S2Biom

Delivery of sustainable supply of non-food biomass to support a "resource-efficient" Bioeconomy in Europe

S2Biom Project Grant Agreement n°608622

D3.4 + D3.6 : Annex 3
Logistical case study in Finland

17 November 2016

About S2Biom project

The S2Biom project - Delivery of sustainable supply of non-food biomass to support a “resource-efficient” Bioeconomy in Europe - supports the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through developing strategies, and roadmaps that will be informed by a “computerized and easy to use” toolset (and respective databases) with updated harmonized datasets at local, regional, national and pan European level for EU28, Western Balkans, Moldova, Turkey and Ukraine. Further information about the project and the partners involved are available under www.s2biom.eu.

Project coordinator

FNR
Fachagentur Nachwachsende Rohstoffe e.V.

Scientific coordinator

Imperial College London

Project partners

About this document

This report corresponds to D3.3 of S2Biom. It has been prepared by:

Due date of deliverable:	31 October 2016 (Month 38)
Actual submission date:	2016-11-05
Start date of project:	2013-01-09
Duration:	36 months

Work package	WP3
Task	3.3
Lead contractor for this deliverable	DLO
Editor	E. Annevelink
Authors	K. Väätäinen, P. Anttila & E. Annevelink
Quality reviewer	Rene van Ree

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services):	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Version	**Date**	**Author(s)**	**Reason for modification**	**Status**
0.1	28/07/2016	E. Annevelink	First version contents sent to WP3 partners with request for additions & comments	Done
0.2	07/09/16	K. Väätäinen & P. Anttila	Draft for review	Done
0.3	20/09/16	K. Väätäinen & P. Anttila	Final draft for review	Done
1.0	17/11/16	K. Väätäinen & P. Anttila & E. Annevelink	Final version	Done

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 608622.

Executive summary

In Finland, the operating environment in timber transports by trucks is challenging. Difficulties in logistics are caused by the high number of timber assortments and end use facilities, as well as high fluctuation in road trafficability, in the weather affecting bearing capacity of roads and in the timber demand of mills. Forest industry together with logistics companies and timber truck entrepreneurs has eagerly searched for the solutions for improving timber transport efficiency.

The logistical case study in Finland tried to find cost-efficient operation models in timber transport logistics by trucks in a preset case environment in Central Finland. As an objective of the study, the influence of a multi-assortment load method was studied and compared to a single-assortment load method. In the single-assortment load method only one timber assortment can be transported during one transport cycle whereas in the multi-assortment load method different timber assortments can be transported in the same load.

Discrete-event simulation was used for studying the timber truck transports for the Finnish case. Simulation model included four trucks operating in Central Finland and supplying 25 different timber assortments to 12 end-use facilities being eight saw mills, two pulp mills and two train loading terminals. The total timber demand of end-use facilities over one year was 258,000 solid-m^3.

The multi-assortment load method was on average 3.3% cheaper than the single assortment load method. In addition, the driving performance - presented as solid-m^3 of timber per 100 kilometers - was 4.0% higher with the multi-assortment load method. Small assortment piles at roadsides caused difficulties in efficient timber transport due to driving between piles and the need of loading many small piles for filling the entire load space. The multi-assortment load method decreased drastically the number of rides between piles and, therefore, improved the performance of the fleet.

The developed model can be used to analyze in depth the effect of different logistical concepts on, e.g., transport costs, transported volumes and the utilization rate of capacity. The model can also be extended to other geographical regions.

Table of contents

1. Introduction

In Finland, 76% of all roundwood transports from roadside storages to end-use facilities is conducted by timber trucks (Strandström, 2016). Timber transports in Finland are a big logistical affair. The operating environment is really challenging, mainly because of the high number of timber assortments and end use facilities, and high fluctuation in road trafficability, in the weather affecting in bearing capacity of roads and in the timber demand of mills.

At the moment, cost-competitiveness, profitability and resource efficiency are of special interest in wood purchasing operations in Finland. A few years ago, new traffic legislation allowed bigger dimensions and masses of trucks to be used in truck transports on Finnish roads (Valtioneuvoston asetus, 2013). Compared to the earlier law allowing truck-trailer units with maximum mass of 60 tonnes, the new law enables trucks with 64, 68 and 76 ton masses depending on the amount of axels in the truck-trailer unit. Moreover, Finnish forest industries jointly released a national vision to enhance wood purchasing efficiency with 30% lower costs in 2025 compared to present situation (Tehokas puuhuolto, 2025). Improvement of timber transport efficiency is playing a key role in the efficient wood procurement 2025 vision.

1.1 Aim of the case study

The simulation study for the S2Biom project tried to find cost-efficient operation models for further studies in timber transport logistics by trucks in a preset case environment in Central Finland. The study concentrated on a way to simulate prevailing and alternative operation models in a case operating environment and to reveal the behavior of the supply system in order to detect and pinpoint places to be improved in the logistics system. As a specific objective, the influence of a multi-assortment load method was studied and compared to a single-assortment load method. In the single-assortment load method only one timber assortment can be transported during one transport cycle whereas in the multi-assortment load method different timber assortments can be transported in the same load.

1.2 Content of report

This report shortly presents the simulation model developed in S2Biom project. In addition, a comparison with the prevailing single-assortment load method with the multi-assortment load method is reported here with values of system performances and relative transport costs. Alternative operation models are listed at the end and finally suggestions are made about research in the future.

2. Assessment methods for logistical case studies

2.1 Introduction

Various logistical assessment methods have been described in Deliverable D3.2 ‘Logistical concepts’ (Annevelink et al., 2015). The following methods have been chosen for further assessments in the logistical case studies for the S2Biom project viz.:

- BeWhere for the European & national level;
- LOCAgistics for the Burgundy and Spanish case on the regional level;
- Witness simulation model for the Finnish case.

