FlexWood

Flexible Wood Supply Chain

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Revision	
Confidentiality	PU

Technological specification of interfaces between manufacturing and logistic concepts

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SEVENTH FRAMEWOR PROGRAMME

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Website: www.flexwood-eu.org

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1. **Executive Summary**

Sawmill wants to get just in time wood raw material - quantity and quality - matching very well product specifications and manufacturing systems resulting high value and volume yield and profitability aimin at to improve improve competitiveness of the company and forest industry. In the present situation sawmills are forced to use and process wood raw material they cab receive. This leads to miss match between desired sawn timber products and available wood raw materials. This situation causes economical looses and a lot of waste.

The results of the various procedures to define and describe industry-relevant parameters of stands and trees to be harvested results in a stand data bank, where trees (single trees or subpopulation of trees) are identified and described with both dimensional (diameter, height) and qualitative (shape, crown, branches) parameters. Due to the fact that these parameters have been measured by remote sensing techniques on standing trees / stands, only parameters which are visible from outside are included in this dataset. Nevertheless through existing wood research-related science based knowledge (limited) conclusions can be also derived for internal quality parameters, namely knots.

In a second step, this list of quantitative and qualitative parameters of trees to be harvested (tree-list) is converted into a databank which contains products (logs) to be delivered to the customer (sawmill). This conversion can be performed by existing simulation software (bucking simulation). Within the Flexwood concept, several conversion softwares are used within the different use cases. The result of this conversion is a log list, which contains again quantitative as well as qualitative parameters of each log and provides also a classification according to the established round wood sorting rules. The logs in this log list can be sorted according to the specific demands or needs of the customers.

2. **Introduction**

According to the Dow, Task 6400 « **Interface to connect manufacturing systems with novel logistics concepts and wood raw material**» VTT has been as Task leader and task participants: VTT, Skogforsk, ALU-FR FobAwi. The task concerns to the following topics.

Conversion models create relevant information about optimal allocation of wood, raw material specifications and requirements (diameters, lengths, qualities etc. – order towards forest) and cross-cutting rules and instructions. Models also strongly support sales activities, selection of orders, customers and product development.

Activities are:

Principal design of the interfaces of the individual conversion models and whole model system will be designed. The links between conversion model system and other FlexWood model systems i.e. harvesting are defined including communication protocols and overall management systems. Very important task is also to design strong links between FlexWood system and existing information systems at the sawmills in order to provide easy access and communication between different systems.

2.1 Objectives of the Deliverable

The objective of the deliverable is to identify potential options for implementation of flexible production and future manufacturing systems in the sawmilling industry.

2.2 Work Package Task Status

Deliverable 6.2 “Concepts of improved conversion chains for the European sawmilling industry” has been produced in WP 6000 Flexible and Customer Adaptive Mill Production and Task 6200 Modelling of conversion chains from wood material to wood products. The Deliverable supports development of simulation and optimisation models to be used as components of FlexWood system as well as realisation of Task 6300 Improving flexibility in production and future manufacturing systems.

The Deliverable 6.2 and the Deliverable 6.5 “Concept on implementation of flexible production and future manufacturing systems in the sawmilling industry” are linked together because they are focusing on the same topic – how to improve efficiency in wood conversion chains. This Deliverable 6.2 will give more general view on different options The Deliverable 6.5 will provide more detail description how to improve and implement advanced manufacturing systems in the sawmill industry.

Table 1. Status of deliverables in WP 6000.

Del. no.	Deliverable name	Delivery date	Status (pending/submitted/accepted)
1.1	Consortium Agreement	Month 6	
6.1	Industrial evaluation of round wood characteristics with respect to product specifications	Month 12	Submitted
6.2	Concept of improved conversion chains for the European sawmilling industry	Month 18	Submitted
6.3	Adapted conversion models	Month 26	Submitted
6.4	Technological specification of interfaces between manufacturing systems and logistic concepts	Month 36	Submitted
6.5	Concept on implementation of flexible production and future manufacturing systems	Month 26	Submitted

3. The Approach

VTT Technical Research Centre of Finland has carried has carried out many research projects on the field Deliverable 6.4 is covering. VTT has also developed models and software systems for simulating and optimising activities throughout entire forest wood chains and individual manufacturing phases. The models are used in research but also in operative and strategic planning operation in the saw mill industry. The models are introduced in this deliverable.

In the industrial implementation VTT’s simulation and optimisation models are strongly linked with companies Enteprice Recourse Planning (ERP) systems. Close co-opeartion with the industry provides wide knowledge to realise D 6.4

4. Industrial needs for evaluation tools and their integration with existing information system

Sawmill wants to get just in time wood raw material - quantity and quality - matching very well product specifications and manufacturing systems resulting high value and volume yield and profitability aimin at to improve improve competitiveness of the company and forest industry. In the present situation sawmills are forced to use and process wood raw material they cab receive. This leads to miss match between desired sawn timber products and available wood raw materials. This situation causes economical looses and a lot of waste.

Avoiding this situation there is big need to develop tools and methods for providing information to

- select right stands for conversion,
- determine optimum cross cutting strategies for those stands,
- sort the logs optimally based on sawn timber orders and properties of individual logs and
- use optimised parameter values in processing.

4.1 Virtual stems describing wood raw material at stands

Traditionally selection of stand to be harvested is based on expert’s fast, visual evaluation of stands. This method offers rough estimation about the quality – good or bad – of sawn timber output from those stands. Method is not accurate. In the sawmill processing logs are accurately measured in terms of geometrical and quality features. This information is analysed thorough sawing simulators and software systems for optimisation of log sorting procedures, sawing set ups and other processing parameters. However scanning of logs is too late because in terms of maximising profitability selection of stands and bucking of stems are most important phases in wood value chain because it’s not possible to correct afterwards mistakes made in the cross cutting phases.

FlexWood project aims at developing scanning of forest recources. This is very important because evaluation of stands necessities representative information about geometrical and quality features of standing trees. In the optimum situation a stand is described in terms of virtual stems to be used in the simulation of conversion procedures (Fig. 1). Simulations can be executed with similar models which are already used in the production planning procedures.

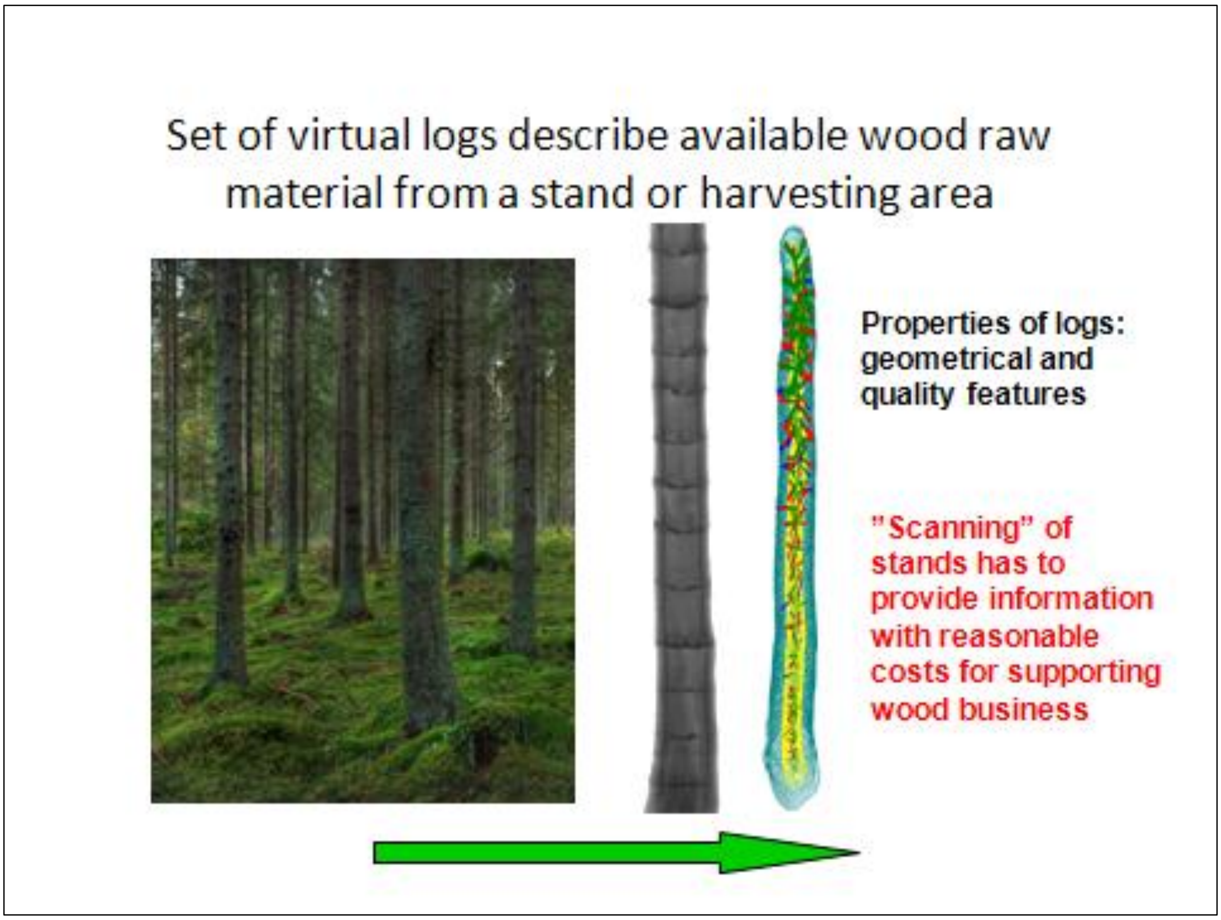


Figure 1. Scanning of a stand provides data to be converted into virtual stems and logs to be used in the simulations of conversion processes.

4.2 Information flows between FlexWood servers

Figure 2 illustraes the principals for converting sawn timber oders into log order providing linking of sawn timber products and wood raw material recourses. Customer's oders and potential orders determine sawn timber demand profile, products specification, which is stored and available in sawmil's information system. Typical log specification profiles are also stored iIn the information system.VTT's FlexWood optimiser – sawing simulators and sawing models - optimisation software tools – provides information which log specification results best sawing output in terms of value and volume yield. VTT's Server for communication sends log order or stand information to server servicing harvesting operation and scheduling of the flow of wood raw material.

