Del. no.	6.5
WP no.	6000
Date	07/05/2012
Version	1.0
Revision	
Confidentiality	CO

FlexWood
Flexible Wood Supply Chain

Concept on implementation of flexible production and future manufacturing systems in the sawmilling industry

Responsible Partner VTT Technical Research Centre of Finland (VTT)

Authors Arto Usenius, Antti Heikkilä, Marika Makkonen and Timo Usenius (VTT)

Project Coordinator University of Freiburg FeLis (ALU-FR)

SEVENTH FRAMEWORK PROGRAMME

The FlexWood project is funded by the European Commission within the Seventh Framework Programme (FP7). The Collaborative Project (small or medium sized focused research project) contributes to "Meeting industrial requirements on wood raw-materials quality and quantity" activities.

FP7 GRANT AGREEMENT No. 245136

Coordination:

FeLis – Department of Remote Sensing and Landscape Information Systems
University of Freiburg
Tennenbacherstr. 4, D-79106 Freiburg, Germany
www.felis.uni-freiburg.de
Contact:
Prof. Dr. Barbara Koch: barbara.koch@felis.uni-freiburg.de
Alicia Unrau: alicia.unrau@felis.uni-freiburg.de

Partners:

Albert Ludwigs Universität Freiburg	ALU-FR	Germany
Stiftelsen Skogsbrukets Forskningsinstitute	Skogforsk	Sweden
FCBA Institut Technologique	FCBA	France
University of Eastern Finland	UEF	Finland
Technical Research Centre of Finland	VTT	Finland
University College Cork	UCC	Ireland
TreeMetrics Ltd	TreeMetrics	Ireland
Forest Research Institute of Baden-Württemberg	FVA	Germany
Norwegian University of Life Sciences	UMB	Norway
University of Natural Resources and Applied Life Sciences	BOKU	Austria
Polish Research Institute	IBL	Poland
Logica Ltd	Logica	Sweden
Foran Ltd	FORAN RS	Sweden
University of Laval	UL	Canada

Website: www.flexwood-eu.org

Table of Contents

1. Executive Summary

Following conclusions can be drawn:

- Wood product business is becoming more and more challenging and market driven.
- Future manufacturing of wood products will emphasize collecting and processing of information.
- Log scanning is the key element for improving value of the production. Potential is 5...20%.
- Skilled and motivated personal is the key for success.

In the following some issues are listed which are important by linking together available wood raw material, wood products and processes.

Global view instead of local view

Traditionally different stages of the wood conversion chain have operated too much independently. In the conversion chain the product of the former phase provides raw material for the latter one. Often in practice raw material and semi-finished products are not optimal or even good in respect to the final product. The incompatibility between wood raw material, conversion products and the final product causes a lot of waste and economical losses. To obtain a good economic result the chain must be seen in its entirety. Wood raw material has to be chosen taking into account the requirements of the final products. This is the way towards optimal utilization of wood raw material.

Value added components and upgrading of sawn timber into components with flexible and adaptive manufacturing systems for sawmills.

Present production systems are effective, however bulk product oriented. They are not flexible and production of components with specified quality features and properties is difficult. Producing value added components – smaller pieces with specific dimensions and quality features – instead of standard products offers sawmills big potential to improve profitability of sawn timber business. Production of components should be started directly from the logs.

Cross cutting of stems and sawing methods

Cross cutting of stems is very important part of wood raw material processing. The maximum value and volume yield is determined in bucking of stems. In later phases in conversion it is not possible to compensate the faults made in cross cutting of stems. Modern harvesters are very sophisticated and effective. However they cannot measure accurately stem properties like internal knots. Best bucking and cross cutting result can be achieved when the stems or part of stems are transported to cross cutting station provided by x-ray scanner and advanced optimisation software. New sawing concepts are in the designing phase.

Information systems and intelligent material flow control

In individual phases of conversion information is growing rapidly. However this information is utilised only locally and then lost. This happens all the way throughout the supply chain. It is not possible to link final products, raw materials and processing parameters together. Strong support for business development could be achieved if the lost information can be stored and utilised in the later conversion phases. Recovery of information can be achieved through marking pieces, reading of the markings and storing the data in a database for utilisation in different applications. Marking of pieces can be done using different techniques i.e. RF-tags and ink jet markings. Reading of marking can be done using antennas or cameras.

Marking - reading – information (MRI) system applications concern quality control, process control, planning procedures and customer service. Marking of pieces is also a way to show the origin of pieces and can be for instance used to ensure that the material originates from a certified source. MRI provides a quite new approach for the management of material and information flows from forest to the end products supporting customer oriented business and added value production.

Scanning of internal properties of stems and logs for characterisation wood raw material and optimisation of sawing operation.

Log scanner systems for measuring shape and internal properties of logs can be used in the following processes:

- Log sorting station - optimisation of borders of log classes based on order files.
- Bucking and cross cutting terminal - optimisation of cross-cutting of stems and sorting of logs.
- Just before sawing - optimisation of log rotation angle and sawing set up for individual logs.
- Harvesting machines - optimisation of cross-cutting of stems.

The purpose of X-ray inspection system is to detect properties of round wood. The analysing software should be tailored to meet application requirements. Typical functions can include measuring of dimensions/volume, moisture content, volume of knots, rot and other defects and heartwood/sapwood ratio. In the future it's possible to full description of wood properties i.e. individual annual ring structure and density profile.

Present problem is the price of scanners. However investigations are carried out in order to provide also cheaper solutions for different applications to be installed at SME - sawmills.

Implementing process performance

There are many options to improve wood processing performance. Potential degree of improvements depends on many factors like quality of wood raw material and product specifications. Some aspects are presented in the following:

- Improvement of communication between building and interior designers and companies offers a channel to increase wood usage. This necessitates development of Electronic libraries of wood products have to support planning processes. The designers, customers and owners have to have direct communication and feedback channels with the woodworking companies.
- Business concepts based on networking taking good care about customers', further conversions' and end users' needs. This approach enables to react quickly on changing circumstances.
- Customers', end users' and refineries' service through developing information component as a part of products.
- Managing and optimisation material and information flows in overall ICT systems and production planning systems. Supporting information flows between different actors in wood chains. Optimisation of wood raw material use: wood raw materials, products and semi-finished with specific properties.
- Strong integration of technological, information and service platforms. Intelligent, flexible and self-learning scanning, production and logistic systems support realisation business. Generation of feedback information to be used in self-learning production systems.
- Developing product specifications and families (strength, appearance, aesthetic aspects) matching wood raw materials

- Early stage information will be available before buying wood raw material and before harvesting and crosscutting of stems. Stem terminal cross cutting.

VTT developed WoodCIM® and InnoSIM model and simulation systems for optimization throughout the conversion chain. Some results presented in this paper clearly show that it is possible to increase sales value and profit of the conversion considerably by implementing new technologies and concepts in the production.

2. Introduction

According to the Dow, Task 6300 « Improving flexibility in production and future manufacturing systems » concerns to the following topics. VTT has been as Task leader. Also industrial co-operation partners have been involved.

1. Flexibility is very important character of future processes. This demands the possibility to switch type production from bulk to value added, from value added to bulk or mixed value added and bulk.
2. In conventional production processes it is very difficult and costly to correct the “mistakes = wood delivery doesn’t corresponds to the order” pre-defined in harvesting operations and cross cutting of stems. Solutions are created on how production processes can adapt resiliently to these “mistakes”.
3. Increase of flexibility in manufacturing provides important option towards forestry and harvesting: sensitivity regarding requirements for wood raw material can be decreased through more flexible industrial production processes. New flexible manufacturing concepts are created and evaluated with the wood industry, machine manufacturers and system suppliers.
4. Simulation models are created from most promising production concepts. These models are mainly based on the models created in task 6200. Economic analysis will be carried out with the models for determining the impact on profitability.
5. An assessment will be carried out on the impact to sustainability, economic, environmental and social aspects.

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.

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. Schedule of deliverable is Month 18. 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.

There are several scientific calculation examples presented in this document. Most of them concern Nordic countries; however VTT has got similar results from other European countries and also countries outside Europe. The conclusion is that there are very similar problems and challenges but also similar improvement options cross Europe.

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 26	Pending
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 6.5 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.

4. Challenges and opportunities in sawmill industry

Sawmills are important centres of first conversion of round wood. Mostly the industry is based on locally operated SM enterprises. Sawmills are utilising forest resources by producing sawn timber to be used in construction, manufacturing of furniture, windows and doors etc. all sustainable products which represent high added value. Sawmills are also supplying pulp mills with high quality chips. Typical production and business features of sawmills are the following.

- Conversion from the forest to the customer is not an unbroken and smooth production chain. Delivery and processing time may require weeks or months.
- Volume output and cost minimisation is emphasized in production.
- Production is not flexible allowing only marginal freedom. Production and business are not adaptive. Feedback information is not generated and thus cannot be utilised.
- Limited volume of reliable and less reliable data is measured, and even so, however only locally used.