BeWhere and LocaGIStics have not been used in this case study. Witness® simulation software (Lanner, 2016) was used for building the simulation environment for the Finnish case. The simulation is based on a discrete-event approach, where the system is chancing as discrete events in predetermined timespans. Discrete-event simulation is a proper method for modelling complex environments, which have a lot of interactions between the modeled objects, where stochasticity is included in the system and where system operations are unstable and time dependent. Timber truck transport logistics indeed have this kind of complexity.

2.4 Witness simulation model

Previously Witness simulation environment has been utilized in various research projects to study biomass logistics (see e.g. Windisch ym. 2015, Asikainen 2001, Karttunen ym. 2012). The *Truck Transport Logistics* -simulation model was compiled in Witness simulation software and combined with an Excel-spreadsheet environment (Figure 1). A combination of these two tools enabled us to study the transport logistics of timber trucks from roadside storages to end-use facilities. Simulation runs are conducted in Witness, whereas the Excel-spreadsheet file controls simulation scenario parameters and combines time and performance data from Witness to cost accounting carried out in Excel workbook.

The simulation requires timber storage data at roadside, data of monthly timber demand of mills, parameter input of the work model and truck characteristics and parameters of timber receptions at the mills. The simulation model reads this information from Excel as initial input data at the beginning of a simulation run.

Before the trucks start to drive unloaded from a truck park, mill or terminal, the model determines the end-use facility, timber assortment and roadside storage for the new transport cycle. A new transport cycle is determined by the highest demand of timber by end-use facilities and certain constraints involved to each transport cycle. The constraints in use were i) maximum arrivals of each truck to a mill per work-shift, ii) daily reception times of timber in each mill, iii) amount of transported sawn wood and pulp wood during a month, iv) available amount of assortments at storage sites and v) maximum storing times for sawn wood and pulp wood at road side storages.

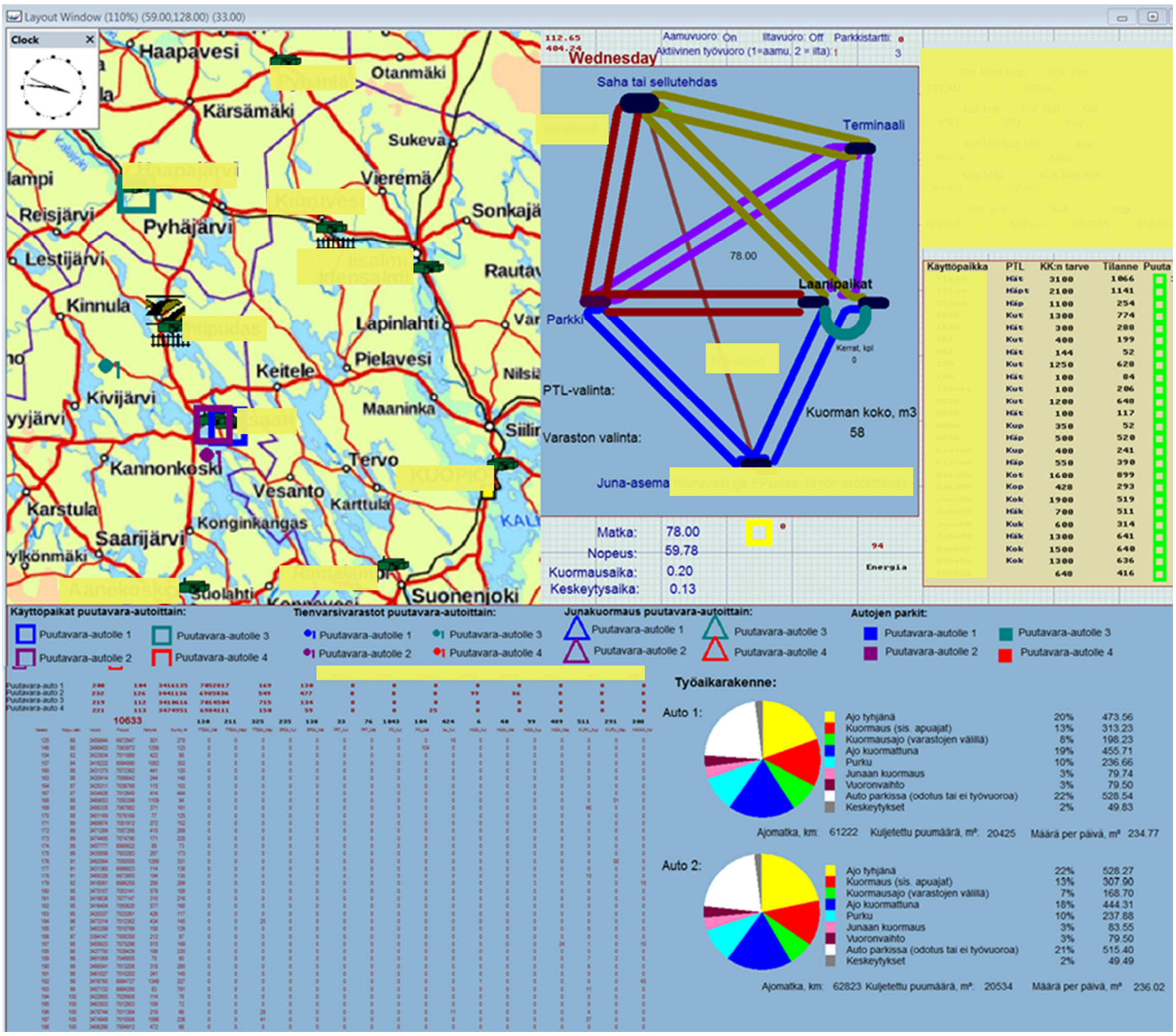

Figure 1. A screenshot from the Truck Transport Logistics -simulation model in Witness® simulation software.