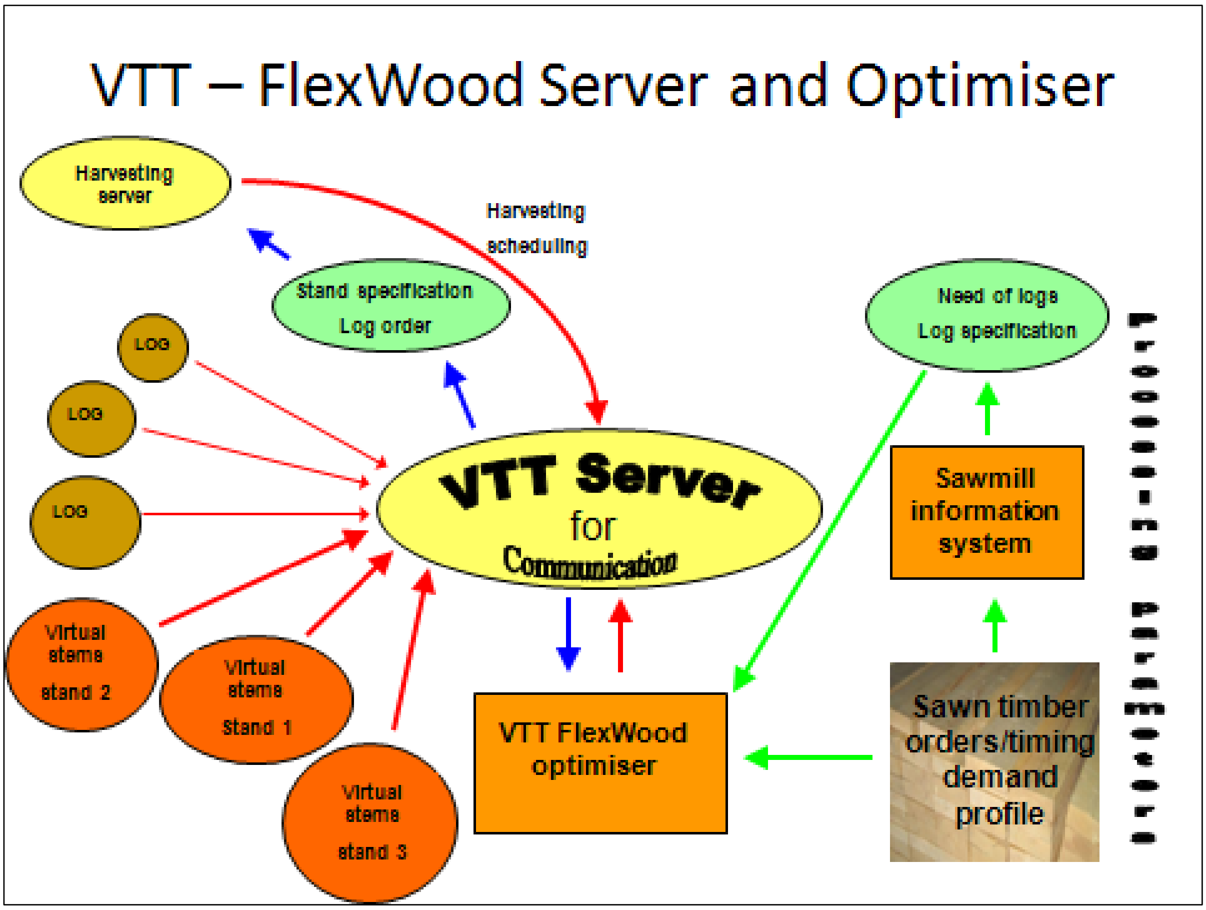


Figure 2. Principal presentation of the optimisation wood raw material specification matching the demand of sawn timber.

Second option is that the harvesting server sends different log specifications to VTT FlexWood optimizer for analysing their suitability for current production. In this case VTT FlexWood server determines the most suitable log specifications to processing.

Third option is that the harvesting server sends different stem specifications to VTT FlexWood optimizer for analysing their suitability for current production. In this case VTT FlexWood optimiser includes also bucking of stems into logs followed by different conversion options, incuding sawing set ups. VTT FlexWood server deternines the most suitable stand(s) for processing including instructions for cross cutting of stems. These insructions will be forwarded to harvesting server.

4.3 Procedure for the evaluation of stands

Figure 3 illustraes the principals for converting sawn timber oders into log order provides linking of sawn timber products and wood raw material recourses. Evaluation of stand provides information for the selection of right stands for processing. The selection criteria is how well sawn timber demand profile and geometrical and quality features of stand's wood raw material corensponds. Most important criteria is the value yield.

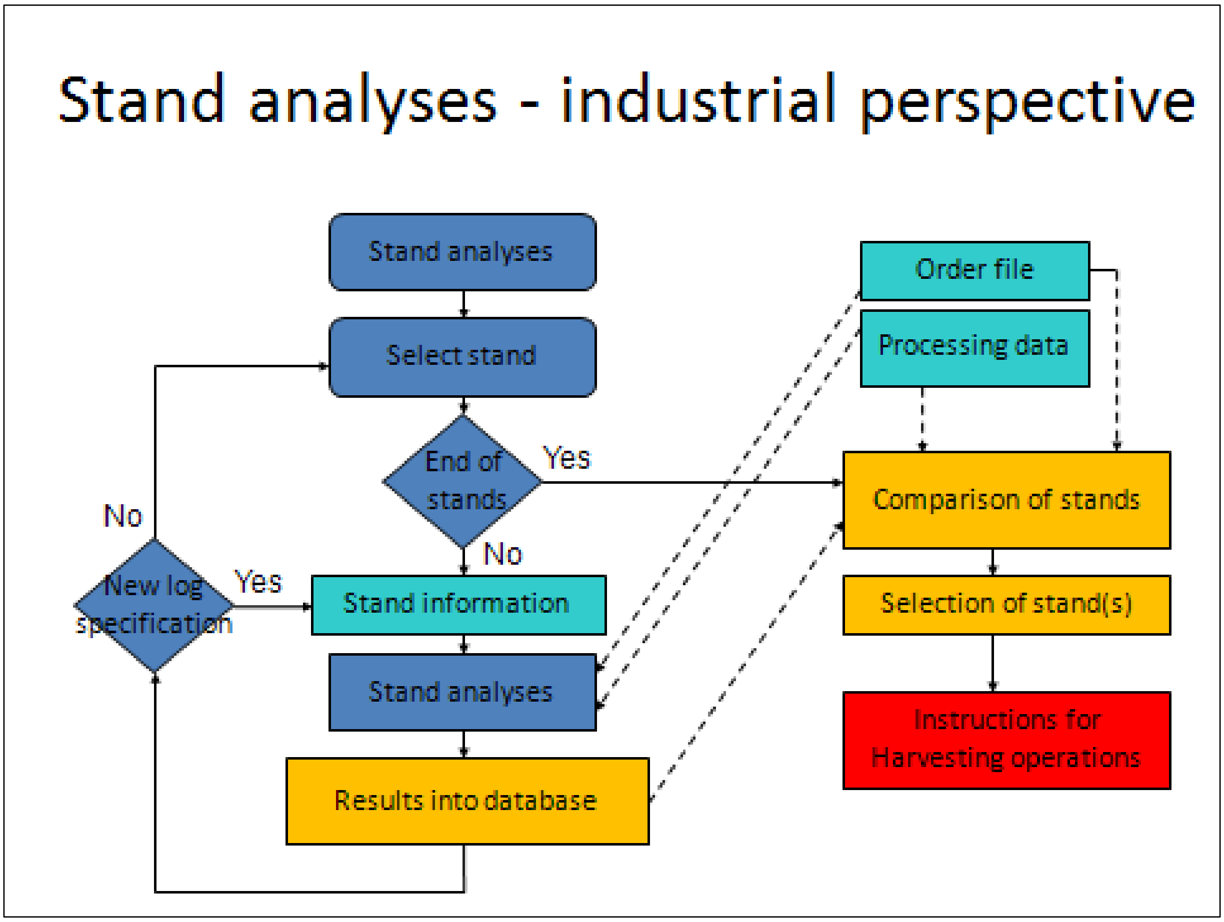


Figure 3. Principal presentation stand analyses for supporting selection of stands and optimisation wood raw material specification matching the demand of sawn timber.

Virtual stems representing stand's wood raw material are converted into logs using sofware for optimisation of bucking, in the first phase of analyses. In the second phase each of the logs are converted into sawn timber pieces using data concerning potential sawing set ups and manufacturing parameters using VTT's sawing simulator. There are always many options to break down same log into sawn timber pieces. Third phase of analyses is executed using VTT's sawing model, which is a software based on linear programming and linking together available logs and sawn timber orders, maximising value yield with a fixed processing period. The ananysing results will be stored into data base. This procedure will be repeted as many times as there different type log specifications.The result of analyses is to find out best possible stand for production and bucking instruction for that spesific stand. There is also possible to integrate different stands together.

When all potential stands are evaluated, final selection will be carried out. This procedure may result that only one stand will be selected or solution can be that several stand are selected in order to satisfyi sawn timber demand.

Customer's oders and potential orders determine sawn timber demand profile, products specification, which is stored and available in sawmil's information system. Typical log specification profiles are also stored iIn the information system.VTT's FlexWood optimiser – sawing simulators and sawing models - optimisation software tools – provides information which log specification results best sawing output in terms of value and volume yield. VTT's

4.4 Sawing simulation model - software for predicting volume and value yield for sawing set-ups

The simulation model mathematically “saws” a log or a log class into sawn timber by grades according to the end-users’ specific needs. Chips and sawdust are sideflows of the sawing process. Before actual sawing, the best blade settings and patterns for each log class are determined by simulations. Sawn timber pieces or flitches can be further converted into components in order to optimise the secondary conversion process. A data file generated by the simulation model forms a basis for all further planning and modelling.

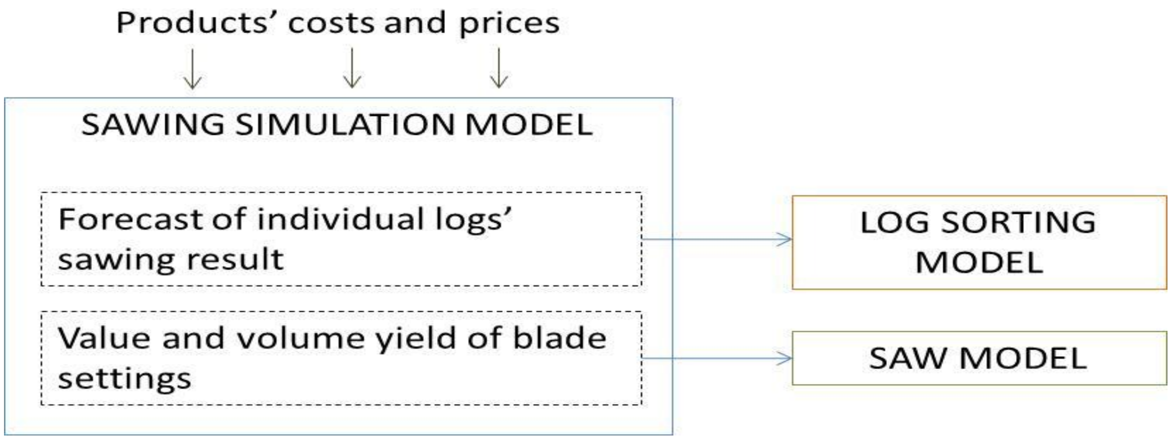


Figure 4. Sawing simulation model provides input information to Log Sorting Model and Saw Model.

The simulation program contains a description of the log and log class, sawing process, factors affecting the value yield and potential sawn timber products. Description of the log class involves the determination of individual logs as objects of calculation. The mathematical description of each log can be divided into two components: description of the log shape and internal features. Input data on raw material quality can be provided by the sawmill statistics, through trial sawing or automatically by the scanning of the internal features of logs using i.e. X-ray systems. Using the trial sawing method combined with statistics allows the creation of mathematical quality distribution functions capable of predicting the probable quality distribution percentages of lumber pieces cut from a certain segment of the log.