- Product properties vary considerably due to the non-homogeneous wood raw material. It is not possible to produce only high-value products with desired and specified properties. Secondary “falling” products which are not desired are inevitably produced along the manufacturing processes.
- Mismatch between wood products and available wood raw material recourses may cause big economic losses.
- Service aspects are missing. Wood working industry is far behind from the other industries providing services. VTT has started 2010 a research project for developing new service concepts to sawmill industry in order to provide better service for the customers and to improve profitability.

In the present sawmills it is not easy to produce products with specific properties. So called “falling” secondary products cause problems and considerable economic losses in spite of representing good inherent wood properties. Sorting only at the end of the process causes high cost and is not effective. Modern scanning technologies for roundwood provide efficient tools to handle and reduce radically these problems. They are important for improving value yield and developing customer orientated sawmilling business. The basic conversion process is not yet adapted to the same targets.

There are many options to real improve wood processing performance and management and control of entire sawmill value chain. Potential degree of improvements depends on many factors like quality of wood raw material and product specifications. In order to make real improvements in the conversion chain, following aspects are presented:

- Improvement of communication between building and interior designers and companies offers a channel to increase wood usage. This necessitates development of Electronic libraries of wood products have to support planning processes. The designers, customers and owners have to have direct communication and feedback channels with the woodworking companies.
- Strong integration of technological, information and service platforms.
- Business concepts based on networking taking good care about customers’, further conversions’ and end users’ needs. This approach enables to react quickly on changing circumstances.
- Customers’, end users’ and refineries’ service through developing information component as a part of products.
- Optimisation of wood raw material use: wood raw materials, products and semi-finished with specific properties.
- Developing business concepts emphasising sustainable development provides data acquisition on that respect.
- Managing and optimisation material and information flows in overall ICT systems and production planning systems. Supporting information flows between different actors in wood chains. Optimisation of wood raw material use: wood raw materials, products and semi-finished with specific properties.
- Intelligent, flexible and self learning scanning, production and logistic systems support realisation business.
- Generation of feed back information to be used in self learning production systems.
- Systematic collection of feed back information from customers and end users provides information for business development between business partners.
- Strong integration of technological, information and service platforms. Intelligent, flexible and self-learning scanning, production and logistic systems support realisation business. Generation of feedback information to be used in self-learning production systems.
- Developing product specifications and families (strength, appearance, aesthetic aspects)   matching wood raw materials.

- Early stage information will be available before buying wood raw material and before harvesting and crosscutting of stems. Stem terminal cross cutting.

4.1 Harvesting with conventional harvesters

Figure 1. Harvesting machine in operation.

Cross cutting of stems is very important part of wood raw material processing. The maximum value and volume yield is determined in bucking of stems. In later phases in conversion it is not possible to compensate the faults made in cross cutting of stems. Mismatch between available wood raw material and products to be manufactured may cause big economic losses. Modern harvesters are very sophisticated and effective. However they cannot measure accurately stem properties like internal knots. Best bucking and cross cutting result can be achieved when the stems or part of stems are transported to cross cutting station provided by x-ray scanner and advanced optimisation software.

Harvesting operation is essential phase of sawmills value chain. Trees are felled by harvesting machines. Pruning of trees is executed using knives. Cross cutting algorithms controlled by matrixes defined by designer tries to determine next cross cutting point based on the tree shape measurements. It is also possible for harvester operator to fix i.e. quality zones which are taking into account in the optimisation procedures. Harvesting is very important part of value chain because during the later processing phases it’s not possible to correct errors made in harvesting operation.

Following issues have to take carefully into consideration by implementations

1. Harvesting operators have to be very well trained.
2. There have to be good data transfer between harvesting machine and sawmill’s information systems in order to ensure effective communication.
3. Different harvesting machines have to be integrated via information network in order to make possible cross communication and in order to overall control management all harvesters simultaneously.

4. There has to be precise quality control systems in order to evaluate systematically performance of harvesting operation including scanning, optimisation, cross cutting accuracy etc. operations.
5. The harvesters have to have marking i.e. colour marking or identifying system for providing information to sawmill's overall information system and for proofing the origin or wood raw material for customers.

4.2 Cross cutting of stems at Stem terminal

Several value chains can be identified between forest and end use of wood products. Phases in conversion chains are impacting each others. In order to achieve good results, the chain has to be considered in its entirety. There may also be interaction between parallel chains. In the optimisation of allocation of wood raw materials and wood flows through whole conversion system, all phases have to be taken into account simultaneously. Because of the profitability, the chain is depending on raw material, manufacturing systems and product specifications. That is why economics of a stem terminal is depending on phases up-stream and down-stream.

Stems or part of stems can be transported to a terminal where bucking and crosscutting can be based on precise scanning of raw wood properties. This provides virtual, mathematical stems (Figure 2) that can be used in optimisation procedures capable to "fill the stems" with desired products. Logs are converted into products in primary and secondary conversion ensuring perfect match between raw materials and product. The terminal station can serve one mill or several mills.

Comparison between crosscutting operations with conventional harvesting machine and terminal crosscutting results information is presented in Table 2. This table clearly shows that smart stem terminal cross cutting offers potential to improve profitability and customer orientation radically.

Figure 2. Transportation of stem parts (above) and stem terminal for cross cutting of parts.

Table 2. Comparison between crosscutting operations with conventional harvesting machine and terminal crosscutting.

Performance Activity	Conventional harvester bucking and cross-cutting	Bucking and cross cutting at terminal (StemTerminal concept)
Diameter measurement along the stem to be detected	Mechanical process; partly based also on estimation of stem profile; Not possible to provide 3D-profile Accuracy: standard deviation 5 mm	Accurate measurement Accuracy: standard deviation 1..2 mm Can provide 3D-profile
Measurement and control of log length	Standard deviation of the same log length is typically 20..30 mm	Accurate log length. Standard deviation is estimated to 3..5 mm.
Detection of knots	Based only on harvester operator's visual estimation. Information concerns only surface knots, general knottiness of a log and bumpiness. Detection accuracy is poor. Impossible to see internal knots	Individual surface and internal knots can be detected with good accuracy
Detection of heartwood core of stems / logs	Impossible	High detection accuracy. Standard deviation of heartwood diameter 2..3 mm
Other properties and defects	Impossible	Possible – depending on the scanning system configuration
Optimisation	Based on measured and estimated stem profile and on the demand and value matrixes for logs. Difficult to determine parameter values in value matrixes	Optimisation is based on real demand of the products. Customer specific product specification can be applied. Optimisation can also be based on log demand, if necessary
Deliveries of logs	Typically it takes weeks to get ordered logs. Minimum time is three days in best cases. Service level is low	Delivery of desired logs can be started and stopped just in time. High flexibility to change log specifications according to the demand. Service capability is high
Impacts on processing capacities	Difficult – almost impossible	Terminal can just in time be provided by parameter values in order to start immediately to produce demanded log profile for maximising processing capacities and minimising through put times.