Depending on the constraints and the actual situation at the roadside storages, the model selects suitable storage sites to visit by the group of rules. The model goes through all storages available at a current simulation time from the active storage matrix. The maximum dimension of the active storage matrix was set to 80, from which the rules will select the storage to be used. Active storage matrix represents the buffer of roadside storages during simulation run. The selection of storages and truck routing is conducted by utilizing this buffer. The model reads a new roadside storage every time, when storage in the active matrix is emptied.

In the selection of storage, the shortest distance method is used, if previously presented constraints are not influencing in the ruling. Time consumption functions and truck speed functions are taken from Nurminen and Heinonen (2007), where time studies for timber truck transports in Finland have been carried out. In addition, loading and unloading parameters are defined in the Excel control file.

3. Set-up of the Finnish case study

3.1 Introduction

In the case study, the simulation model included four trucks operating in Central Finland and supplying timber to 12 end-use facilities being eight saw mills, two pulp mills and two train loading terminals. A simulation run covered a period of one year. Timber trucks were operating with the following shift arrangement; six 12 hours morning shifts + five 12 hours evening shifts. Each scenario was simulated by five stochastic repetitions and the average values of these five repetitions were used for calculating the result data of a certain scenario.

Two simulation scenario sets were simulated in Finnish case study. The business as usual scenario corresponded to timber transports with the single-assortment load method, whereas the multi-assortment scenario included the multi-assortment load transports. Each simulation scenario was repeated five times and the averages of the five repetitions were used for comparing scenario results.

3.2 The region

The logistics company owning the trucks operates mainly within the province of Central Finland. The relatively high forest productivity and numerous forest industry facilities both within and surrounding the province form the basis for active forestry and timber logistics. The general challenges of timber transport in Finland described in the Introduction are also valid in Central Finland. The company operates within a radius of roughly 100 km and the annual demand of timber for all end-use facilities was set to 258 000 m^3/year, in total.

3.3 Biomass value chains

In the Finnish case study, saw logs, pulp wood and delimbed energy wood stems were transported to end-use facilities. In total, 25 different timber assortments were included in the supply chain in this case.

Currently, each timber assortment is transported as single-assortment loads to the end-use facility. Due to the small volume of individual assortments in a roadside storage, the timber trucks often have to collect timber from several roadside storages to obtain a full load. This kind of driving between piles at different roadside storages and setup times at these piles are relatively time consuming elements in the whole transport cycle. Therefore, a scenario with a multi-assortment load option was introduced to the case study. The multi-assortment load opportunity is only available for timber assortments, which are all transported to a same end-use facility. Table 1 presents the end-use facilities, their timber assortments and the multi-assortment availability.

Table 1. Timber assortments, end use facilities and multi-assortment possibility for each assortment.

End use facility	wood assortment	Abbreviation for wood assortments	Multi-assortment option
Sawmill 1	sawn wood, pine	Assortment 1	yes
Sawmill 1	mall sawn wood, pin	Assortment 2	yes
Sawmill 1	beam log, pine	Assortment 3	yes
Sawmill 2	sawn wood, spruce	Assortment 4	yes
Sawmill 2	sawn wood, pine	Assortment 5	yes
Sawmill 3	sawn wood, spruce	Assortment 6	yes
Sawmill 3	sawn wood, pine	Assortment 7	yes
Sawmill 4	sawn wood, spruce	Assortment 8	yes
Sawmill 4	sawn wood, pine	Assortment 9	yes
Sawmill 5	sawn wood, spruce	Assortment 10	no
Sawmill 6	sawn wood, spruce	Assortment 11	yes
Sawmill 6	sawn wood, pine	Assortment 12	yes
Sawmill 6	beam log, spruce	Assortment 13	yes
Sawmill 6	beam log, pine	Assortment 14	yes
Sawmill 7	beam log, spruce	Assortment 15	yes
Sawmill 7	beam log, pine	Assortment 16	yes
Sawmill 8	sawn wood, birch	Assortment 17	yes
Sawmill 8	beam log, birch	Assortment 18	yes
Train terminal 1	pulpwood log, birch	Assortment 19	yes
Train terminal 1	pulpwood log, pine	Assortment 20	yes
Train terminal 1	pulpwood log, spruce	Assortment 21	yes
Train terminal 2	pulpwood log, pine	Assortment 22	no
Pulp mill 1	pulpwood log, birch	Assortment 23	no
Pulp mill 2	pulpwood log, birch	Assortment 24	no
Energy terminal	energy wood log	Assortment 25	no

The multi-assortment load method can be introduced to timber transports without any modifications to trucks, load spaces or loaders. When loading more than one assortment to same truck load, additional time occurs in relocating and set ups between piles at the same roadside storage as well as during unloading at the end-use facility. Simulation offers an opportunity to study the impact of the multi-assortment load method in the prevailing timber supply environment.

All four trucks had a capacity of 64 tonnes carrying 48 solid-m^3 of timber. The vehicles consisted of a three-axle timber truck with a loader and a four-axle trailer. The total own mass of a vehicle was 22.2 tonnes leaving a maximum capacity of 41.8 tonnes for the load.

4. Type of data requirements

The Truck Transport Logistics -simulation requires timber storage data at roadside, data of monthly timber demand of the end-use facilities, parameter input of the work model, truck characteristics and the parameters of timber receptions at the end-use facilities (Table 2). The simulation model reads this information from an Excel workbook as initial input data at the beginning of a simulation.