4.4.1 Input data for sawing simulator

The input data for the simulator includes details of sawlog properties, nominal and green dimensions of sawn goods, sawkerfs, and prices of sawn timber by dimensions and grade, grade distributions of heartwood sawn timber and side boards allowed in sawing. The input data are based on information obtained from research on wood raw material, sawing processes and products and of the statistics from sawmills. The prices used in the simulation are usually based on existing sales prices.

Input data for sawing simulation program is listed below:

- Statistical log properties by log grades and log top diameter classes
    - Length distribution
    - Taper, average and standard deviation
    - Sweep
    - Ovality
    - Volume with bark
    - Bark percentage of the log volume by log grades and top diameter classes
    - Price of the raw material at the sawmill

- Statistical quality distribution of sideboards by log grades and top diameter classes
    - Grade distribution depends on the position of the sideboard in the sawing patter

- Dimensions of sawn timber

Nominal and green dimensions of sawn timber and saw kerfs are presented in the Figure 8. There can be two sawing lines which may have different dimensional accuracy and different green dimensions. In the primary and secondary breakdown the outmost saw kerfs can be given separately when surface finishing blades are used.

- Nominal and green thicknesses of center goods and sideboards
- Saw kerfs of sawing machines

- Grades of sawn timber
    - Center goods, allowed wane in thickness, width and length
    - Sideboards, allowed wane in thickness, width and length

- Prices of the products
    - Center goods by grade, thickness and width
    - Sideboards by grade, thickness and width
    - By products. Chips, puru and bark

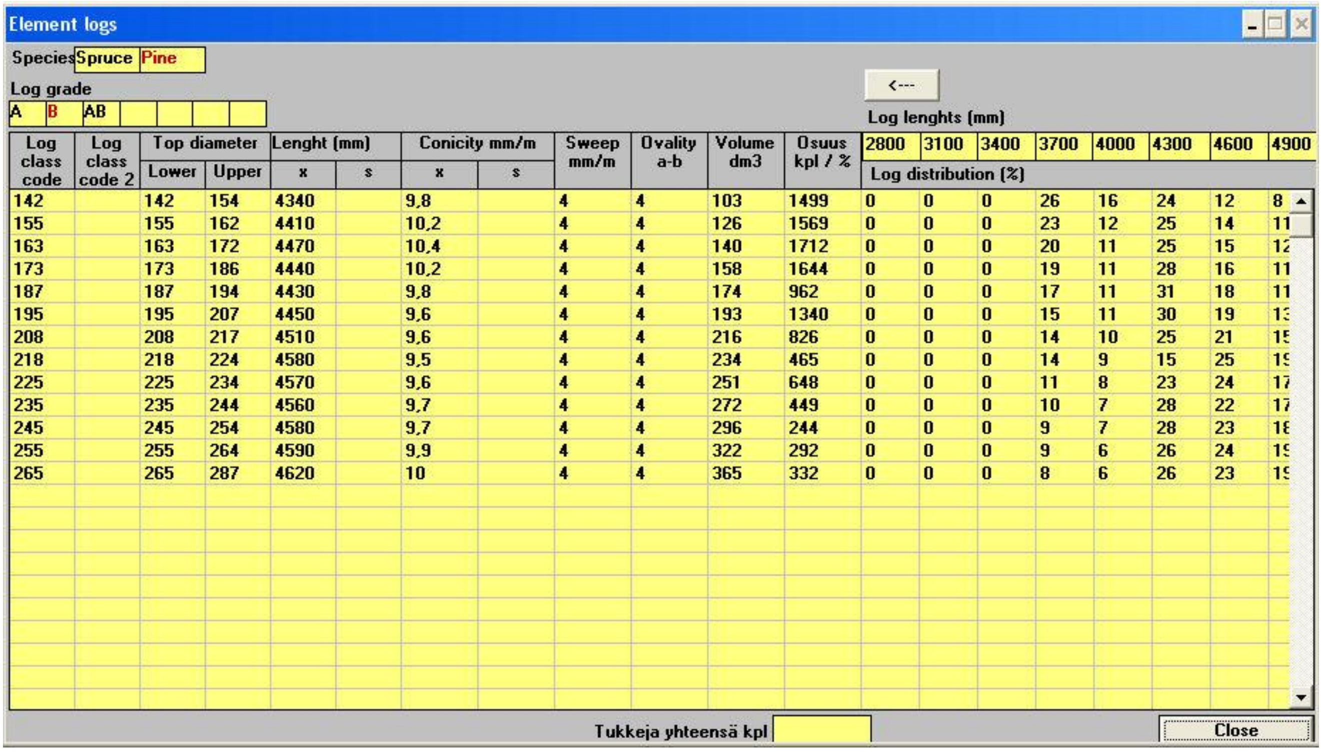
- Costs

    - Log prices at the sawmill
    - Log handling costs at the sawmill
    - Sawn timber manufacturing costs by grades and dimensions

- Sawing patterns
    - List of allowed sideboard patterns, when sideboard patterns s are optimised
    - Set-ups
        - Center good patterns, including sideboard patterns if they are fixed
        - Statistical grade distributions of center goods

4.4.2 Examples of input data windows in the sawing simulation software

Geometrical properties of logs and distributions of logs by length and top diameter are presented in Figure 5. Length distribution, taper, sweep, ovality and log volume are presented by top diameter classes. This data has been got from the 3D-scanner of log sorting station.



Element logs

Species: Spruce | Pine

Log grade: A | B | AB

Log lenghts (mm)

Log class code	Log class code 2	Top diameter Lower	Top diameter Upper	Lenght (mm) x	Lenght (mm) s	Conicity mm/m x	Conicity mm/m s	Sweep mm/m	Ovality a-b	Volume dm3	Osuus kpl / %	2800	3100	3400	3700	4000	4300	4600	4900
												Log distribution (%)							
142		142	154	4340		9,8		4	4	103	1499	0	0	0	26	16	24	12	8
155		155	162	4410		10,2		4	4	126	1569	0	0	0	23	12	25	14	11
163		163	172	4470		10,4		4	4	140	1712	0	0	0	20	11	25	15	12
173		173	186	4440		10,2		4	4	158	1644	0	0	0	19	11	28	16	11
187		187	194	4430		9,8		4	4	174	962	0	0	0	17	11	31	18	11
195		195	207	4450		9,6		4	4	193	1340	0	0	0	15	11	30	19	13
208		208	217	4510		9,6		4	4	216	826	0	0	0	14	10	25	21	15
218		218	224	4580		9,5		4	4	234	465	0	0	0	14	9	15	25	19
225		225	234	4570		9,6		4	4	251	648	0	0	0	11	8	23	24	17
235		235	244	4560		9,7		4	4	272	449	0	0	0	10	7	28	22	17
245		245	254	4580		9,7		4	4	296	244	0	0	0	9	7	28	23	18
255		255	264	4590		9,9		4	4	322	292	0	0	0	9	6	26	24	19
265		265	287	4620		10		4	4	365	332	0	0	0	8	6	26	23	19

Tukkeja yhteensä kpl

Close

Figure 5. Input window of sawing simulator: Geometrical properties of logs, length and top diameter distributions.

4.4.3 Example of output data windows in the sawing simulation software

The software creates as output data the dimensions (thickness, width) and lengths by grades probably achieved in sawing. The computer also calculates on the basis of the input data a certain number of economically best blade setting alternatives for a sawlog or sawlog class. It is also possible to calculate the log sizes that give optimal production of heartwood lumber.

- Volume and value yield of sawing patterns from certain log class
    - Recovery of sawn timber by grade, width and length
    - Per one thousand log pieces
    - Per one thousand raw material (logs with bark) cubic meters

- Comparison of sawing patterns
- Generation of input data for saw model

Main output of sawing simulation is presented in Figure 6. Proceeds of sawn timber and by products are presented per sawn timber cubic meter and per raw material cubic meter. Log use ratio describes how many cubic meters logs are needed to produce one cubic meter sawn timber. Volume yield of products are presented per one thousand log cubic meters.

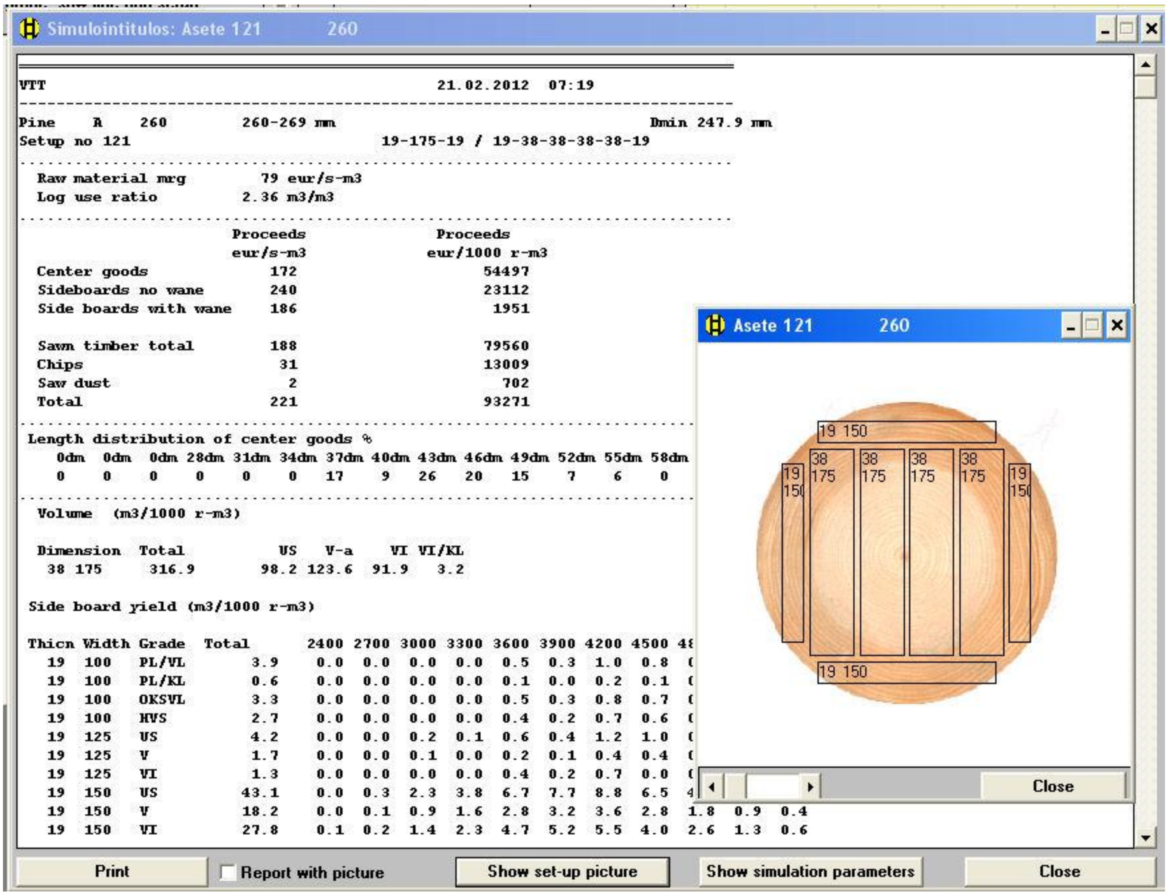


Figure 6. Output window of sawing simulator: Simulation result of a sawing pattern. Volume recovery by products and economical key figures are presented.