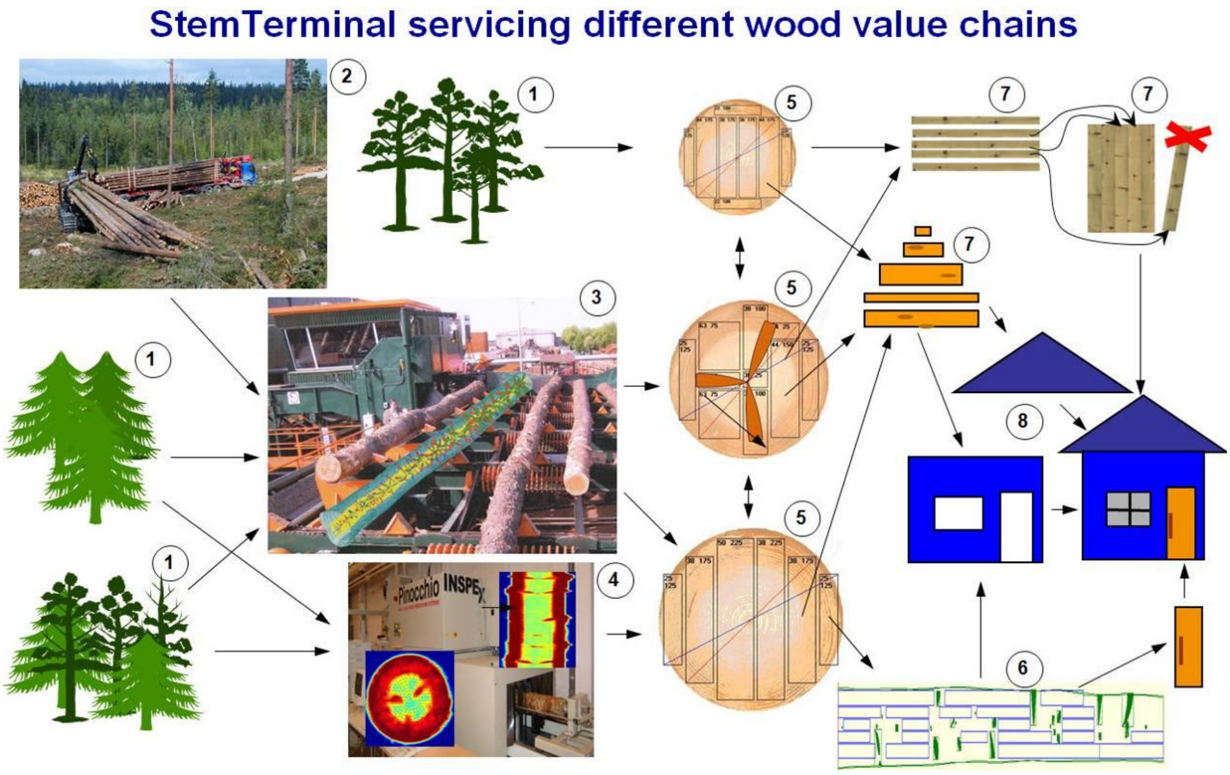


Figure 3. The Optimising allocation of wood raw materials and wood flows. 1) Stands to be harvested, 2) Transportation of stems, 3) StemTerminal for optimised bucking and cross cutting of stems, 4) X-ray scanner at log sorting station, 5) Different primary sawing processes, 6 and 7) secondary conversion and 8) buildings.

Following issues have to take carefully into consideration by implementations

1. Transportation costs of long logs compared to short logs. Investments and running costs. Combination of short log harvesting and long log harvesting is an alternative.
2. Stem terminal operators have to be very well trained.
3. There have to be good data transfer between stem terminals information system and sawmill's information system.
4. Precise scanning of geometrical and quality features i.e. knots of stem parts is very important part of terminal providing fundamental information for cross cutting optimisation.
5. Scanning systems and optimisation software are the cores at stem terminal. In a simple system stems are converted only into required logs. In an advanced system a stem is converted into logs and further logs converted into required sawn timber. Only this ensures optimal solution from sawmill's perspective.
6. Stem terminal has to be provided with good mechanics.
7. There has to be precise quality control systems in order to evaluate systematically performance of harvesting operation including scanning, optimisation, cross cutting accuracy etc. operations.
8. It is easy to provide stem terminal with colour marking or identifying system for providing information to processing and for proofing the origin or wood raw material.

4.3 Sorting of logs

Sorting of logs

Process	1970	2000	2020
Log Sorting	Shadow measuring 20 sorting bins	Speed 13 000 pcs/8 h 3D-scanning 40 or more sorting bins	Speed 15 000 pcs/8 h 3D + X-ray scanning Better measuring of logs –> better control of final products Increased number of bins Bucking also at cross cutting terminals

Figure 4. Log sorting plant and log storage. Evolution of log sorting systems and prediction for 2020.

There are two main ways to process logs into sawn timber. First way is to saw each of the logs individually. The second way is sawing in batches. A group of logs is sawn with a fixed sawing set up. This means considerable improvement of production capacity because logs can be sawn end to end without any caps between logs.

There are several parameters describing geometrical and quality features of logs. Typical quality features are knots, annual ring width, rotten etc. Geometrical features are i.e. top diameter, length, sweep and ovality. Conventional scanners are capable to measure only geometrical properties of logs i.e. 3D log model for process control.

Big step in scanning technologies is implementation of X-ray inspection system capable to detect also internal properties of round wood. X-ray information to be analysed requires a special software which should be tailored to meet application requirements. Typical functions can include measurement of dimensions/volume, moisture content, volume of knots, rot and other defects and heartwood/sapwood ratio. In the future it's possible to get a full description of wood properties i.e. individual annual ring structure and density profile.

Logs are sorted into homogenous groups at log sorting station provided by number of sorting bins. An example of log sorting system and indicators for evolution of sorting plant evolution is presented in Figure 4.

Following issues have to take carefully into consideration by implementations

1. Number of sorting bins is influencing very much for sawmill's economy. If the number of bins is too low both value and volume yields are decreasing. If the number of sorting bins is too high the increase in income cannot cover the costs of "extra" sorting bins.
2. Optimum number on sorting bins can be calculated using VTT's WoodCIM® software system. Number of optimum sorting bins is depending on characteristics of wood raw

material, product specifications and prices to be manufactured and manufacturing systems.

3. It is very important to determine boarders of log classes correctly. VTT's WoodCIM® software has a module for optimisation of log classes. Parameters to be recorded by scanning of logs can be criteria for log classification. Parameters concern geometrical and quality features of logs like knottiness, heartwood content etc. Log length distribution is in many cases important criteria in order to ensure match the length distribution requirements of customer specific sawn timber.
4. There are several philosophies for sorting of logs: conventional sorting based on top diameter classes, product based sorting of logs, sawing set up based classification, sorting based on picking logs yielding best value yield for individual order.

VTT's WoodCIM® software system for optimising sawlog class limits

In the Nordic countries logs are normally sorted into log classes. Logs of one log class are sawn using fixed blade settings. This means a much higher capacity compared to the sawing operation where the blade setting can be changed individually for each log. Sorting criteria are log characteristics like wood species, top diameter, log quality, length, taper and sweep.

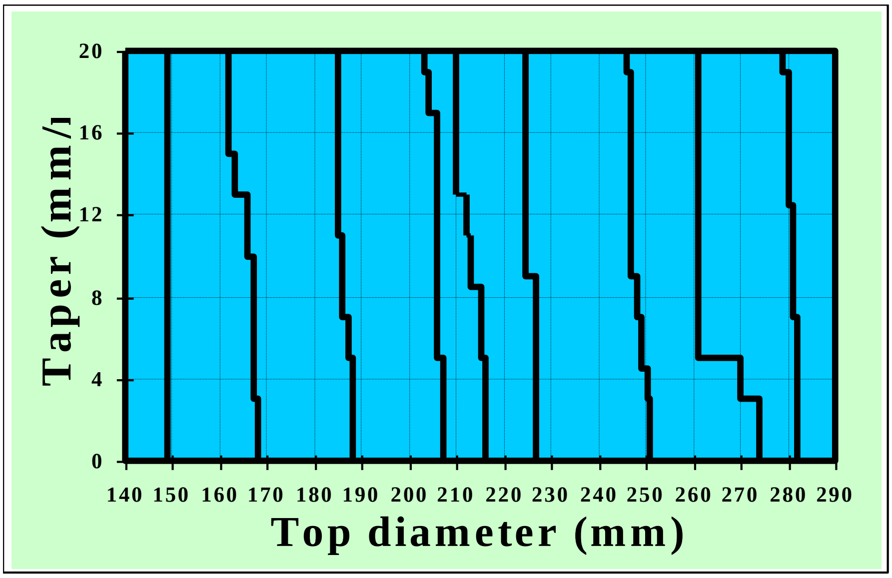


Figure 5. Limits of log classes top diameter and taper as sorting criteria (example). A log with high taper value can be sorted into lower top diameter class.

The **WoodCIM®** optimisation software for log sorting requires as input data the volume and value yield figures produced from the sawing simulation modules. Additional inputs include the sawn timber marketing factors, demand and prices as well as end-users' requirements. The model produces a number of best sorting alternatives and best blade settings for each log class. The principle of the software is described in more detail in D 6.3.

In the optimising software a log distribution is presented in terms of element logs with top diameter increment of one millimetre. Each element log is described in terms of criteria to be used in the sorting and proportion from the total number of logs. The number of log classes cannot exceed the number of sorting bins.

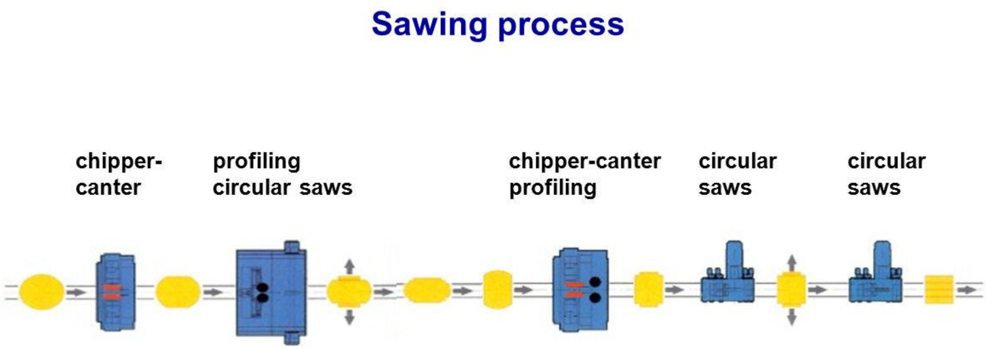
The determination of log class limits can be carried out as follows:

1. determining diameter limits of log classes using average taper values and a number of best set-ups for specified log classes;

2. varying the values of taper, length and ovality of a log in the sawing simulation model, to determine a specific log class - set-up combination that is most beneficial for the specific log.