Roadside storage data includes co-ordinates, the volumes of each timber assortment and the transport distances of each timber assortment to the final destinations. The storage data have to fulfill the demand of the end-use facilities for one year. For each timber assortment the monthly demand in cubic meters is determined in demand matrix according to the data acquired from the logistics company.

In addition, several parameters specifying truck driving, mill receptions and truck characteristics need to be defined.

Table 2. Required input data for the Truck Transport Logistics simulation.

Category	Attribute description (unit)
Timber storage data at roadside	Coordinates
	Volume of a timber assortment (solid-m^3)
	Distances from storage to truck parks and end-use facilities (km)
	Cutting date of timber in each storage
Timber demand of end-use facilities	Monthly demand for each timber assortment (solid-m^3)
Characteristics for working model	Set-up of work shifts (days, hours, rest times, etc.)
	Adjustment of operating shares of trucks for each timber assortment (%)
	Maximum storing times for sawn timber assortments and for pulp timber assortments (days)
	Number of truck arrivals to saw mills, pulp mills and train terminals per work shift
	Arriving day as in weekday (1-7), Arriving interval of train to train terminals (hours), Load space of train unit (solid-m^3)
Characteristics for timber truck	Loading and unloading times for each timber assortment (minutes / solid-m^3)
	Load space of timber truck (m^3)
	Cost accounting factors (capital costs, personnel costs, variable costs) (€)

5. Actual data used for case study

5.1 Storage and demand data

The roadside storage data was sorted according to the time when the logging operation was finished and the timber had been completely forwarded to the roadside. The data included fairly big amount of timber assortments of Sawmill1 (Figure 2). The storage volume of Assortment1 (pine sawn wood) was nearly 50,000 solid-m³ in total. The other timber assortments were smaller-sized and varied from 220 to 22,000 solid-m³. The supply of the timber assortments had to fulfill the demand every month and, therefore the available volume of the roadside storage matrix was bigger than the annual demand. The remaining capacity of the roadside storages was not transported in the scenario runs. The demand of end-use facilities in each wood assortment is presented in Figure 3.

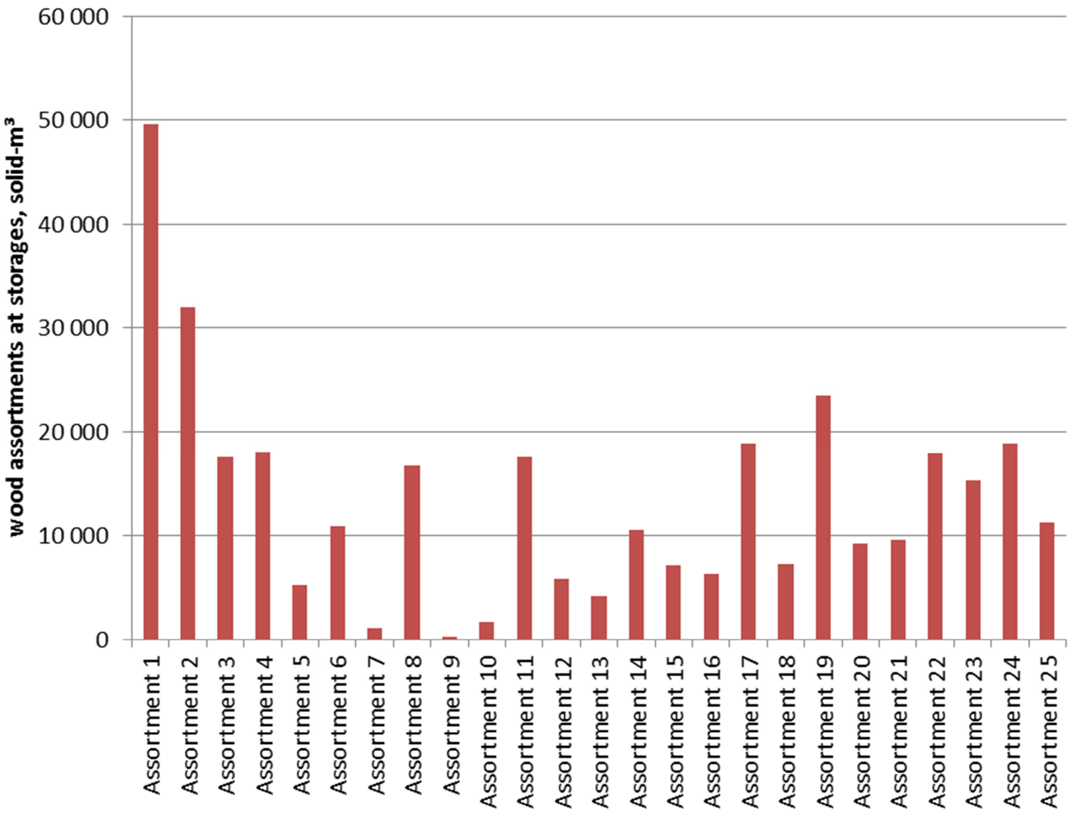

Figure 2. The amount of timber assortments in roadside storage matrix in solid-m3.