4.4.4 Input data for sawing simulator and it's links to sawmill's information systems

Different input data catergories for sawing simulator and their links to sawmills information systems are presented in table 1. It's possible to recognize that the rate of change varies from slow to fast. Prices of sawn timber may vary very fast due to market situations. Changes in production costs, sawn timber grade distribution and log distribution are slow. Sone parameter values like green dismensions of sawn timber ja saw kerfs are constant.

Table2. Input data catergories for sawing simulator. The columns in the table link input data to sawmill companie's business environment, especially to information system.

Input-data	Rate of change	Who determines	Source of data	Impact
Log distribution and characteristics	Slow	Production planner	Scanner of log sorting, harvester reports, ALS, TLS	Matching logs with demand
Prices of logs	Medium	Procurement organisation	Procurement organisation, company policy	Profitability
Green dimensions of sawn timber	Fixed	Production manager	Dimension control	Sawn timber yield
Saw kerfs	Fixed	Production manager	Dimension control	Sawn timber yield
Grades of sawn timber	Slow	Production manager	Sales organisation, customers	Filling customer needs
Prices of sawn timber	Fast	Sales	Markets	Profitability
Production costs	Slow	Production manager	Cost control	Profitability
Grade distribution of sawn timber	Slow	Production planner and manager	ERP, statistics	Profitability
Sawing patterns	Medium	Production planner and manager	Practice, optimisation programs, customer needs	Sawn timber yield, profitability

Input data parameter values for sawing simulations are typically determined by production manager or/and production planner supported by companie's Enterprice Recourses Planning (ERP) information system. Typically there are continuous data flow between sawing simulator and ERP system. Input data sets are transferred from ERP to sawing simulator and calculation results are transferred in the opposite direction. Strong integration between simulator and ERP is the key for succesfull planning of production, sales activities and harvesting operations.

There are several data sources servicing planning operation conventional and x-ray scanners for logs providing data from actual log features. ALS and TLS are considered to be important data sources for the evaluation of statnd's wood raw material. Dimension control is quality control procedure resulting information for determination of green dimensions for sawn timber pieces and determination of saw kerfs. Prices of sawn timber and wood raw material will be determined by marketing department and harvesting department based on company's business policy. Sales organization in close co-operation with production management will determine sawn timber grades. ERP system will store and process information about production costs. This data will be transferred to sawing simulator's input data. Sawing patterns and sawing set ups are determined by production planner supported by sawing simulator based on actual orders and experiences.

Log distribution and characteristics determine how well purchased wood raw material matches the damnded sawn timber profile. The match impacts much on the profitability to be achieved in conversion.

Prices of logs and sawn timber, operational costs and grade distribution of sawn timber influence directly on the profitability. Green dimensions, saw kerfs and sawn timber dimesnions affects directly on the value and volume yield in sawing operations.

4.5 Sawing model - optimisation software based on linear programming supporting planning of production, harvesting and marketing

The optimum sawing strategies for a time period(s) (one month, for instance) can be drawn using an optimisation model based on linear programming. The goal is to achieve the best profitability for sawing periods. The possibilities of using the best blade setting for a sawlog class are often restricted. There are always sawn timber dimensions and grades having only limited demand on the market. In contrast, when the demand is high the desired product has to be sawn from several different log classes. The WoodCIM® sawing model optimally combines the log supply, sawing possibilities and sales (Fig. 10).

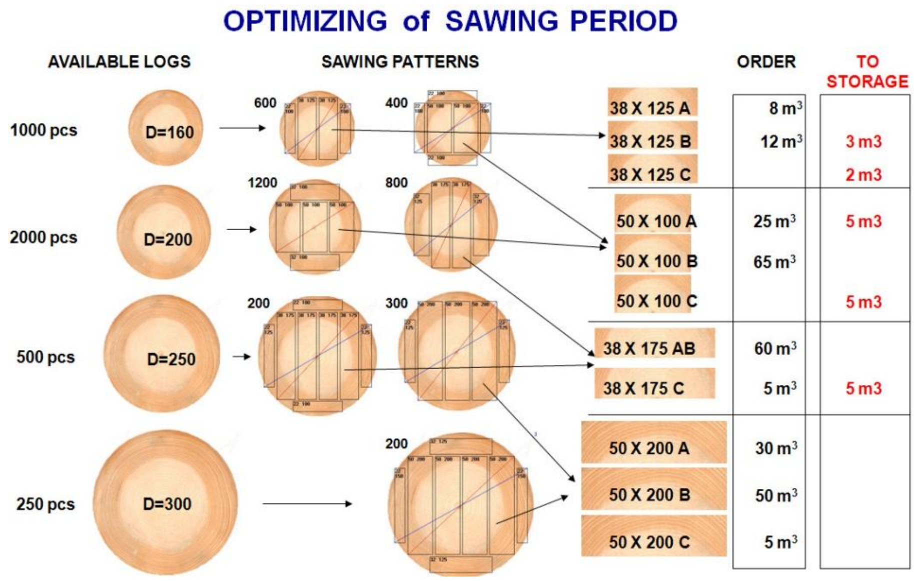


Figure 7. Objective in the optimisation activities in planning periods is to combine the orders and available logs together yielding maximum value yield and profit.

In the simplified case presented in figure 7 total demand of sawn timber is 200 m^2. There are four log classes available for sawing. One or two sawing set ups per log class, result different quality classes of sawn goods. Maximising profit in this sawing period gives following results. The logs belonging to biggest log class (D=300 mm) are going to be sawn using only one set-up. In other log classes two set ups are used. In the optimum sawing operation all the logs belonging to three smallest log classes will be used. From the biggest log class 200 out of 300 logs will be exploitated, because they fit the order file.

4.5.1 Input data for sawing model

Input data contains details of log supply (available logs), yield factors produced by set-up simulation, orders and sales potential, product prices and capacities of production lines during the time period to be planned.

The input data for sawing model software is listed below:

- Sawing period
    - Starting date and ending date

- Sawing needs
    - Products to be manufactured during the sawing period
        - Product: dimension, grade ,drying degree
        - Minimum and maximum volume to be manufactured
- Available logs
    - Minimum and maximum amount to be used

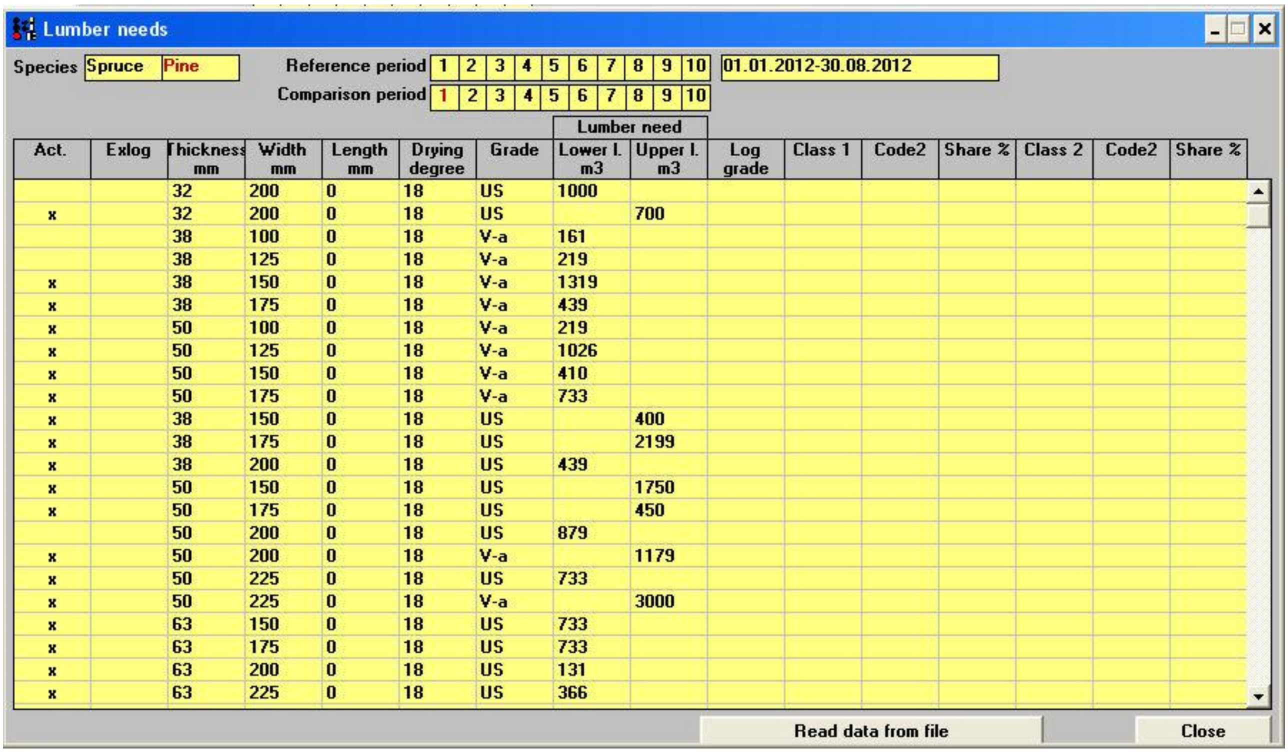
- Costs
    - Annual costs, fixed to planning period by starting and ending date
    - Driving costs of sawmill compartments

- Capacities
    - Driving hours of sawmill compartments in the sawing period

- Production efficiency
    - Running speeds of sawmill compartments
    - Drying times of different dimensions

4.5.2 Examples of input data data windows in the sawing model software

Sawing needs for sawing period are presented in Figure 8. Products are described by exlog, thickness, width and grade. Each product can be given a minimum and maximum amount to be produced. If maximum amount is not given, there is no upper limit for that product.



Act.	Exlog	Thickness mm	Width mm	Length mm	Drying degree	Grade	Lumber need Lower l. m3	Lumber need Upper l. m3	Log grade	Class 1	Code2	Share %	Class 2	Code2	Share %
		32	200	0	18	US	1000								
x		32	200	0	18	US		700							
		38	100	0	18	V-a	161								
		38	125	0	18	V-a	219								
x		38	150	0	18	V-a	1319								
x		38	175	0	18	V-a	439								
x		50	100	0	18	V-a	219								
x		50	125	0	18	V-a	1026								
x		50	150	0	18	V-a	410								
x		50	175	0	18	V-a	733								
x		38	150	0	18	US		400							
x		38	175	0	18	US		2199							
x		38	200	0	18	US	439								
x		50	150	0	18	US		1750							
x		50	175	0	18	US		450							
		50	200	0	18	US	879								
x		50	200	0	18	V-a		1179							
x		50	225	0	18	US	733								
x		50	225	0	18	V-a		3000							
x		63	150	0	18	US	733								
x		63	175	0	18	US	733								
x		63	200	0	18	US	131								
x		63	225	0	18	US	366								

Figure 8. Input window of saw model: Sawing needs for a certain sawing period. Products (thickness, width and grade) and their minimum and/or maximum amounts to be sawn are presented.