The software calculates for each element log the values of all possible centre planks and side board model combinations. In the second step of the optimising procedure the software creates possible element log combinations, log sorts. The number of best sorting strategies can be identified by calculating the value of each potential log sorting option. An example of log class limits is presented in Figure 5.

4.4 Primary sawing methods



Process	1970	2000	2020
Sawing	Frame sawing Cant sawing Manually controlled edging of sideboards	Circular and band sawing Cant sawing Automatic edging	Circular and band sawing Cant and live sawing Sophisticated edging Better guide systems for blades Higher sawing speed

Figure 6. Primary sawing methods.

Present production systems are effective, however bulk product oriented. They are not flexible and production of components with specified quality features and properties is difficult. Producing value added components – smaller pieces with specific dimensions and quality features – instead of standard products offers sawmills a big potential to improve profitability of sawn timber business. Production of components should be started directly from the logs.

Three basic sawing methods, presented in Figure 7, are cant, live and profile sawing.

Cant sawing method. There are three phases in the cant sawing operation. In the first phase a symmetrical cant is sawed from the middle of the round log. Simultaneously side board billets are taken from the sides of the log. In the second phase of processing the cant is typically sawn into symmetrical centre goods pieces maximising thicknesses. The widths of the pieces are same as the height of the cant. Cant sawing phase produces also side board billets. In the third phase of the operation side board billets are edged to allowed widths maximising yield.

Profile sawing method. Profile sawing method is in principal similar to cant sawing (Figure 7). However it is like a pipeline because all the operations are executed in the same straight line by using fixed blade settings or by moving side board widths.

Live sawing method. There are two phases in the live sawing operation (Figure 7). In the first phase log is sawn into thick flitches, centre pieces and thin flitches, pieces taking from the side parts of the log. All those flitches are transported to edging machines cutting them to desired widths maximising yield.

Live sawing method as a part of component sawing. Component sawing method starts by live sawing operation (Figure 7). The flitches received in the first phase of sawing are transported to edging machines provided by scanning system and multi blade settings. Scanning will result description of timber properties for optimisation value of wooden bars taking from the flitch. The bars are cross cut into desired lengths.

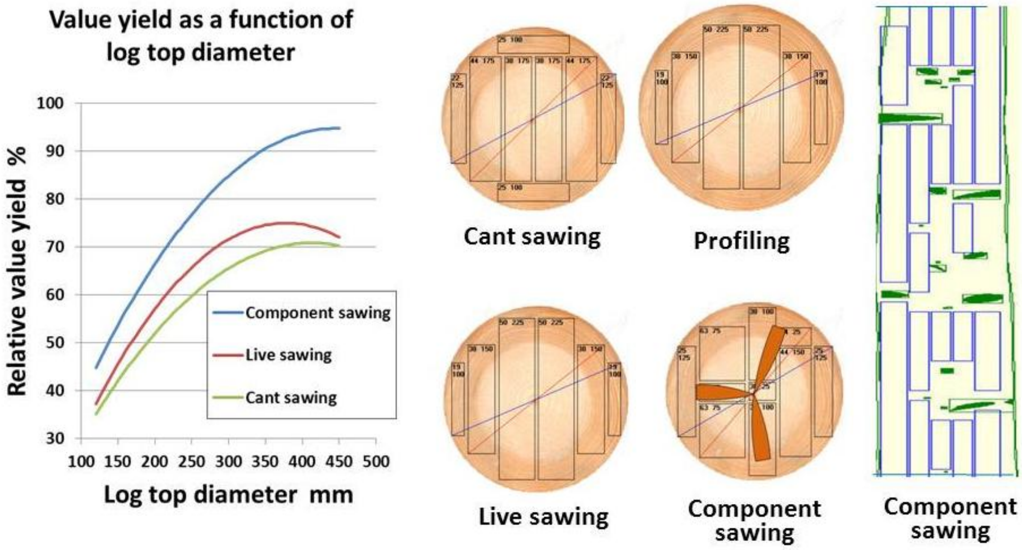


Figure 7. Principal presentation about cant, profiling and component sawing methods. Value yield as function of top diameter for cant sawing, live sawing and component sawing methods.

Three different sawing methods are compared in Figure 8. In the live sawing method the slice can be edged into one or two sawn timber pieces. In the component sawing method the slice can be divided into one or two bars, which can be crosscut into components. The best value yield is achieved by using the component sawing method 2, value yield is 170 €/m^3 by top diameter of 250 mm. By using the live sawing method, value yield is 150 €/m^3 when the top diameter is 250 mm and in the cant sawing method the corresponding value yield is 135 €/m^3.

It is absolutely necessary to take into account all the impacts each type of sawing method will bring, e.g. transportation of sawn timber pieces, flitches, in evaluating and comparing cant sawing method and live sawing methods.

Profile sawing method is sensitive for flexibility of changing saw blade settings (Figure 7). If there is not possible to change setting you have to run saw line with fixed setting. This means that you have to use the sawing set up which is good for smallest log diameter. Regarding bigger logs you may lose a lot of wood raw material into form of chips and saw dust. In case the sawing system is very flexible and can adapt optimal sawing set ups for all type of logs earning may increase radically, up to 20 per cent compared to fixed set up for all logs.

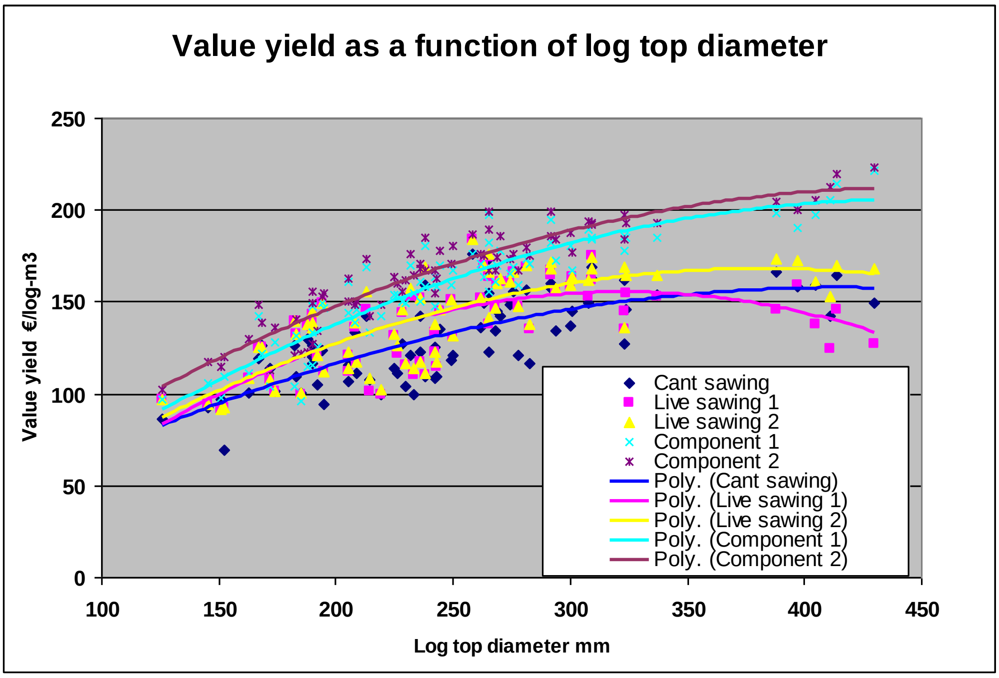


Figure 8. Value yield as function of top diameter for cant sawing, live sawing and component sawing methods.

Technically there are four principles concerning execution of extracting boards from a log or cant: frame saw, circular saw, band saw and chipper canter. Big advantage for frame sawing is robustness. However surface smoothness is poor and feeding speed is low. That's why frame sawing is disappearing. Advantages for circular sawing are high feeding speed, fairly low price compared to capacity and good surface smoothness. Advantages for band sawing are capability to break down big logs, good surface smoothness, high feeding speed and thin sawkerf. Advantages for profile sawing are good surface smoothness and high feeding speed. There is no need for edging machines because profiling includes also edging operation which means also reduced need for floor space.

Positioning of log and cant

Positioning and correct rotation angle of a log is very important. It's similar situation for a cant as well.

Following issues have to take carefully into consideration by implementations

1. Quality of sawn timber has to be evaluated using scanners in terms of surface smoothness, dimensional accuracy and quality of chips and saw dust. These factors are also depending on feeding speed at sawing line. Target values have to be set carefully and evaluated during performance analyses by purchase of new machines.
2. Based on sawing accuracy, shrinkage of wood raw material and evaluation procedure concerning quality of sawn timber by customers target green dimensions have to be determined.
3. There has to be a balance between sawline input and output and other departments.
4. Implementation of systematic quality control system for sawn timber pieces is necessary
5. Implementation of systematic procedure for monitoring performance of machines ensures avoiding breaks. Evaluation can be done also thorough services from outsiders like machine manufacturers.