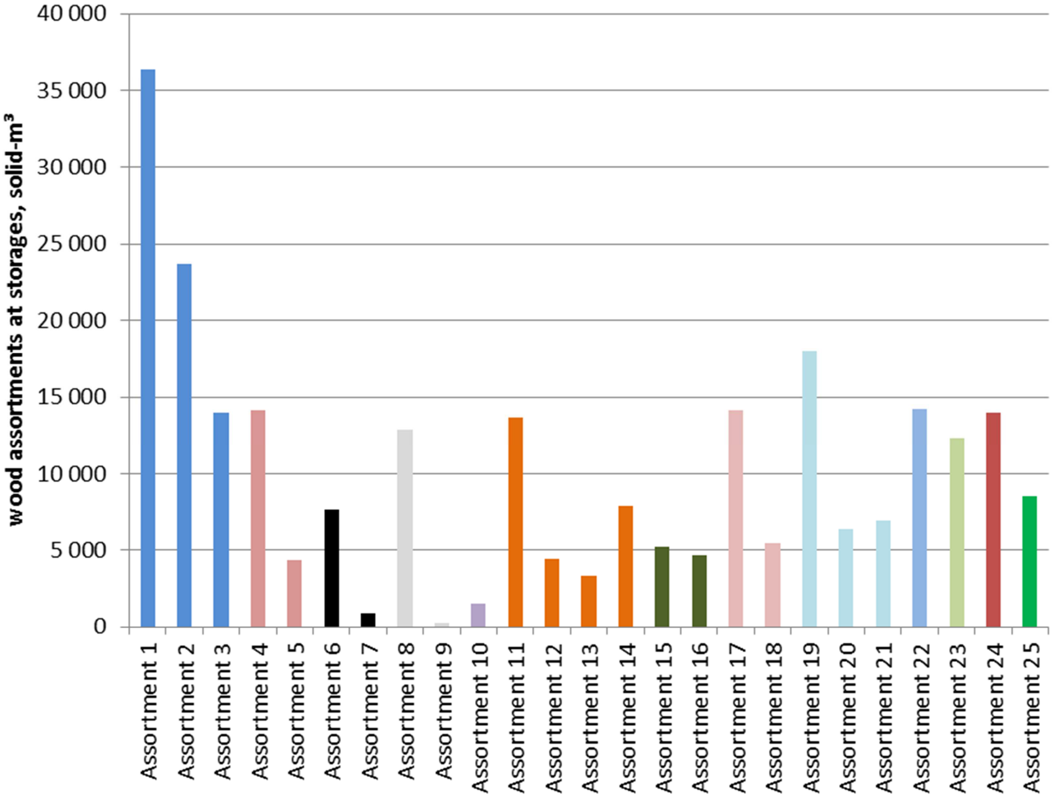

Figure 3. Demand of each wood assortment in each end use facility over one year. Different colors represent different end-use facilities in the case Finland.

5.2 Transport data

The reception times for each end-use facility varied from 10 hours to 24 hours per day (Table 3). The reception stations for pulp wood and energy wood were all open round the day 24 hours.

Table 3. Reception times of timber reception stations in end use facility.

End use facility	wood assortment	Reception opens at	Reception closes at	Open time, h
Sawmill 1	Assortment 1	6	6	24
Sawmill 1	Assortment 2	6	6	24
Sawmill 1	Assortment 3	6	6	24
Sawmill 2	Assortment 4	6	22	16
Sawmill 2	Assortment 5	6	22	16
Sawmill 3	Assortment 6	6	16	10
Sawmill 3	Assortment 7	6	16	10
Sawmill 4	Assortment 8	6	16	10
Sawmill 4	Assortment 9	6	16	10
Sawmill 5	Assortment 10	6	16	10
Sawmill 6	Assortment 11	6	22	16
Sawmill 6	Assortment 12	6	22	16
Sawmill 6	Assortment 13	6	22	16
Sawmill 6	Assortment 14	6	22	16
Sawmill 7	Assortment 15	6	16	10
Sawmill 7	Assortment 16	6	16	10
Sawmill 8	Assortment 17	6	16	10
Sawmill 8	Assortment 18	6	16	10
Train terminal 1	Assortment 19	6	6	24
Train terminal 1	Assortment 20	6	6	24
Train terminal 1	Assortment 21	6	6	24
Train terminal 2	Assortment 22	6	6	24
Pulp mill 1	Assortment 23	6	6	24
Pulp mill 2	Assortment 24	6	6	24
Energy terminal	Assortment 25	6	6	24

Working shifts for truck transports were fixed for the whole simulation period. Morning shifts were from Monday to Saturday, whereas evening shifts were from Monday to Friday (Table 4).

Table 4. Working shift spesifications for timber transports.

Morning shift			Evening shift		
	work time	rest time	work time	rest time	
Monday	12	12	12	12	hours
Tuesday	12	12	12	12	hours
Wednesday	12	12	12	12	hours
Thursday	12	12	12	12	hours
Friday	12	12	12	12	hours
Saturday	12	12	0	24	hours
Sunday	0	24	0	24	hours

Driving distances to and from truck parks and end-use facilities were derived from digital road network data (Table 5). The parking lot of truck 1 was located close to Sawmill1, whereas the parking lot of truck 3 was located close to Sawmill6. For truck 2 and 4 there was no end-use facility close to their parking lots.

Table 5. Road distances in kilometers from end use facilities to truck parks.

End use facility	Truck 1	Truck 2	Truck 3	Truck 4
Sawmill 1	4.1	22.1	55.6	48.4
Sawmill 2	38.2	49.1	89.7	82.5
Sawmill 3	115.6	122.7	72.6	75.4
Sawmill 4	119.3	89.0	109.1	73.3
Sawmill 5	124.5	115.1	175.9	146.4
Sawmill 6	53.8	60.9	1.2	36.2
Sawmill 7	81.6	88.7	71.4	35.6
Sawmill 8	44.9	42.6	96.3	89.2
Train terminal 1	81.2	88.3	71.0	35.2
Train terminal 2	1.6	20.9	54.4	47.2
Pulp mill 1	153.5	129.2	181.6	145.9
Pulp mill 2	97.6	108.5	149.1	141.9
Energy terminal	4.1	22.0	55.5	48.4

Speed functions for timber trucks were taken from the Nurminen and Heinonen (2007) work study which focused on timber truck transports in Finland (Figure 4).