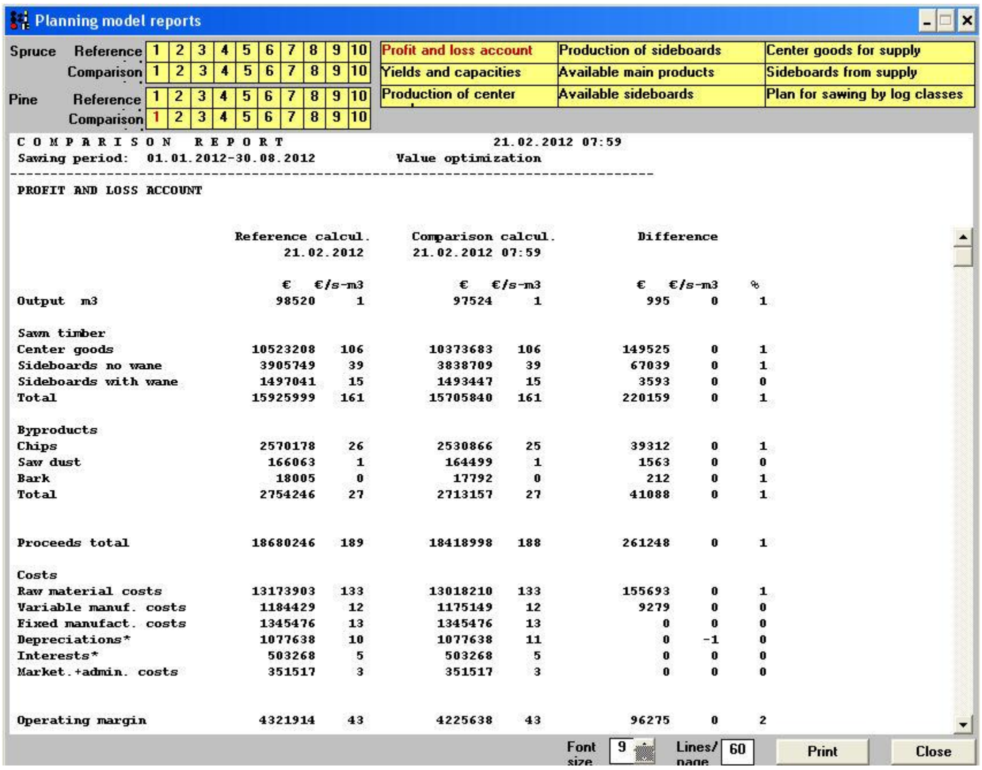
4.5.3 Output data from sawing model and examples of output tables

The software estimates the profit for the time period, the number of sawlogs to be sawn using a certain set-up, the number of sawlogs to be left in storage and the product assortment (dimensions, lengths and grades) to be manufactured. Shadow Price-analysis results in valuable information to management. Output data and reports of Saw model are presented below.

Saw model output data contains information of:

- Predicted economical key figures for certain sawing period
- Use of capacities during sawing period
- Predicted production of center goods during sawing period
- Predicted production of sideboards during sawing period
- Sawing program for sawing period
- Amount of logs to be sawn by certain sawing pattern

Main output of the saw model is presented in Figure 9. Proceeds of center goods, side boards and by products are presented. Also costs are presented. Operating margin is also presented. The result is compared to the result of preceding execution of the program.



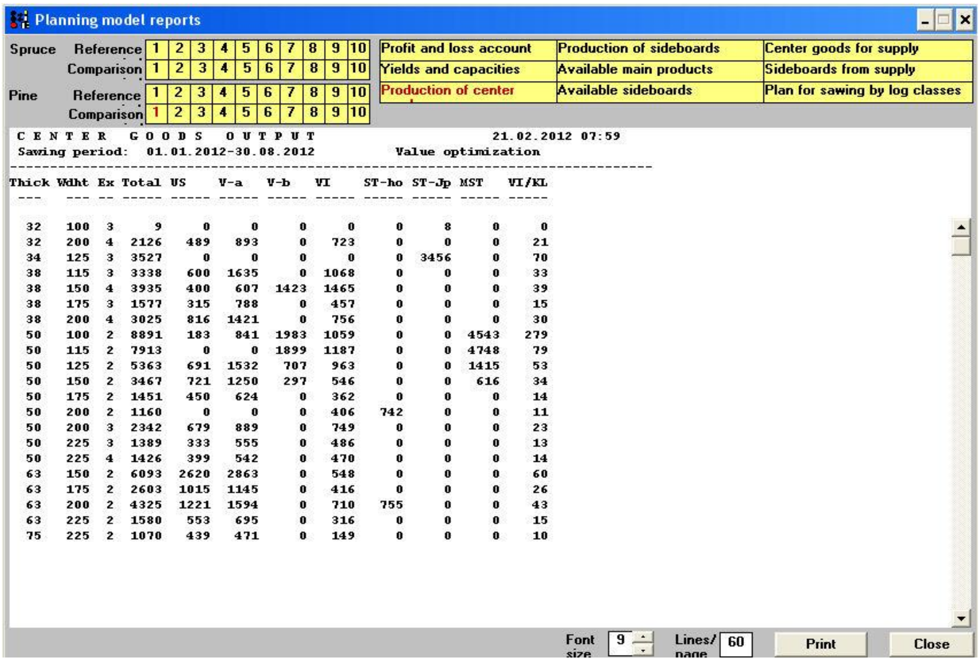
C O M P A R I S O N   R E P O R T   21.02.2012 07:59
Sawing period: 01.01.2012-30.08.2012   Value optimization

PROFIT AND LOSS ACCOUNT

	Reference calcul. 21.02.2012		Comparison calcul. 21.02.2012 07:59		Difference		
	€	€/s-m3	€	€/s-m3	€	€/s-m3	%
Output m3	98520	1	97524	1	995	0	1
Sawn timber							
Center goods	10523208	106	10373683	106	149525	0	1
Sideboards no wane	3905749	39	3838709	39	67039	0	1
Sideboards with wane	1497041	15	1493447	15	3593	0	0
Total	15925999	161	15705840	161	220159	0	1
Byproducts							
Chips	2570178	26	2530866	25	39312	0	1
Saw dust	166063	1	164499	1	1563	0	0
Bark	18005	0	17792	0	212	0	1
Total	2754246	27	2713157	27	41088	0	1
Proceeds total	18680246	189	18418998	188	261248	0	1
Costs							
Raw material costs	13173903	133	13018210	133	155693	0	1
Variable manuf. costs	1184429	12	1175149	12	9279	0	0
Fixed manufact. costs	1345476	13	1345476	13	0	0	0
Depreciations*	1077638	10	1077638	11	0	-1	0
Interests*	503268	5	503268	5	0	0	0
Market.+admin. costs	351517	3	351517	3	0	0	0
Operating margin	4321914	43	4225638	43	96275	0	2

Figure 9. Output window of saw model: Main report; Economical key figures of the run. Results are compared with the preceding run. Using of the program is interactive. Normally changes in the input data and new runs must be carried out until practicable result will be reached.

Production of center goods is presented in figure 10.



C E N T E R   G O O D S   O U T P U T   21.02.2012 07:59
Sawing period: 01.01.2012-30.08.2012   Value optimization

Thick	Wdht	Ex	Total	US	V-a	V-b	VI	ST-ho	ST-Jp	MST	VI/KL
32	100	3	9	0	0	0	0	0	8	0	0
32	200	4	2126	489	893	0	723	0	0	0	21
34	125	3	3527	0	0	0	0	0	3456	0	70
38	115	3	3338	600	1635	0	1068	0	0	0	33
38	150	4	3935	400	607	1423	1465	0	0	0	39
38	175	3	1577	315	788	0	457	0	0	0	15
38	200	4	3025	816	1421	0	756	0	0	0	30
50	100	2	8891	183	841	1983	1059	0	0	4543	279
50	115	2	7913	0	0	1899	1187	0	0	4748	79
50	125	2	5363	691	1532	707	963	0	0	1415	53
50	150	2	3467	721	1250	297	546	0	0	616	34
50	175	2	1451	450	624	0	362	0	0	0	14
50	200	2	1160	0	0	0	406	742	0	0	11
50	200	3	2342	679	889	0	749	0	0	0	23
50	225	3	1389	333	555	0	486	0	0	0	13
50	225	4	1426	399	542	0	470	0	0	0	14
63	150	2	6093	2620	2863	0	548	0	0	0	60
63	175	2	2603	1015	1145	0	416	0	0	0	26
63	200	2	4325	1221	1594	0	710	755	0	0	43
63	225	2	1580	553	695	0	316	0	0	0	15
75	225	2	1070	439	471	0	149	0	0	0	10

Figure 10. Output window of saw model: Production of center goods by dimensions and grades.

4.5.4 Input data for sawing model integrating sawn timber demand and available logs and it's links to sawmill's information systems

Different input data catergories for sawing model and their links to sawmill's information systems are presented in table 3. It's possible to recognize that the rate of change varies from slow to fast. Prices of sawn timber may vary very fast due to market situations. Changes in production costs, sawn timber grade distribution and log distribution are slow.

Table 3. Input data catergories for sawing model. The columns in the table link input data to sawmill companie's business environment, especially to information system.

Input-data	Rate of change	Who determines	Source of data	Impact
Sawing needs	Fast	Production planner	Sales organisation, ERP (sawn timber in stock)	
Volume and value yield of sawing patterns	Fast	Production planner	Sawing simulation program, ERP	Linking sawing needs with logs optimally
Available logs	Fast	Production planner	ERP (logs in sawmill stock), estimate of accumulating log stock during sawing period	
Operation time of sawmill departments during sawing period	Medium	Production manager	Market situation, bottlenecks in the process	Production volume
Production efficiency	Slow	Production manager	Speed of production lines, speed of machines, practice	Production volume
Annual costs and driving costs of sawing departments	Slow	Production manager	Cost control	Profitability

Input data parameter values for sawing model are typically determined by production manager or/and production planner supported by companie's Enterprice Recourses Planning (ERP) information system. Typically there are continuous data flow between sawing simulator and ERP system. Input data sets are transferred from ERP to sawing simulator and calculation results are transferred in the opposite direction. Strong integration between simulator and ERP is the key for succesfull planning of production, sales activities and harvesting operations.

There are several data sources servicing planning operation conventional and x-ray scanners for logs providing data from actual log features. ALS and TLS are considered to be important data sources for the evaluation of statnd's wood raw material. Dimension control is quality control procedure resulting information for determination of green dimensions for sawn timber pieces and determination of saw kerfs. Prices of sawn timber and wood raw material will be determined by marketing department and harvesting department based on company's business policy. Sales organization in close co-operation with production management will determine sawn timber grades. ERP system will store and process information about production costs. This data will be transferred to sawing simulator's input data. Sawing patterns and sawing set ups are determined by production planner supported by sawing simulator based on actual orders and experiences.

Log distribution and characteristics determine how well purchased wood raw material matches the damnded sawn timber profile. The match impacts much on the profitability to be achieved in conversion.

Prices of logs and sawn timber, operational costs and grade distribution of sawn timber influence directly on the profitability. Green dimensions, saw kerfs and sawn timber dimesnions affects directly on the value and volume yield in sawing operations.

4.6 Managing data and information flows

Different type and level of information systems has been implemented in sawmill industry. Bigger companies have large information systems. Small companies have implemented simpler systems. The movement is however very clear, future sawmill business is more processing of information than wood material.

The triangle in Figure 11 presents the architecture and structure of a future information system. This structure is already at least partly implemented in front edge companies. There are two basic levels in the ICT system: process control level (floor level) and planning level. Planning level can be divided into two parts: Administration level like material and storage control systems, book keeping etc. and planning level which comprises tools for designing activities and decision making. Process control level means individual machines and their operations.