6. Implementation probably leads to improved quality and potential to reduce target green dimensions. 1 mm reduce means 2.5 per cent increase in value yield.

4.4.1 Positioning of logs and cants

Correct rotation angle of a log in sawing has a major impact on value yield of log sawing. A case study shows that the difference in value yield between the best rotation and the worst rotation is on average 15 per cent for cant sawing (Figure 10) and 10 per cent for live sawing (Figure 11). The variations are due to the fact that different volumes and grades of sawn timber will be received on different rotation positions. Log shape and internal log characteristics have to be measured and taken into account in determining optimum log position in the sawing operations.

The graphics in Figure 9 shows the impact of log rotation angle on value yield. Small difference in the angle may cause major change in yield. This is because of quality of sawn timber pieces which is determined by positions of defects i.e. knots in the piece. Typically difference between the highest and the lowest value is rather big.

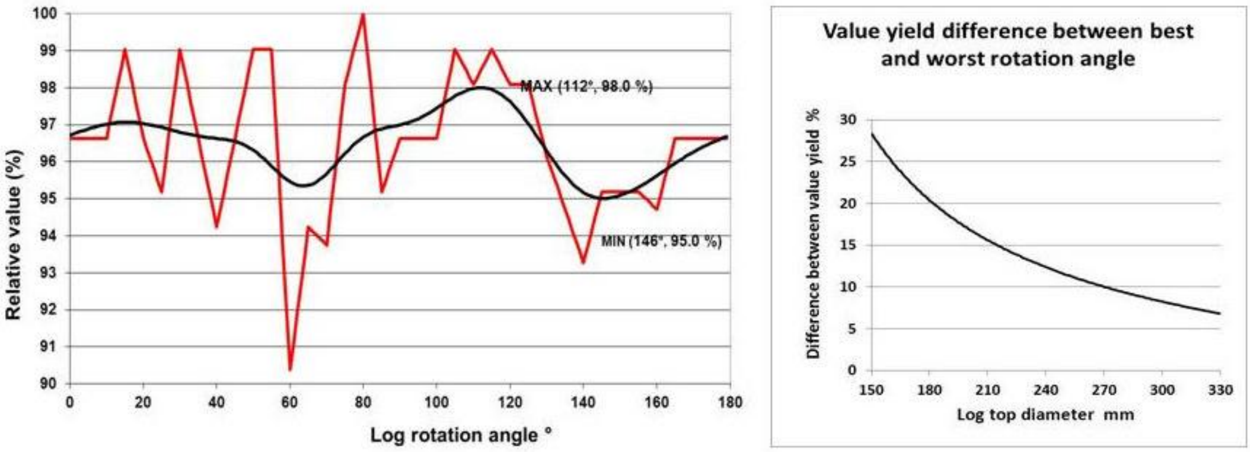


Figure 9. Value yield as a function of log rotation angle for live sawing.

Positioning of a log is not an easy task even for sophisticated devices. Always some rotation errors may occur due to mechanics. Loss in value yield as a function of rotation error for cant sawing method and live sawing method are presented in Figure 12. Functions are linear. An error of 10 degrees in standard deviation means 1.8% loss in value for cant sawing and 3.5% for live sawing. Those errors have to be taken into account in optimisation procedures.

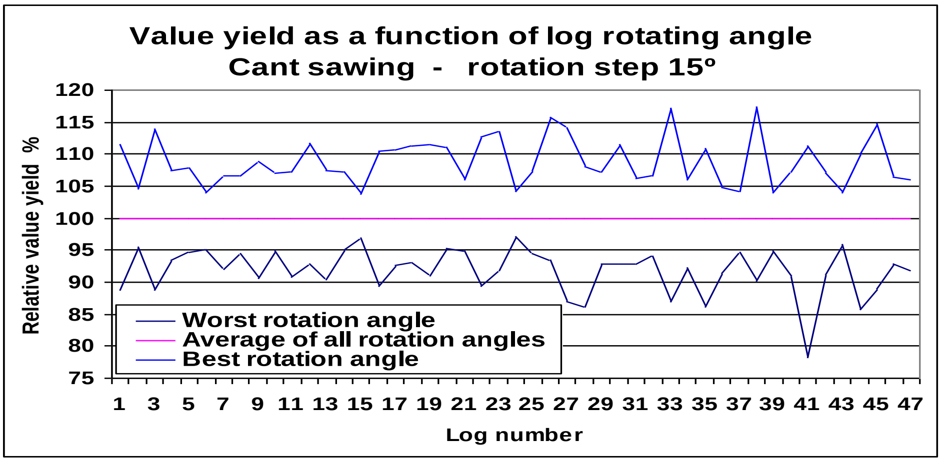


Figure 10. Value yield as a function of log rotation angle for cant sawing.

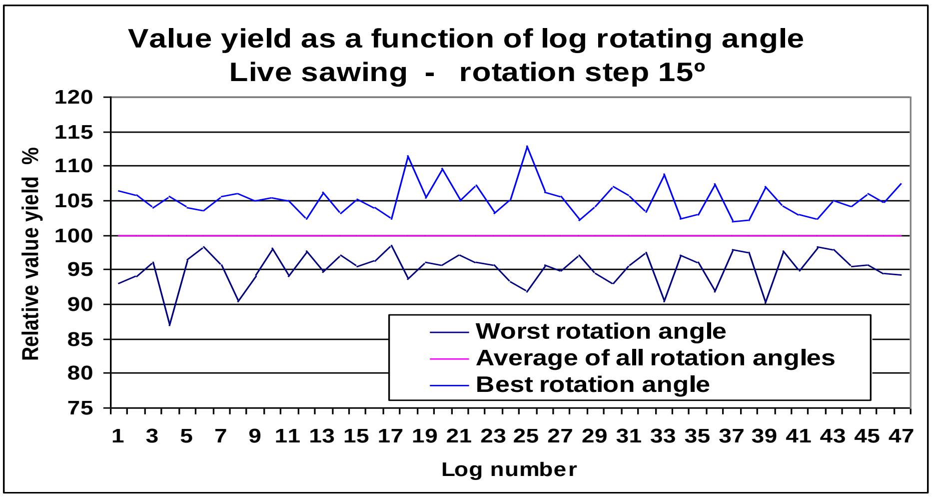


Figure 11. Value yield as a function of log rotation angle for live sawing.

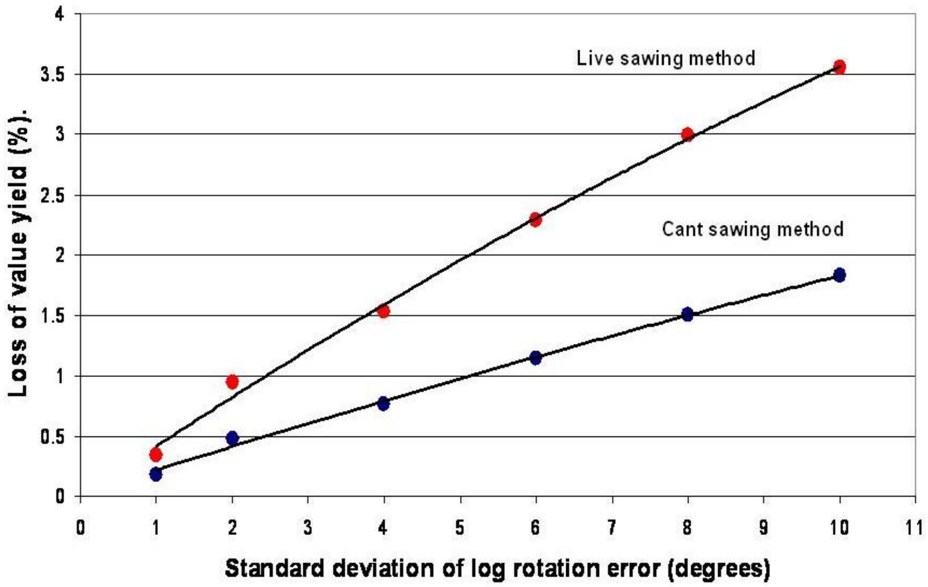


Figure 12. Impact of log rotation error on value yield.

Positioning accuracy is also important in sawing of the cants (Figure 13). It is possible to achieve maximum yield if sawing operation can follow the form of cant. Straight sawing of curved cant may influence big economic losses up to 15 per cent by sweep parameter of 20 mm. Positioning errors have to be taken into account in the optimisation procedures concerning all process control applications.