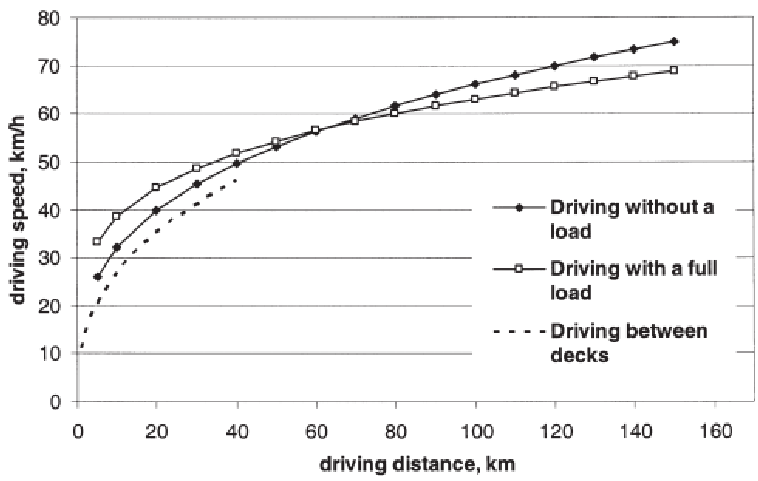

Figure 4. Speed functions for timber trucks used in the simulations (Nurminen and Heinonen 2007).

Loading times were partly taken from Nurminen and Heinonen (2007) and partly based on expert data (Table 6). Unloading times were 0.1 to 0.2 minutes per solid-m³ lower that loading times. Separate set up times after arriving to pile at roadside were used from Nurminen and Heinonen (2007).

Table 6. Loading and unloading times of timber trucks.

Wood assortment	loading time, min/m³	unloading time, min/m³	transport method
sawn wood	0.44	0.34	single-assortment
pulp wood, long	0.84	0.64	single-assortment
pulp wood, short	1.25	1.15	single-assortment
energy wood	1.3	1.15	single-assortment
sawn wood, 2 assort.	0.54	0.44	multi-assortment
sawn wood, 3 assort.	0.64	0.54	multi-assortment
sawn wood, 4 assort.	0.74	0.64	multi-assortment
pulp wood, 2 assort.	0.94	0.74	multi-assortment
pulp wood, 3 assort.	1.04	0.84	multi-assortment

5.3 Cost accounting data

Cost accounting of each truck was carried out in the Excel workbook after the simulation run. The initial cost accounting data was collected in spring 2016 from the personnel of SKAL (Finnish Transports and Logistics association) and the truck dealers from Finland. Cost accounting includes the investment costs of the truck, interest rate, depreciation, personnel costs, variable costs and entrepreneur risk margin (Table 9). The simulation values for calculating the transport costs are taken from the average of five simulation runs; operating hours, other working hours, driving kilometers, transported wood amount (in solid-m³).

Table 9. Cost accounting for timber trucks.

	Cost calculation of 64 ton truck 3+4 axels								
Input from simulations		Obtained value							
	Operating hourts	**6 044.5**		h/a					
	Other working hours	**357.5**		h/a					
	Driving kilometres	**212 479**		km/a					
	Transported wood	**63 711**		m³					
Capital factors		Enter valu	Counter us	unit	intermediate result				default
	Truck	145 000	145 000	€	137 750				141 000
	Trailer	65 000	65 000	€	57 800				80 000
	Equipments	37 500	37 500	€					40 000
	Crane + cabin	70 000	70 000	€					
	Number of truck wheels	10	10	€					10
	truck wheels €/piece	725	-7 250	€					623
	Number of trailer wheels	16	16	€					16
	trailer wheels €/piece	450	-7 200	€					437
	Vehicle price (tyres not included)				303 050	€			
	Truck life time	5	5	a					7
	Trailer life time	5	5	a					7
	max distance for tyres	120 000	120 000	km					120000
	Interest percentage	5.00	5	%	10 008	€/a			5
	Depreciation of capital				41 794	€/a			
	Insurance	4 000	4 000	€/a					11000
	Traffic costs	1 500	1 500	€/a					2500
	Administration costs	4 500	4 500	€/a					5000
	Maintenance costs	2 000	2 000	€/a					1000
	Uncompensated driving	2 000	2 000	€/a	1 176	€/a			4000
	Entrepreneurial risk, margin	5	5	€/a					
Salary factors									
	Driver salary (hourly cost)	18.00	18	€/h	115 236	€/a			14
	Indirect salary percentage	68	68	%	78 360	€/a			66
Variable cost factors									
	Fuel price	0.90	0.9	€/l					1.00
	Fuel consumption	55	55	l/100 km	0.495	€/km			43
	lubricants cost	4000	4 000	€/a	0.018825383	€/km			2000
	Repair/service	28000	28 000	€/a	0.131777679	€/km			17000
	Tyres (coating)	300	300	€/tyre	0.09	€/km			200
	Total variable costs				0.74	€/km			
Costs									
	Fixed costs	**64 978**	€						
	Salary costs	**193 596**	€		Costs for standing	**46.2**	€/h		
	Variable costs	**156 180**	€		Tot hourly costs	**72.0**	€/h		
	Entrepreneurial risk	**20 738**	€						
	TOTAL costs	**435 492**	€						
	Unit costs	**6.84**	€/m³		Kiinteät kust. (aika)		**42.78**	€/operating hour	
					Muuttuvat kust. (matka)		**0.74**	€/km	
	Mileage costs	**2.05**	€/km						

6. Results case study

6.2 Results of the simulation study

The multi-assortment method decreased the time consumption particularly for driving between piles (see Figure 5). The number of rides between piles was 1,152 times in the single-assortment load method, whereas in the multi-assortment load method driving between piles was 794 times. This is a 31% decrease. On the other hand the off-shift time increased in the multi-assortment load method mainly because of roadside storages was finished earlier during June before the holiday month (July) in the multi-assortment load method.