Interaction and integration of these three levels is very important in order to manage whole business system properly. Planning level develops information and control value to be transferred to process control level and individual machines. A lot of information is collected from machines operating at the floor level. This information has to be transferred to upper, administration level where the data is processed and stored into data bases. Planning operations, simulations and optimisation procedures needs also a lot of information from floor level and also from orders, storages etc. This information is available through administration level.

Measurements and observations throughout the chain produce data and information. In individual stages information is growing rapidly. This information is, however, used only locally. After the wood material has left the processing phase, almost all gathered information is dropped. This happens all the way throughout the supply chain. It is not possible to link final products, raw materials and processing parameters together. The picture also shows an accumulated curve assuming that all the information from previous phases would be available in the later phases. If the lost information could be regained, much more effective business could be realised. Information "recovery" can be achieved through marking pieces, reading of the markings and storing the corresponding data in a database

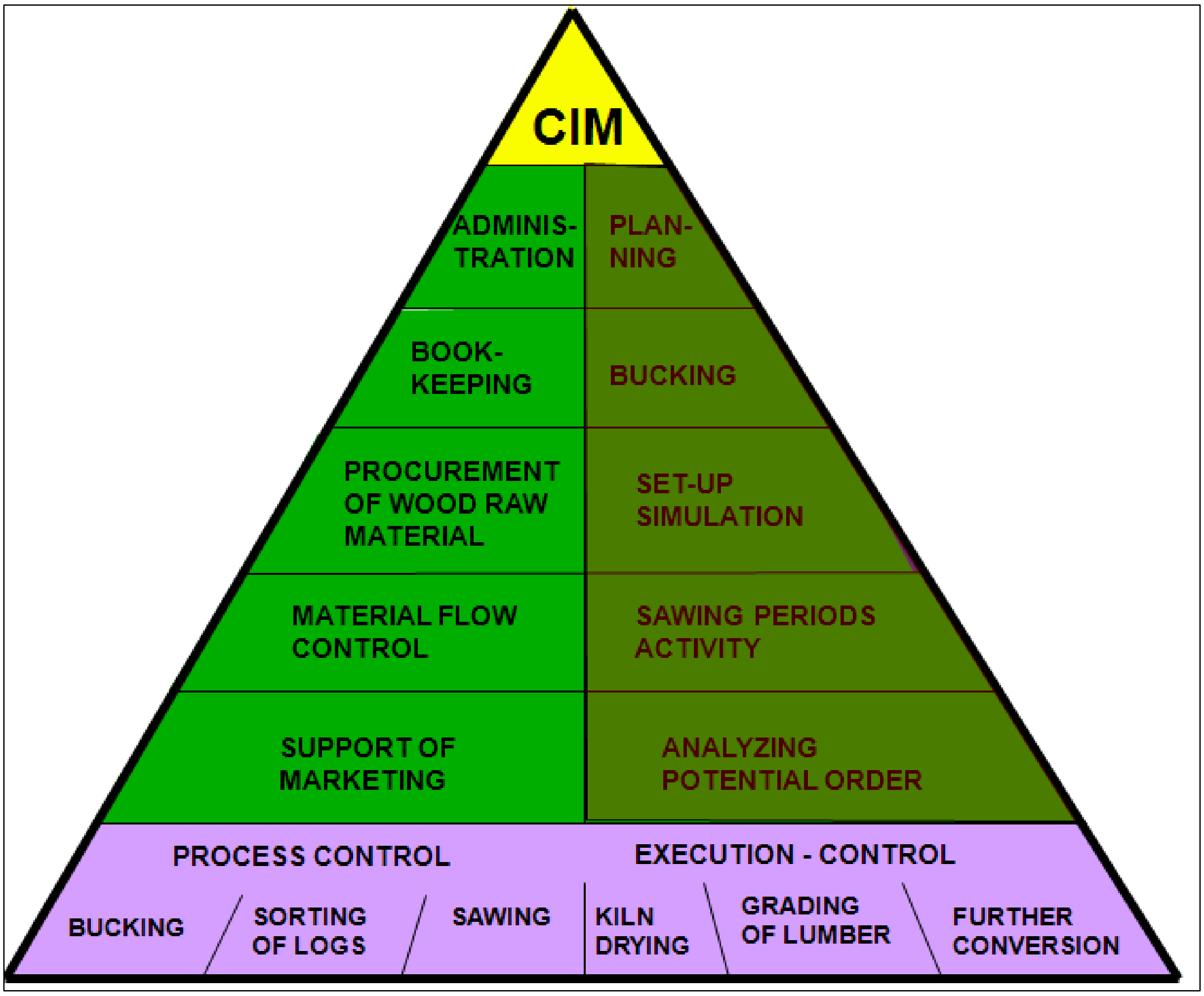


Figure 11. Typical information system for sawmill company can be devided into two main levels : planning level supported bu administative functions and floor level, individual processes and processin chains. The yellow triangle on the top, CIM or ERP integrates all the parts on business area together.

4.7 Assesement of stands using virtual stem approach

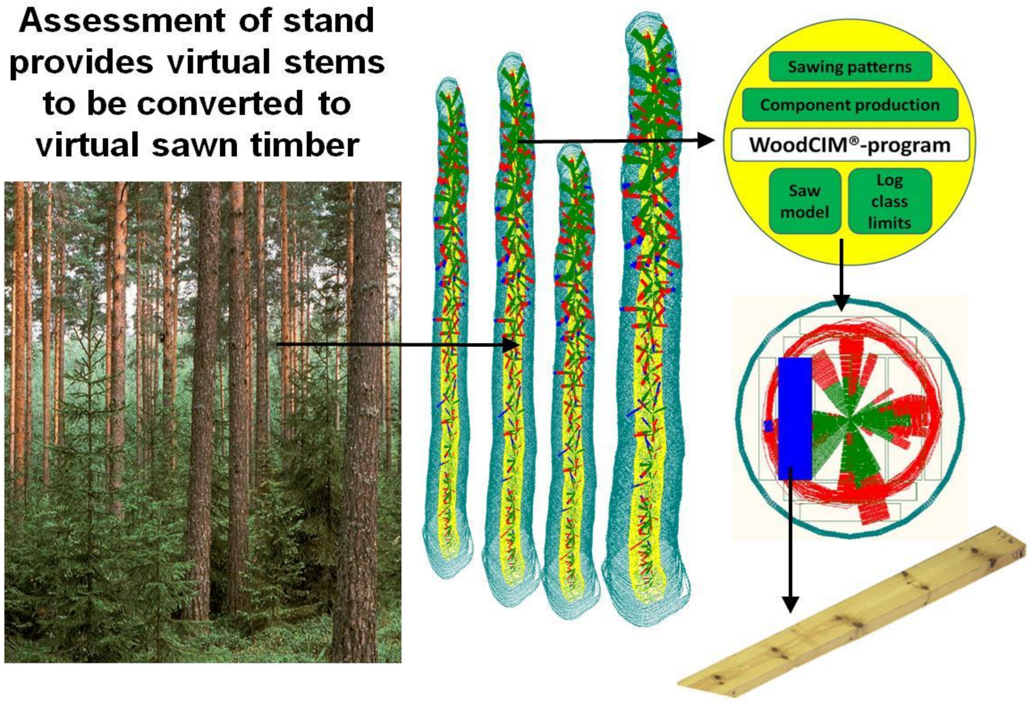


Figure 12. Principal presentation of assessment of stand. How well the wood raw material matches the requirements of sawn timber

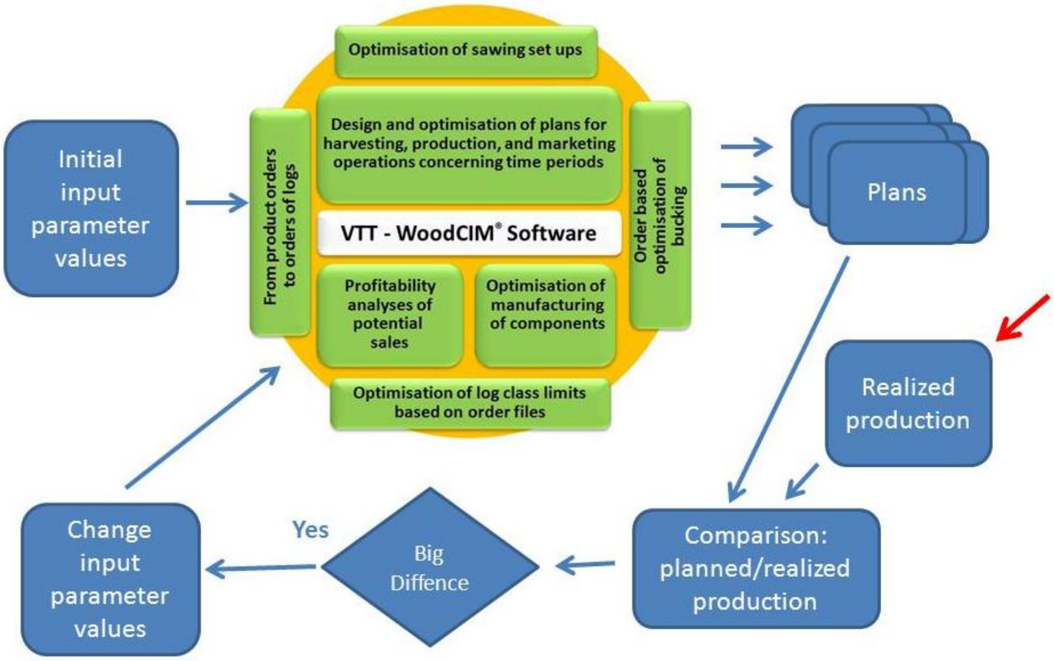


Figure 13. VTT's WoodCIM® consists of integrated software modules and loops for realising self learning procedures for adjusting parameter values in software systems.

Important part of the future sawmill business is the creation of feedback information. In the WoodCIM® procedure measured log or batch of logs characteristics are recorded to the system as an output data. This output is then compared with the estimated output through WoodCIM® software. The procedure results to information of possible needs to change parameter values in the software. If yes,a new parameter values are determined and implemented in the software. This is the way to improve prediction accuracy.

Optimisation of activities throughout conversion chains is very important issue in the future sawmill business. Two types of optimisation can be identified:

Global Wood Chain Optimization seeks to achieve maximum profit in the conversion chain – from the forest to the end product - in its entirety. In the global approach the supply chain phases are actively interacting ensuring the best possible economical result.

Suboptimization means a procedure to achieve the maximum output in the individual phases of the conversion chain. In the suboptimization different phases in the chain are in a loose interaction or they have no interaction at all. From the economic point-of-view, global optimization is much more important than the suboptimization of individual process phases. The big advantages using the Global Wood Chain Optimization approach are to

- manage to match the available wood raw material with the market demands and orders
- manage and control the procurement of wood raw material
- promote dynamic lumber sales and marketing
- control the production processes as a whole to achieve best possible value yield, minimum through-put times and minimum storages in the chain.