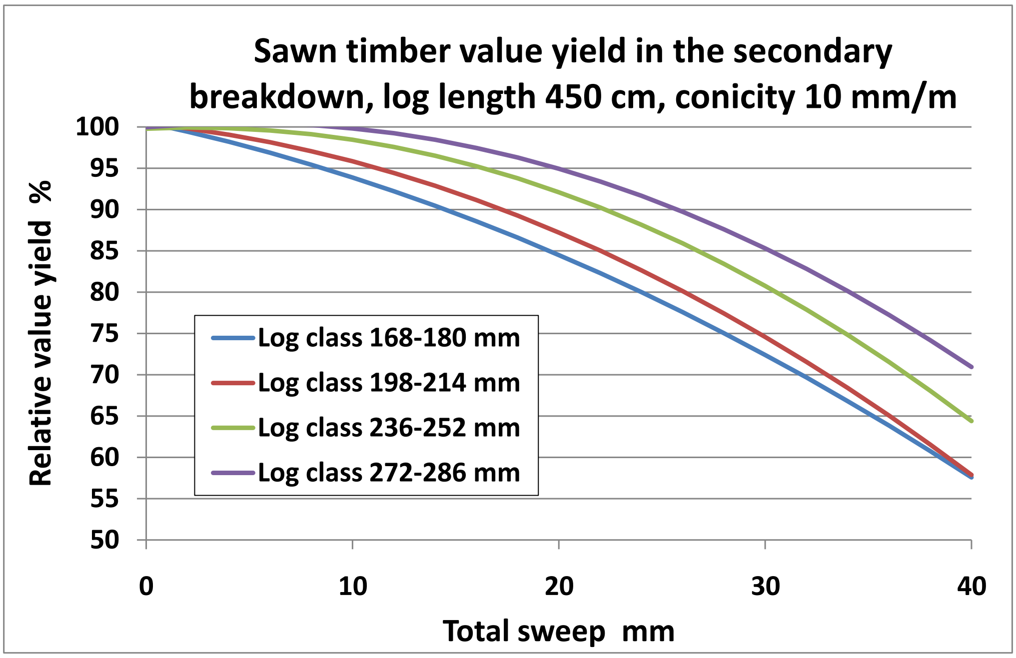


Figure 13. Sawn timber value yield in the secondary breakdown of cant sawing as a function of log total sweep and log top diameter class.

4.5 Sorting of green sawn timber

Green sorting of timber

Process	1970	2000	2020
Green sorting	Automatic dimension sorting into bins	Automatic dimension and grade sorting, more bins	More precise grade sorting, more bins and higher speed Real time control of dimensions

Figure 14. Sorting of green timber.

At many sawmills sawn timber is sorted in green condition just after sawing operation. This means that homogenous batches regarding the quality of sawn timber can be formed. In some cases timber length is also taken into account as sorting criteria in order to manage sawn timber length distributions.

Following issues have to take carefully into consideration by implementations

1. Grading, quality sorting of sawn timber is normally based on colour scanners providing information from surface properties and defects concerning four sides of sawn timber pieces emphasising defects which may cause down grading of the piece.
2. It’s important before buying and implementation of grading system to purchase information about commercially available systems. Scanning technology providers can provide information. However it’s important to discuss with sawmillers already having such systems. Colleagues may also offer possibility to carry out some trials using candidate’s own sawn timber pieces.
3. Implementation activities include mechanical assemblies of conveyors, scanners, sorting bins etc. Scanners have to be connected into sawmills information system. Scanners have to be provided by initial input data.
4. Before system is ready for production use, trials has to be carried out in order to ensure that whole system is working properly.
5. Implementation of systematic quality control system for automated grading. Implementation of systematic procedure for monitoring performance of machines ensures avoiding breaks. Evaluation can be done also thorough services from outsiders like machine manufacturers.
6. Green sorting grader may provide an excellent tool to collecting data for planning of production, harvesting or sales activities. This issues should be considered right from beginning.

4.6 Stacking of green sawn timber

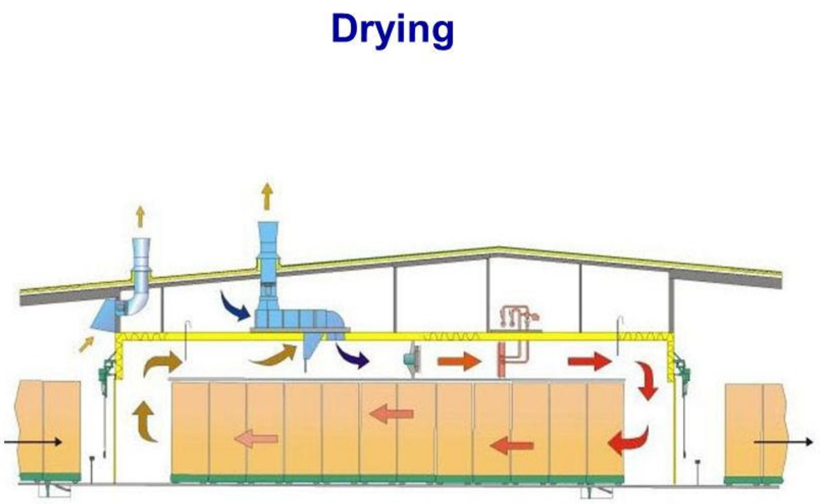
Figure 15. Stacking plant for green sawn timber.

Before drying operation, packages are formed from piece flow. A package includes sawn timber layers and ribs between layers for air flow thorough package in the drying process.

Following issues have to take carefully into consideration by implementations

1. Stacking plant has to fulfil capacity requirements
2. Packages to be formed have to be stable
3. Mechanical handling of pieces must not break the pieces or ribs
4. Ribs are reused many times and that's why handling of ribs have to be carefully in order to ensure long life time

4.7 Drying of sawn timber



Process	1970	2000	2020
Drying	Compartment and progressive kilns	Increased number of progressive kilns	Intensifying of present drying methods

Figure 16. Drying process for sawn timber.

In wet condition sawn timber products exposure for damages, fungus etc. That's why sawn timber has to be dried. Drying process is an important phase of sawmilling because final quality of sawn timber is very much depending on the quality of drying process. Two main types of drying system can be identified: kiln drying (Figure 16) primary for volume drying and chamber drying for high quality drying.

Following issues have to take carefully into consideration by implementations

1. Requirements concerning drying have to be very precisely determined: sawn timber dimensions and grades and corresponding target moisture contents, capacities etc.
2. Key issue in drying is avoiding cracks, splits and checks, because in the later manufacturing phases it's not possible to eliminate them. Cracks are critical properties in the evaluation of quality of sawn timber. Cracks may cause radical down grading of pieces. In many cases the sawn timber parts having serious cracks have to cross cut away which means loosing of wood and increasing amount of waste.
3. From the point of view of sustainable development, drying is extremely important in processing phase, because at least 80 per cent of energy used at sawmills is used in

sawn timber drying. This means that all actions to reduce energy consumption are very important. Ways are i.e. pre-sorting wet sawn timber based on moisture content, designing of drying schedules using simulators by skilled operators and advanced control system.

4. Drying simulators describing progressing of drying from wet to dry conditions provides good tool for designing drying system configuration and for strong support of effective use of drying systems.
5. Essential parts of dryers are information system controlling operations. Design of control system is key issue in the implementation of drying. Drying technology providers can offer their support during the designing process. Some research institutions can provide also a lot of information, experiences and tools for designing phase.
6. Continuous control system for drying system performance control in important to design and implement.
7. Measuring of moisture content has to be done accurately in order to eliminate drying errors and in order to adjust parameter in drying systems.
8. Drying batches to be dried in the same kiln or chamber simultaneously should contain similar wet moisture content.

4.8 Sorting of dried sawn timber

Final sorting of timber

Process	1970	2000	2020
Final sorting	Manual sorting Limited number of grades, no customer grades, length sorting at separate plant	Automatic sorting	Self learning sorting automats. Knots could be scanned at green sorting and knot information could be used at final sorting by using marking of sawn timber pieces. Final sorting can also be carried out at green sorting

Figure 17. Sorting of dried sawn timber.

Final sorting of sawn timber is very important processing phase, because grading has to provide exactly sawn timber pieces matching customer’s order(s) or specifications defined company’s sales people. Sorting criteria are dimension (thickness x width) and length. Quality grading criteria are based on quality features of wood like knots, splits, wane edge, rotten, annual ring width or orientation, spiral graing etc. Sorting and grading rules may be based on standards or they may be customer specific.