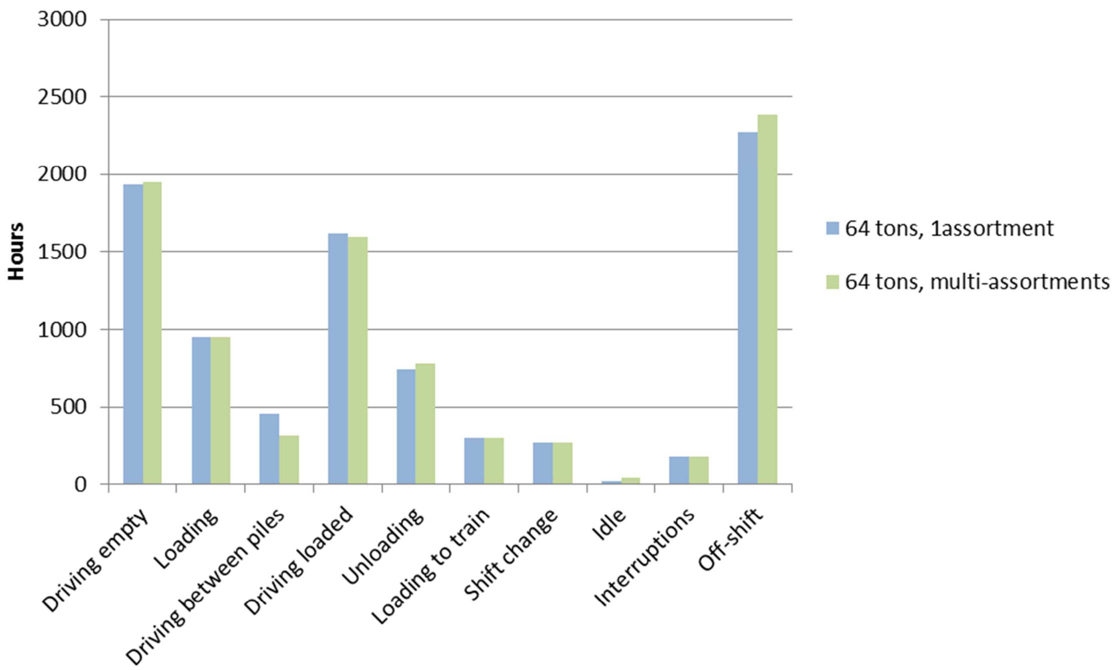

Figure 5. Time element distribution and time durations for studied scenarios. One year simulation experiments.

The given total timber demand of 258,000 solid-m³ was a bit too high for both scenarios to be completed with the preset work shift arrangements by four trucks. The multi-assortment method could achieve 253,175 m³, whereas the single-assortment method could achieve a bit less: 249,895 m³ (Figure 6). With a 2% smaller amount of operating hours the multi-assortment method still achieved 1.3% more transported timber during the simulation run of one year.

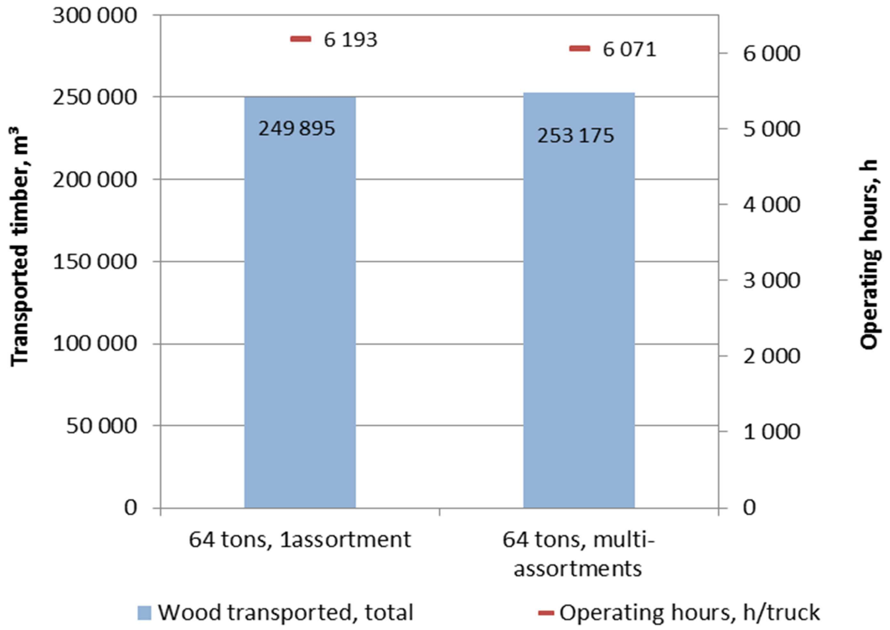

Figure 6. Performance values in transported timber and total operating hours per one year.

The multi-assortment load method was on average 3.3% cheaper than the single assortment load method (Figure 7). In addition, the driving performance - presented as solid-m³ of timber per 100 kilometers - was 4.0% higher with the multi-assortment load method.