5. StanForD2010 (Skogforsk)

5.1 StanForD2010

An extensive general description can be found in the document Arlinger et al. 2011 “Introduction to StanForD2010 - Structural descriptions and implementation recommendations”. The hpr-message can be read by general programmes operating on xml-files (Extensible Markup Language). The older pri-format is not as easily readable without adapted programmes like Skogforsk TimAn or products from commercial software developers like Logica. (more about StanForD below). These contain a summary of the individual stem and log information that is actually measured in the harvester felling head and/or directly calculated by the harvester computer. In addition to this coordinates of the machine position is continuously logged when operating (most harvesters have GPS). The information provided in hpr-files, the new xml-format (hpr=harvester production report) or the previous pri-files (can now be converted to hpr) is briefly as shown in table 4. It contains tree ID, stem diameter and coordinates, log positions and the products (assortments). These are controlled by the production instructions, the measurements in the harvester felling head operators detection of unacceptable faults causing forced cuts and/or downgrading and the bucking optimisation program. The general quality requirements described in deliverable D3.1 “Industrial requirements, gaps and improvement needs”, (Bajric et al 2011, WP 3000) is a common basis for normal sorting and quality classifications. However individual customers may have different demands and preferences. As long as they can be expressed for automatic or manual decisions at full production speed or at the stand level previous to cutting that can be performed as well.

The structure of the production instruction used for either harvester (simulation mode or real operation) bucking etc. is handled in Task 5400. Three separate messages are used for controlling optimized bucking in harvesters. These messages, *production instruction*, *species group instruction* and *object instruction*, are not to overlap each other. The ProductKey is used as a unique key in all production messages (running number set in machine, globally unique when used in combination with MachineKey). The ProductUserId is used as an identifier in production definition and object instruction messages (set by logging organization) (Arlinger et al 2011). By this the production controller can define each product(assortment) to be produced by the harvester and the required apportionments of e.g. length and diameter classes and values per m³ of each product (price matrices for specific products and dimensions)

Table 4. The general, now standardised information from Cut-To-Length harvester production reports. Tree and Log(within tree counted from but end) are current unique numbers within a unique harvesting object number. DBH= Breast height diameter (mm). Coordinates (here RT90). Slash for bioenergy show that forest fuel will be produced from this stem. In StanForD 2010 Products (assortments) are strictly defined in the Production instruction, (described at page 13, Arlinger et al 2011). Log diameters are given as Top, and Mid (mm) over bark (Butt diam=Top at previous log except for the stump end which is not measured). Length is measured in cm. Add lengths within tree and you get tree height to top diameter of the top log.

StanForD provides enhanced production reports information on individual stems and logs

SKOGFORSK

Tree	Species	DBH	X-coord	Y-coord	Slash for bioeneregy
1	Pine	330	6347115	1481603	1=Yes

Tree	Log	Product (assortment)	Top diameter	Mid diameter	Length
1	1	Sawlog, butt	271	302	553
1	2	Sawlog, mid	233	252	432
1	3	Sawlog, sound knot	196	212	512
1	4	Saw small log	165	178	342
1	5	Pulpwood	95	132	491

Input files for simulation in the Northern Europe case are containing information as described in Deliverable 4.1 (Vauhkonen et al. 2012, Task 4400). We are bringing ALS information (in our case provided by Foran) interpreted to STM-files (or other readable/compatible input files). To get realistic frequencies and distributions of stem faults we also apply previously recorded, statistically based rates and structures of logs downgraded (stem faults) by the harvester operator (hpr-files from final cuts in the laser scanned region).

This interface to customers demands expressed by standardised production instructions and when applicable also extendable by additional stand type specifications or e.g. index value to adjust for values concerning desirable or undesirable requirements (This design of interface is Skogforsk’s additional contribution to Task 5300 and 5400).

The bucking simulations are performed to support the delivery plans developed by the planning tools developed and described in Task 5500 (and applied in Task 8100). By this procedure the next step is to decide and transmit (to all machines involved) the final production instructions (Task 5400) based on log diameter, log length, log type (log number from butt, distance from butt etc.) and if specified possibly also other available (measured or predicted) log characterization parameters. Our possibilities to add such information to the standardised hpr/pri-files are presented in the document "Extended pri description of content English" at the document Repository Wp 5000 at the Flexwood homepage as are the examples of such extended pri-files given in simple text formats presented in table 5.

Table 5. Files included in the uploaded "Pri-körning mOTORPET.zip" file at the Flexwood portal.

Name	Type	Modified	Size	Ratio	Packed	Path
HarvestedProduction_V1p0.xsd	XSD File	2011-02-08 08:...	27 980	87%	3 592	
Motorpet_LogData.txt	Text Docume...	2011-09-07 09:...	2 686 6...	69%	843 466	
Motorpet_StemData.txt	Text Docume...	2011-09-07 09:...	314 596	73%	83 584	
S.Mortorp FA.pri	PRI File	2010-12-21 09:...	1 690 6...	73%	456 139	
S.Mortorp FA_1.hpr	HPR File	2011-06-28 14:...	32 329 ...	96%	1 282 ...	
StanForD2010CommonDefinitions_...	XSD File	2011-05-16 07:...	142 364	88%	16 731	

These subjects are also further described in the Northern Europe case, Task 8100 and in Deliverable D5.4.

In WP 7000, tasks 7200 and 7300 we are also contributing with data and procedures fitting to the ordinary production instructions we can handle within the frames of Skogforsks research tools.

5.2 Why StanForD

In the StanForD work all content of the decided standard is continuously documented. StanForD is coordinated by Skogforsk (John Arlinger and Johan Möller,) and Metsäteho (Tapio Räsinen and Juha-Antti Sorsa) in cooperation. The standard work is open and directly supported by machine manufacturers (worldwide), software developers, forest companies and other organisations in many countries (including Germany (KWF), France (FCBA), Latvia (LVM)), working with Cut To Length systems. New ideas and additional needs are continuously discussed and taken into a decision process for approval when applicable. In general we strongly suggest working this way, if possible. We believe that it facilitates efficiency significantly. We make it possible to maintain each step of progress we make in cooperation with all partners project by project and achieve sustainable progress when project ends and others are started.

There is much to gain by using these standardised files as a basis for sustainable progress. That's why we have planned and generally recommend all possible development work to consider StanForD as an efficient basis for development also of new interfaces forestry <–> industry. Beside forest machines we are involved in the papiNet standard development (www.papiNet.org) for business to business communication in the user group Forest Wood Supply and its connections to user groups WoodX (Wood products), Pulp, Paper and other.

At the national level we have also initialized and are also centrally involved in the development of a national standard for “Data concerning forests and utilisation of forests” coordinated by SIS (SIS TK358) (http://www.sis.se/sok/?q=data om skog).

5.3 Further possibilities beyond Flexwood

An interface providing standardised 3D-pictures (external shape) and internal wood and knot properties cannot be developed (at least not by us) within this project, but we have already applied for another such project together with you at VTT (and some other). Unfortunately it was not approved. A new application on this subject (Cut To Length to Sawmill and forward) can be considered.

6. Interface and methods to meet market based quality and quantity requirements (FobAwi)

6.1 General concept

Within the Work Package 5000: Novel harvesting and logistic concepts to integration of forest industry, “Interface and methods to meet market based quality and quantity requirements” have been developed in Task 5300. The results are stated in deliverable D 5.3 including a conceptual description elaborated for the Central Europe use case (Karlsruhe) in detail. (see also WP 8000 “Implementation and demonstration of the Flexwood concept” with Deliverable D 8.1 as well as D 5.4).

1. The results of the various procedures to define and describe industry-relevant parameters of stands and trees to be harvested results in a stand data bank, where trees (single trees or subpopulation of trees) are identified and described with both dimensional (diameter, height) and qualitative (shape, crown, branches) parameters. Due to the fact that these parameters have been measured by remote sensing techniques on standing trees / stands, only parameters which are visible from outside are included in this dataset. Nevertheless through existing wood research-related science based knowledge (limited) conclusions can be also derived for internal quality parameters, namely knots.

2. In a second step, this list of quantitative and qualitative parameters of trees to be harvested (tree-list) is converted into a databank which contains products (logs) to be delivered to the customer (sawmill). This conversion can be performed by existing simulation software (bucking simulation). Within the Flexwood concept, several conversion softwares are used within the different use cases. In the example elaborated below the software package *Holzernte* is used, which has been developed specifically for the forest and market conditions which exist in South West Germany.
The result of this conversion is a log list, which contains again quantitative as well as qualitative parameters of each log and provides also a classification according to the established round wood sorting rules.
Logistic decisions (transport, allocation) are supported by the coordinates of the stand which are part of the tree list and are transferred into the log list.

3. The logs in this log list can be sorted according to the specific demands or needs of the customers. Depending on the market situation and the structure of the customers, two alternative solutions are possible:

a) the forest owner/manager sends the complete log list to a number of customers as an “offer”, and the customers (sawmills) react and bid for those logs, which they are interested to take over. These customers support their decision by feeding the log list into their internal sawing simulators. Logistic and transport aspects (distance, costs, min/max size of the order) can also be included in this selection process.

b) the forest owner/manager makes himself a sorting of the log list according to the demand lists of several customers, which have been forwarded to him. He offers a selection of specific logs to these customers. If pre-contracts (frame contracts) have already been negotiated, he can also select the most suitable logs and deliver them according to the specifications of these pre-contracts to the respective customers.

6.2 Example

The following example shows the dataflow and interfaces for the use case Central Europe (Karlsruhe).
The tree list shown in Table 6. includes beech (FASY) as well as pine (PNSY) trees including the volume of the potential long log depending on the specifications from the respective mills on maximum large end diameters and minimum small (top) end diameters.

Table 6. Tree list. Example with PNSY and FASY) from Central European use case

Tree # #	Geo coord. x [m]	Geo coord. y [m]	Dia bh [cm]	D 7m [cm]	Height top [m]	Length crown [m]	Height cr.Base [m]	Species code #	Length stem [m]	Dob mid [cm]	Dub mid [cm]	Dub top [cm]	Vol sub [m³]
1	3458005,55	5435405,39	23,3	20,5	19,20	6,67	12,53	PNSY	12,67	20,92	19,74	14,25	0,36
2	3458009,40	5435406,33	20,7	15,9	19,62	12,39	7,23	PNSY	8,53	17,60	15,96	14,15	0,19
3	3458013,16	5435404,82	29,0	24,6	22,39	4,90	17,49	PNSY	16,41	23,77	22,43	14,25	0,63
4	3458012,39	5435396,40	23,0	20,7	21,69	10,56	11,13	PNSY	14,19	20,65	19,48	14,25	0,40
5	3458007,32	5435396,73	29,0	24,6	21,82	4,20	17,62	PNSY	15,69	23,58	22,25	14,25	0,76
6	3458003,37	5435394,24	28,5	23,1	20,55	9,69	10,86	PNSY	14,61	22,87	21,58	14,25	0,53
10	3457991,42	5435402,00	26,3	21,0	19,34	10,87	8,47	PNSY	12,98	21,38	20,17	14,25	0,41
12	3457994,14	5435408,88	27,2	23,4	19,73	5,77	13,96	PNSY	14,20	23,33	22,01	14,25	0,51
13	3458000,73	5435404,15	22,9	19,6	19,64	9,04	10,60	PNSY	12,37	20,10	18,96	14,25	0,33
14	3457998,28	5435408,52	26,2	19,6	19,40	4,02	15,38	PNSY	12,21	20,28	19,14	14,25	0,37
15	3458001,73	5435408,53	31,5	25,0	20,59	10,47	10,12	PNSY	15,24	24,47	23,09	14,25	0,64
1	3456404,02	5433007,51	53,2	35,6	26,19	4,06	22,13	FASY	24,10	32,14	30,96	9,42	2,07
2	3456412,14	5432998,29	50,9	44,1	28,13	7,84	20,29	FASY	26,26	39,83	38,42	9,42	2,86
5	3456401,42	5433005,30	59,4	52,4	27,00	4,03	22,97	FASY	19,25	50,70	49,00	36,55	3,63

For each tree taper curves can be generated based on the inventory results (see Figure 141 and Figure 15 for an example of each FASY and PNSY indicating also the cross-cut lines resulting from the respective mills’ roundwood specifications.