Following issues have to take carefully into consideration by implementations

1. Grading of sawn timber is normally based on colour scanners providing information from surface properties and defects concerning four sides of sawn timber pieces emphasising defects which may cause down grading of the piece. It is important to also to see inside wood piece in order to get information from heart wood part orientation or strength of the piece. Future implementations will be based on multisensor system providing different type of information because different sensors are able to detect different wood properties with different accuracy.
2. It’s important before buying and implementation of grading system to purchase information about commercially available systems. Scanning technology developers are able to introduce information. It’s very important to discuss also directly with sawmillers who already have the system of interest. Colleagues may also offer possibility to carry out some trials using candidate’s own sawn timber pieces. Research institutions and universities working on scanning field have very much relevant information supporting decision making.
3. Implementation activities include mechanical assemblies of conveyors, scanners, sorting bins etc. Scanners have to be connected into sawmills information system. Scanners have to be provided by initial input data.
4. Before system is ready for production use, trials has to be carried out in order to ensure that whole system is working properly.
5. Implementation of systematic quality control system for automated grading. Implementation of systematic procedure for monitoring performance of machines ensures avoiding breaks. Evaluation can be done also thorough services from outsiders like research institutions or machine manufacturers.
6. Final sorting and grading system may provide an excellent tool to collect data for production planning, harvesting or sales activities. This issue should be addressed right from the beginning before implementation of new technologies.
7. In the final sorting phase sawn timber pieces are labelled with markings informing normally about the supplier(trade mark) and quality class of sawn timber.
8. In the future is possible to mark the pieces also individually, which makes possible to inform customers and end users about the origin of timber pieces. The markings can be used also for identification of individual wood pieces.
9. Number of sorting bins has to be designed carefully taking future needs and business concepts into account. Handling of pieces has to be sensitive, because it’s not possible to correct mishandling afterwards.

4.9 Packaging of sawn timber

Figure 18. Packaging of sawn timber.

Sorted and graded sawn timber pieces are dropped into sorting bins of final sorting systems. The bins are emptied one by one on vertical conveyor transporting timber pieces to packaging station where the sawn timber bundles are formed and providing cover against to rain. There is also a label on bundles face informing about customer and content of bundle. It's very important that the bundles look nice, because it's like business card towards the customer.

4.10 Deliveries

Figure 19. Wood products on the way to customer.

Final phase of value chain is delivery to the customer.

5. Secondary Wood conversion

5.1 Sawn timber products

One of the key issues in the sawmill industry is that the future saw mills have to move forward in value chain – from bulk products towards more value added products i.e. components or specially cut and sorted timber pieces. This doesn't exclude production of standard products if their prices are high enough. Products and product families determine configuration of value chains and production systems.

5.2 Marketing aspects

Sawmilling industry represents business area, where the absolute free competition has traditionally been prevailing due to hundreds of suppliers and hundreds of purchasers. Competition has been very hard and there has been a possibility to substitute products from one supplier to another. This phenomenon has been very profitable for the importers and wholesalers, who have been holding the information about the markets in their possession and stopped the direct information flow from end-users to sawmills. Two factors have strengthened this. First the very general sorting rules, which have meant that no producers neither the end-user really can use the characteristics to the best use. The other has been the financing of trade and general small size of all related parties.

These hindrances can be changed in the favour of both end-users (further processing industry) and the sawmilling enterprises and thus finally in the favour of wood as raw-material. As sorting to custom specific rules is now possible through automatic scanners and thus one sawmill can have tens or even hundreds of different qualities and dimensions, each produced to specific needs of certain end-use or next level processor. This is possible but needs very sophisticated scanning devices and efficient information flow.

One change is the possibility to dispatch even small quantities (container / rail-wagon / lorry) at affordable prices compared to full vessels, from producing countries to further processors. But the most important is the possibility to transfer the accurate and on-line information between the supplying sawmill and the end-user / further processor. By eliminating the free trade barriers, European Union has enabled also remove many factors, which have helped in the process, such as easy transfer of money, no customs between EU-countries, same currency in most countries and necessary information flow being easy etc.

All above means, that the information flow is fast and accurate, contacts between related parties are close and feedback from any necessary is fast. This enables to bypass the old heavy and costly importer / wholesale level at least in the Inter-European businesses. This will cause less bound capital in trade, better know-how of needs and qualities and as the most important potential, less rejects and less waste and thus better competitiveness of wood material.

As some sawmill producers are exporting sizeable quantities to North-Africa, USA and Far-East (Japan and China) they are in many cases still forced to use old fashion importer structure. But the inevitable consequence of the model possible in Inter-European trade will on the long run also become possible in exporting to more remote areas. One of the main obstacles here being the long geographical distance, the trade practices and also in some cases corruption.

5.3 Component products

Sawn timber can be upgraded into smaller wooden pieces, components. Figure 20 presents potential of increasing value yield. Value increase is 150% when lower C-grade sawn timber pieces are cut into components. When better A- and B-grade sawn timber pieces are upgraded into components, value yield increase is 40%. In some pieces the value increase is negative which means that there is also risk of losing money by upgrading. However this can be avoided by sorting sawn timber before processing.

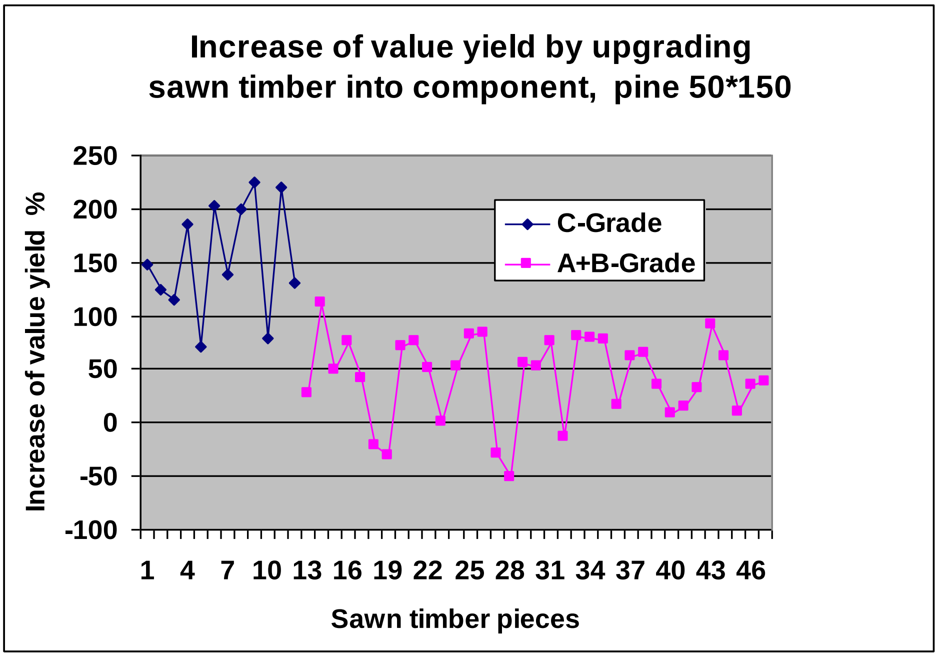


Figure 20. Value yield increase or decrease by transferring bulk sawn timber production to component type of production.

Component sawing

For assessing suitability of certain grade of logs for cutting some grade of sawn goods, InnoSIM can be a very useful tool. In a case study, logs of a foreign species are concerned, which, comparing with Nordic Scots pine logs, appear having less knots, however with considerably bigger sizes. Additionally the logs are more likely to have bigger crookedness as well, again compared with Scots pine logs.

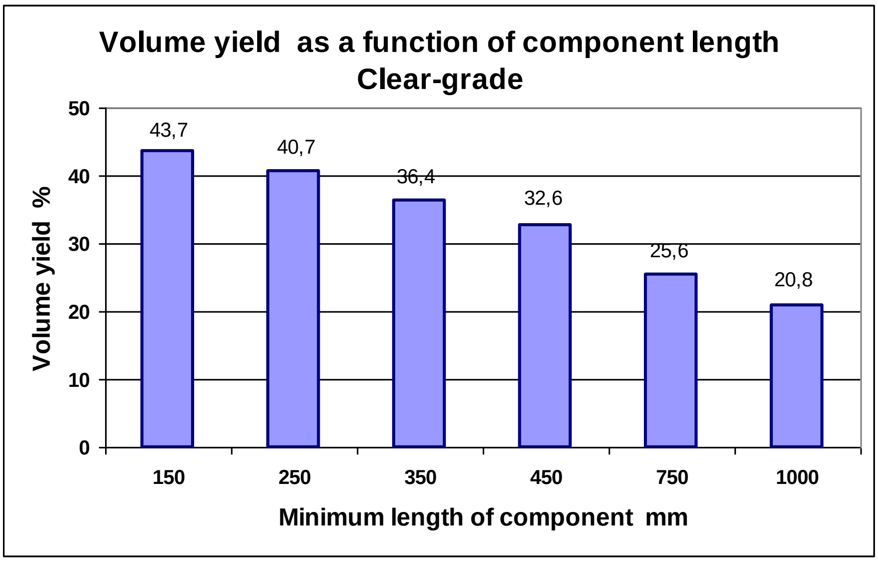


Figure 21. Volume yields of Clear-grade components with varying minimum component lengths.

As wood components production is concerned, those logs with large knots or/and crookedness suit better for component cutting than for lumber production. The reason is that these defects are less harmful for component cutting than for lumber cutting. Preliminary simulation results with a batch of sample logs have shown very high volume yield even for just cutting clear-grade components (Figure 21). It is very interesting to notice that with growing minimum allowed component length the yield drop is quite moderate, in an almost linear relationship. This reveals also the special knot structure features of the logs.

