norway, with one field operator in each region. Preliminary results will be available by the end of 2018.

Ongoing work with HCT and public road deformation in Sweden - 74 tonne trucks and their impact on the infrastructure

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The Swedish Transport Administration (STA) is preparing the introduction of 74 tonnes as the maximum gross vehicle weight. In response to government assignments, two extensive investigations have been carried out, and the STA is now considering remaining knowledge gaps. The effects of 74 tonnes trucks on road degradation and increased need for road maintenance are of particular interest. STA has contracted Skogforsk and VTI, the Swedish National Road and Transport Research Institute to study these issues.

Deepening the knowledge about how road wear is affected by the introduction of 74 tonne vehicles under different conditions, the study will create an understanding of the cost / benefit ratio of heavier vehicles. Further, it provides decision support for the decision of allowable road-network for 74-tonne trucks and for maintenance and upgrade strategies. Skogforsk will be responsible for four of the seven work packages of the study.

Initially, currently available data for the study area will be compiled and combined with additionally needed data and measurements during the study period. Then, a geographically-linked, zero-ranking description of road load in the study area may be established. In cooperation with STA, data from PMSV3 and other systems are made available as geographic (spatial) data. Subsequently this material and spatial data from the Swedish Traffic Administration System, from new deflection measurements and data from SDC, the data hub of Swedish forestry will be combined to produce new road surface data. A final model, thus based on the best available data, will analyse the interrelationship between road degradation, gross vehicle weights, road construction, climate and soil type.

A cost-benefit analysis of the heavier trucks is performed in a special WP. The CBA will include direct factors such as extent of implementation as a percentage of total truck traffic, average direct hauling costs, cost and depreciation of additional road infrastructure investments (reinforcement of bridges as a probable main part) and cost of road maintenance. The CBA will also estimate indirect factors such as changes in carbon dioxide emissions, effects traffic safety and risk of accidents, traffic digestion performance of the road network (queueing and traffic jam), and effects on transport efficiency.

Ongoing work with road bearing capacity and new planning tools in Finland

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Background

In Finland, construction of forest roads is based on Metsäteho's Forest road guidelines (Forest road guidelines 2001), which also has the status as a national standard.

Forest roads have been classified to four separate surface layer classes in current standard and each class has different bearing capacity. Classes 1 and 2 are suitable for year-round timber transportation. Heavy traffic and loads are not possible in other two classes during the thawing period. Highest bearing capacity (80 MN/m^2 in spring) is in surface class 1.

Gross weight of combinations of vehicles were raised in 2013 to 76 ton and they have rapidly become most commonly used combinations on timber transportation. The majority of forest roads in Finland have constructed when gross weights were lower. For this reason, questions have been presented, if bearing capacity of forest roads ought to be raised.

Metsäteho's forest road guidelines is being updated and some of the most important sections including surface layer classes have already been updated. These materials can be found on Metsäteho's website and will be published later as part of a revised guidelines.

Material and methods

Surface layer classification were updated in close cooperation with Metsäteho ltd, Mitta ltd and road construction specialist of Finnish Forest Centre / Otso ltd. Calculation of bearing capacities are based on Odemark's equation.

Results and discussion

Minimum bearing capacities of surface layer classes were preserved unchanged (Table 1), but surface material quantities of all layers were recalculated (Table 2). Totally new, user-oriented tool to calculate road bearing capacity and thickness of surface layers were also developed (Fig 1).

The tool gives user possibility to change for example surface layer material, their E-modules, layer thickness as well as dimensions of road and do own calculations. User also get surface material volumes in cubic meters and in tonnes. Cross-sectional view changes all the time according user's choices and all the information seen in user interface can be printed.

Table 1. Updated surface layer classes.

Surface layer class	
1	Minimum bearing capacity in spring 80 MN/m^2
2	Minimum bearing capacity in spring 60 MN/m^2
3	Minimum bearing capacity in summer 60 MN/m^2, no heavy trafic / loads during thawing period in subsoil classes D, E and F
4	Minimum bearing capacity in summer 50 MN/m^2, no heavy trafic / loads during thawing period in subsoil classes D, E and F

Table 2. An example of updated surface layers on different subsoil – Class 1, minimum bearing capacity in spring 80 MN/m^2.