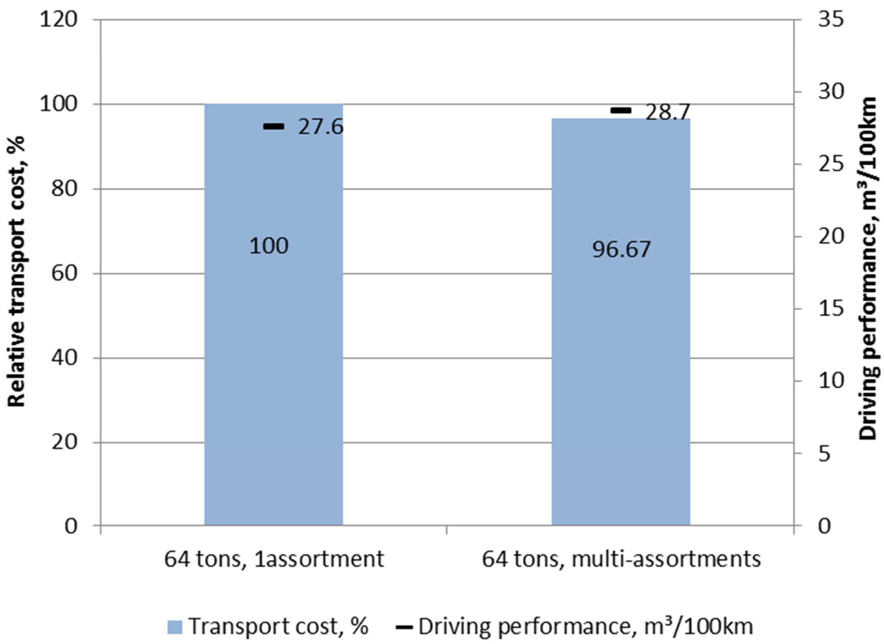

Figure 7. Relative transport costs and driving performance in the scenario comparisons. A cost level of 100% was set for the single-assortment load method.

6.3 Discussion

For these simulations, original roadside storage data of the logistics company was not available. Therefore, a reconstruction of data from previous roadside storage material covering the same area was carried out. Data adjustments were done by using knowledge of the operational environment offered by company members. Nevertheless, storage data can vary a lot even between subsequent years, and therefore, simulation with reconstructed data was justified. For the future studies, simulations allow to test different kind of operational environment with varieties in storage data.

The simulation scenarios did not include elements which would affect with longer lay down periods for the trucks such as thaw seasons or sudden changes in timber demand. Timber transports were running with the preset shift arrangement through the year, and therefore, results in transport performances of trucks were overestimations and transport costs were underestimations. However, this did not have any effect on the reliability of results when comparing scenarios.

7. Conclusions and recommendations

7.1 Conclusions

A detailed and precise simulation model for analyzing timber truck transport logistics was compiled in S2Biom project using the Witness software. The simulation model has proved to express well the behavior of truck transports of timber. According to the first feedback from the personnel of the logistics company, the model could certainly be used for supporting their decisions on enhancing the transport operations.

Compared with the other logistical assessment methods in S2Biom, i.e., BeWhere and LocaGIStics, *Truck Transport Logistics* is the most detailed one. This means that it can simulate the operation of real logistical chains and even the interactions between logistical components and stochasticity can be taken into account. The downside of this ability is that very detailed input data, which not always is available, is needed. The model also needs to be tailored to the operating environment which requires expertise. Therefore, *Truck Transport Logistics* is not publicly available unlike the two other tools. The ones interested in the model are advised to contact the authors of this report.

The multi-assortment load method offers a nearly 4% improvement potential for the transport economy compared to the prevailing single-assortment load method. Small assortment piles at roadsides cause difficulties in efficient timber transport due to driving between piles and the need of loading many small piles for filling the entire load space. The multi-assortment load method decreases drastically the number of rides between piles and, therefore, improves performance of the fleet.

7.2 Recommendations

Research topics for the future in timber transports by road with the Witness simulation model would be to study the effect of bigger roadside storage sizes, smaller number of timber assortments, including terminals and including high capacity trucks for long distance transports. In addition, the influence of bigger trucks for transporting timber from roadside storages to mills could be tested with the Witness simulation model.

References

Asikainen, A. 2001. Simulation of logging and barge transport of wood from forests on islands. International Journal of Forest Engineering. Volume 12(2).

Karttunen, K., Väätäinen, K., Asikainen, A. & Ranta, T. 2012. The operational efficiency of waterway transport of forest chips on Finland's Lake Saimaa. Silva Fennica 46(3): 395–413.

Lanner 2016. 2016. http://www.lanner.com/technology/witness-simulation-software.html

Strandström, M. 2016. Puunkorjuu ja kaukokuljetus vuonna 2015. Metsätehon tuloskalvosarja 4a/2016. Metsäteho Oy. 32 slides.

Tehokas puuhuolto 2025. 2015. Metsäteho Oy. 12 p.

Valtioneuvoston asetus 2013. 2013. Valtioneuvoston asetus ajoneuvojen käytöstä tiellä annetun asetuksen muuttamisesta. 407/2013. http://www.finlex.fi/fi/laki/alkup/2013/20130407?search%5Btype%5D=pika&search%5Bpika%5D=ajoneuvon%20mitat%20ja%20massat

Windisch, J., Väätäinen, K., Anttila, P., Nivala, M., Laitila, J., Asikainen, A. & Sikanen, L. 2015. Discrete-event simulation of an information-based raw material allocation process for increasing the efficiency of an energy wood supply chain. Applied Energy 149: 315-325.