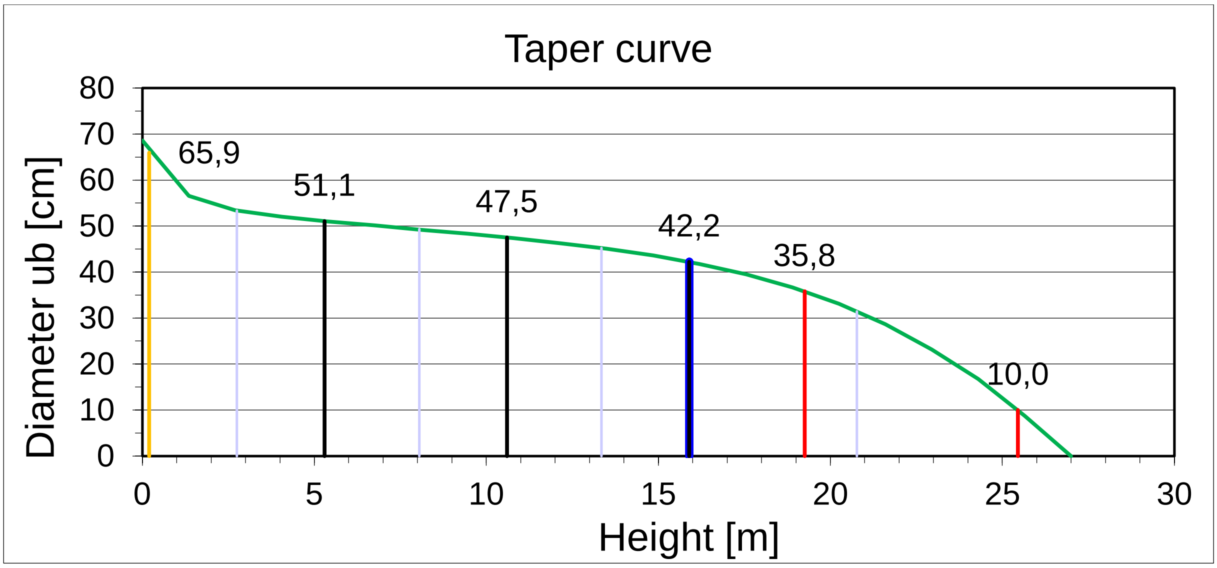


Figure 141. Taper curve. Example of FASY tree with cross cut lines depending on mill specifications

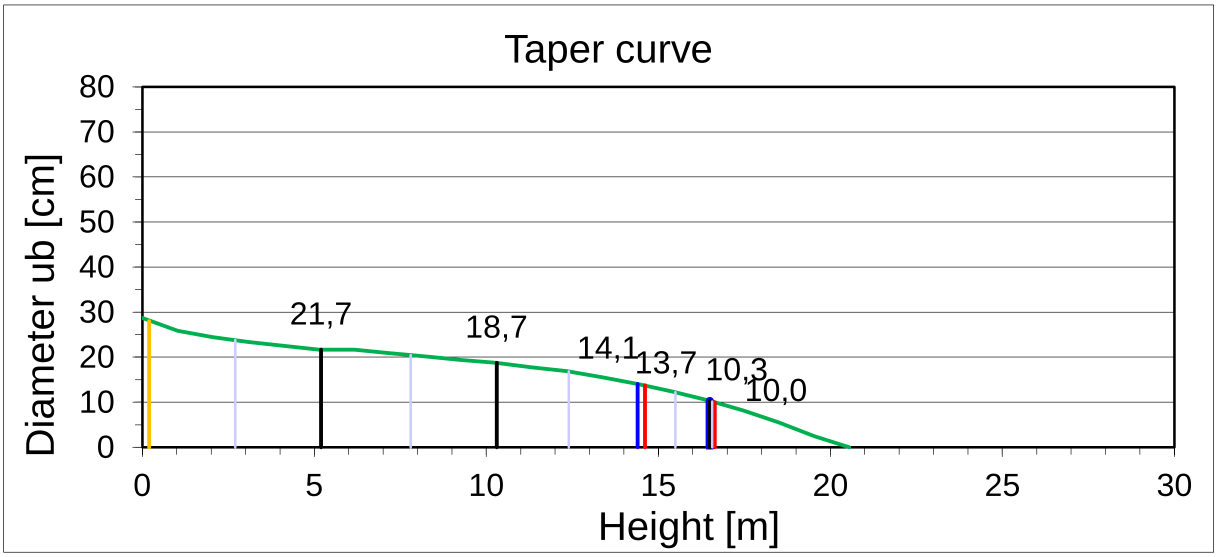


Figure 15. Taper curve. Example of PNSY tree with cross cut lines depending on mill specifications

Depending on (i) the available and applied harvesting and logistic system and (ii) the mills' production requirements it can then be decided which product output to choose and to which mills these products should be allocated to.

As information on the standing timber is available well in advance before harvest it is for example therefore still an option to cut long logs, which is very much practiced in traditional Beech (FASY) harvesting operations in Central Europe. In this case the stem length shown in Table 6. corresponds to the log length where the respective roundwood requirements are met and e.g. the demanded minimum top end diameters are respected.

Based on the tree and stem information log lists can be created with support of *Holzernte* as described above according to demand specific dimensional and qualitative parameters according to alternative (b) mentioned above. The logs can subsequently be sorted as shown as an example in Table 7, which allows allocating the right products to the right mills depending on the respective requirements.

Table 7. Log list. Example based on mill specific roundwood requirements

Log #	Species code	length [m]	allow. [m]	mid Dub [cm]	top Dub [cm]	Vol sub [m³]	Taper [mm/m]	Quality	Grade
1	FASY	25,8	0	38,44	10,50	3,00	21,64	Ind	Ind
4	FASY	9,3	0	32,22	10,50	0,76	34,76	Ind	Ind
3	FASY	18,3	0	29,63	10,50	1,26	12,42	Ind	Top log
1	FASY	5,1	0,2	54,09	51,83	1,17	8,87	Saw B	Butt log
2	FASY	5,1	0,2	50,09	48,27	1,01	6,98	Saw B	Top log
1	FASY	5,1	0,2	43,85	37,04	0,77	26,72	Saw C	Butt log
3	FASY	5,1	0,2	45,94	43,00	0,85	10,34	Saw C	Top log
2	FASY	2,5	0,2	34,72	33,26	0,24	15,09	Saw C	Top log
4	PNSY	3	0	13,30	11,26	0,04	12,89	Ind	Ind
4	PNSY	3	0	14,27	11,51	0,05	17,30	Ind	Ind
4	PNSY	2	0	13,06	11,45	0,03	15,84	Ind	Ind
3	PNSY	2	0	13,64	13,00	0,03	6,42	Ind	Ind
4	PNSY	2	0	12,28	11,47	0,02	7,63	Ind	Ind
4	PNSY	2	0	14,10	12,37	0,03	17,01	Ind	Ind
4	PNSY	2	0	12,73	10,79	0,03	18,94	Ind	Ind
4	PNSY	2	0	12,28	10,77	0,02	14,83	Ind	Ind
4	PNSY	2	0	12,63	11,13	0,03	14,51	Ind	Ind
4	PNSY	2	0	13,75	11,63	0,03	20,67	Ind	Ind
1	PNSY	5	0,1	25,41	23,68	0,25	6,90	Saw B	Butt log
1	PNSY	5	0,1	20,65	19,71	0,17	3,77	Saw B	Butt log
1	PNSY	5	0,1	25,45	23,70	0,25	6,98	Saw B	Butt log
1	PNSY	5	0,1	24,53	22,40	0,24	8,51	Saw B	Butt log
1	PNSY	5	0,1	20,18	18,84	0,16	5,36	Saw B	Butt log
1	PNSY	5	0,1	26,91	24,36	0,28	10,20	Saw B	Butt log
1	PNSY	4	0,1	21,05	20,20	0,14	4,24	Saw B	Butt log
1	PNSY	4	0,1	17,72	16,00	0,10	8,58	Saw B	Butt log
1	PNSY	4	0,1	22,40	20,01	0,16	11,96	Saw B	Butt log
2	PNSY	5	0,1	22,69	20,93	0,20	5,50	Saw B	Top log
2	PNSY	5	0,1	22,68	20,83	0,20	5,75	Saw B	Top log
2	PNSY	5	0,1	21,22	19,23	0,18	6,34	Saw B	Top log
2	PNSY	4	0,1	19,76	18,48	0,12	4,30	Saw B	Top log
3	PNSY	4	0,1	16,73	14,61	0,09	9,67	Saw B	Top log
2	PNSY	4	0,1	15,39	14,28	0,07	4,30	Saw B	Top log
2	PNSY	4	0,1	19,38	18,27	0,12	3,61	Saw B	Top log
3	PNSY	4	0,1	16,80	15,13	0,09	7,86	Saw B	Top log
1	PNSY	5	0,2	22,48	20,40	0,20	8,31	Saw C	Butt log
1	PNSY	5	0,1	24,14	22,58	0,23	6,22	Saw C	Butt log
3	PNSY	5	0,1	18,61	15,77	0,14	10,32	Saw C	Top log
2	PNSY	5	0,1	21,50	19,34	0,18	6,48	Saw C	Top log
2	PNSY	5	0,1	18,01	16,18	0,13	5,31	Saw C	Top log
2	PNSY	5	0,1	22,95	20,77	0,21	7,17	Saw C	Top log
2	PNSY	4,5	0,2	19,35	17,55	0,13	6,34	Saw C	Top log
3	PNSY	4,5	0,2	15,10	11,68	0,08	13,06	Saw C	Top log
3	PNSY	4	0,1	18,88	16,70	0,11	10,33	Saw C	Top log
3	PNSY	4	0,1	17,31	14,58	0,09	11,64	Saw C	Top log
2	PNSY	4	0,1	19,00	17,56	0,11	6,12	Saw C	Top log
3	PNSY	4	0,1	15,91	14,03	0,08	8,82	Saw C	Top log
3	PNSY	4	0,1	18,73	15,76	0,11	12,52	Saw C	Top log
3	PNSY	2,4	0,1	17,90	16,51	0,06	11,82	Saw D	Top log
4	PNSY	2,4	0,1	14,43	12,16	0,04	18,10	Saw D	Top log
3	PNSY	2,4	0,1	14,97	13,73	0,04	10,22	Saw D	Top log

These lists are then transferred to the respective customers in a format that allows feeding them i.e. into their sawing simulators.

7. References

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