Subsoil class	A–F	A	B	C	D	E		F
Wearing coarse	**cm**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Crushed rock/gravel, #0–16 mm	m³-rtr / m	0.2	0.2	0.2	0.2	0.2	0.2	0.2
E-module 150 MN/m²	ton / m	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Base coarse/subbase	**cm**	**10**	**10**	**10**	**30**	**15**	**25**	**30**
Crushed rock/gravel, #0–32...56 mm	m³-rtr / m	0.5	0.5	0.5	1.5	0.7	1.2	1.5
E-module 200 MN/m²	ton / m	1.2	1.2	1.2	3.6	1.7	2.9	3.6
Filter layer	**cm**	**—**	**—**	**—**	**—**	**—**	**60**	**—**
(sand)	m³-rtr / m	—	—	—	—	—	4.0	—
E-module 50 MN/m²	ton / m	—	—	—	—	—	9.6	—
Filter fabric	type	—	—	—	—	N3	N3	N3
Embankment (C-class material) E-module 100 MN/m²	**cm**	**—**	**—**	**—**	**—**	**40**	**—**	**55**
Total	**cm**	**15**	**15**	**15**	**35**	**60**	**90**	**90**
	m³-rtr / m	0.7	0.7	0.7	1.7	3.2	5.4	5.4
	ton / m	1.7	1.7	1.7	4.1	7.7	13.0	13.0
Bearing capacity	In spring	270	155	85	85	80	80	80
MN/m²	In summer	270	200	115	105	85	80	110

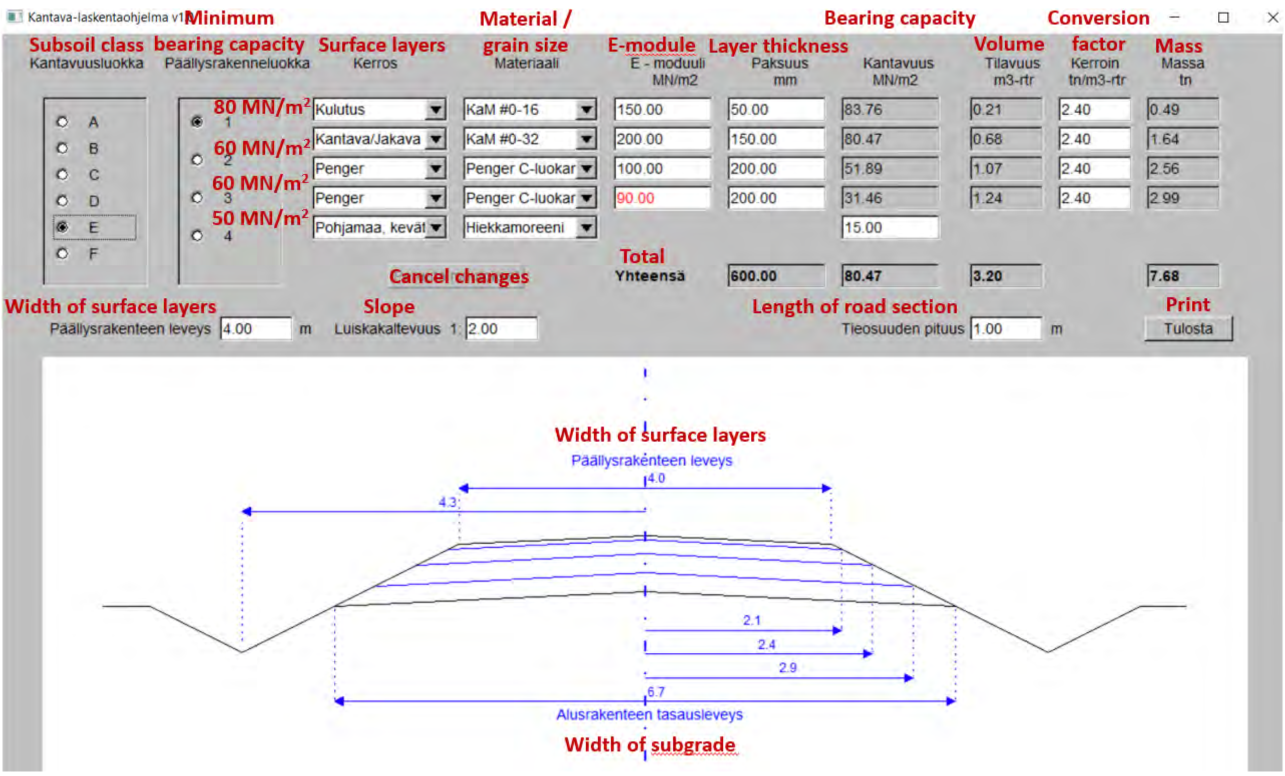

Figure 1. User interface of new, dynamic planning tool (Kantava-software).

References

Metsätieohjeisto. (2001). Metsäteho Oy. Available: http://www.metsateho.fi/metsatieohjeisto/