While taking component production as a business concept, however, customers´ needs and profitability issues have to be assessed with care. Manufacturing costs are more sophisticated since component production involves much more material handling, production control and coordination activities.

5.4 Aesthetic features

In quality and marketing research it is generally accepted that it is decisive to know consumer opinion on quality. Also, that the perception of quality is dynamic and changes over time. These facts emphasize the need of continuously measure the signs from the market. Van Kleef et al. 2005, state the importance of incorporating the ‘voice of the consumer’ in early stages of the new product development process and that it is a critical success factor for new product development. When studying a products quality and value together with consumer preferences it has got both tangible and intangible dimensions whereas the issue of aesthetics may be referred to the latter dimension.

Wood is a biological material with inherent aesthetic properties which can give the final product a competitive advantage over other materials with incremental variations on outlook of surfaces. Broman et al. (2001) have studied people’s feelings and preferences for Scots pine (Pinus sylvestris) wood surfaces have been examined. Special methods have been developed for measuring people’s preferences toward different looks of wood and to connect the subjective preference data with objective measurements of wood features.

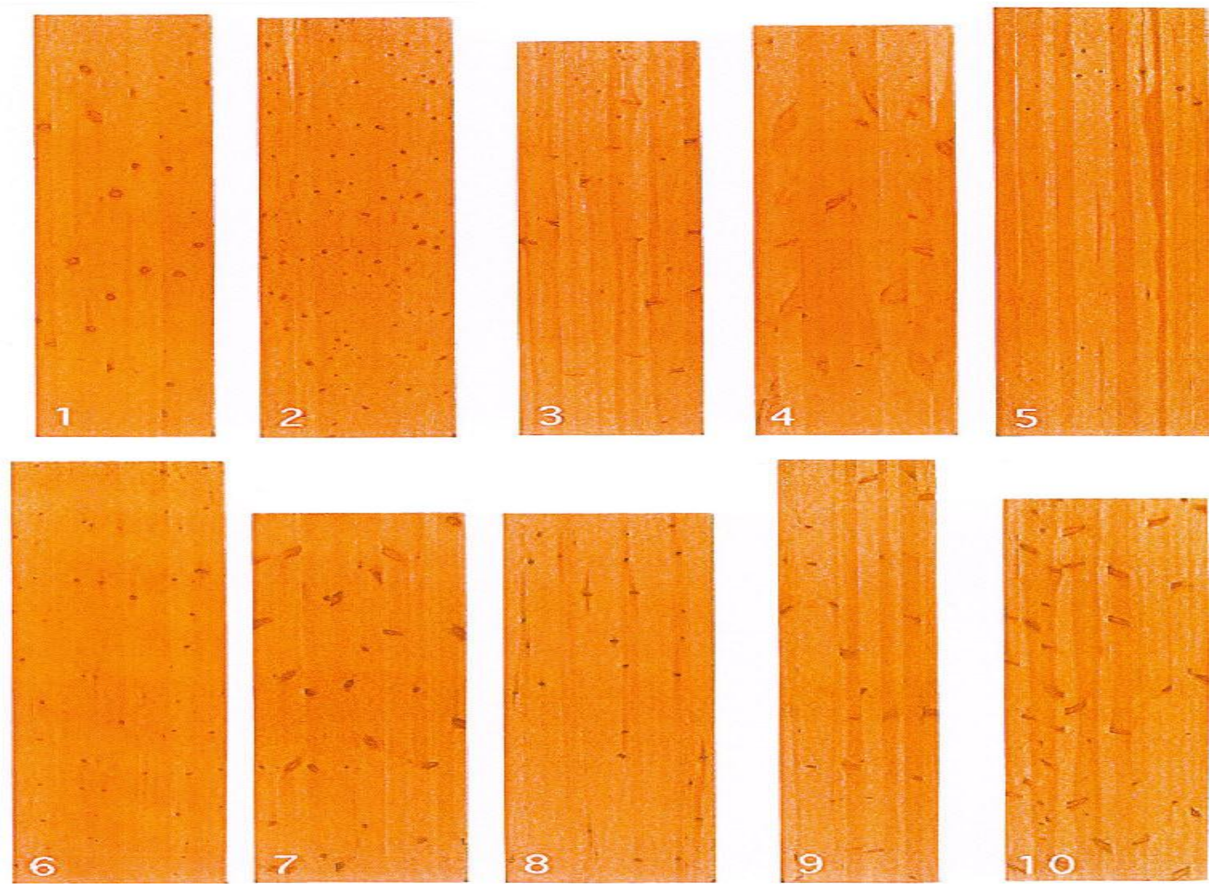


Figure 22. Samples representing the four different sorting strategies (A–D) used in the two preference studies in Sweden and Norway. A1–A3 show the spread within the current sorting and for the new sorting, B1–B3.

Interviews made clear that people prefer different blends of wood features (Figure 22). There are two qualitative differences that are of importance for people's impressions and valuations of wood: The overall blend of wood features and divergent features that mismatch in a surface. It was found that divergent features are more important than the overall mixture of features. But if there are no defects that mismatch, the overall mixture will then be the key to a person's appreciation of a wood surface. Wood surfaces should stimulate people's interest and be fresh looking. A clear surface is naturally rather harmonious, elegant and easy to look at. On the other hand, a clear surface should be stimulating to look at, should be exciting and it should not look like an imitation. Knotty surfaces usually are less harmonious. Therefore, questions about harmony, easiness to look at and balance are of importance. Just as for clear surfaces, a knotty surface should also stimulate people's interest, have a fresh look, be exciting and stimulating to look at.

Increased knowledge about people’s preferences for the aesthetic properties of wood will lead to a better understanding of which wood features should be measured and controlled in the future. In the future processing of wood raw material should emphasise more aesthetic aspects. This means that aesthetic aspects have to be taking into account in all phases of conversions starting by selection of stands and stems in the forest. It is important to develop smart scanning and optimisation systems supporting manufacturing of aesthetic wood products. This approach offers opportunity to improve conversion chains in European sawmills industry much.

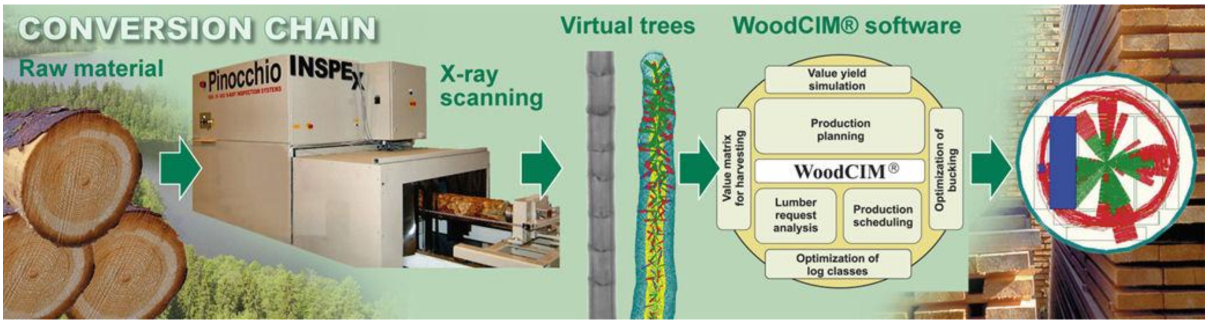


Figure 23. Conversion chain.

6. Adaptive optimisation of activities throughout conversion chain

Traditionally different stages of the wood conversion chain have operated too much independently. In the conversion chain the product of the former phase provides raw material for the latter one. The raw material and semi-finished products are not optimal or even good in respect to the final product. The incompatibility between the wood raw material, conversion products and final product causes a lot of waste and considerable economic losses. The stages involved in converting the wood raw material into final products influence on each other as well as the result. To obtain a good economic result, the chain must be seen in its entirety. The wood raw material has to be chosen taking into account the requirements of the final products. This is the only way for optimal utilization of the wood raw material. The material flow proceeds from the forest to the customers. The information flows in the same direction but should also take the reverse course.

Optimisation means determining the best possible solution within given constraints limiting freedom in business. In the wood products business there are always three main types of business constraints: Wood raw material, production capacities and wood products markets. There always have to be the criteria to be optimised – maximised or minimised. One of the most important criteria is annual profit. In the future criteria describing sustainable development have to be taking into account in the optimisation procedures.

Concerning the wood chain, 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. **Sub optimization** means a procedure to achieve the maximum output in an individual phase of the conversion chain. In the sub optimization 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 sub optimization 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.

VTT Technical Research Centre of Finland has developed WoodCIM® (Figure 24) that is a model and software comprising seven modules for global optimisation purposes. The system describes the whole conversion chain from the forest to the end products. In industrial applications WoodCIM® system is normally linked to administrative information systems at the sawmill from where input data is available. WoodCIM® will deliver information for decision making purposes.

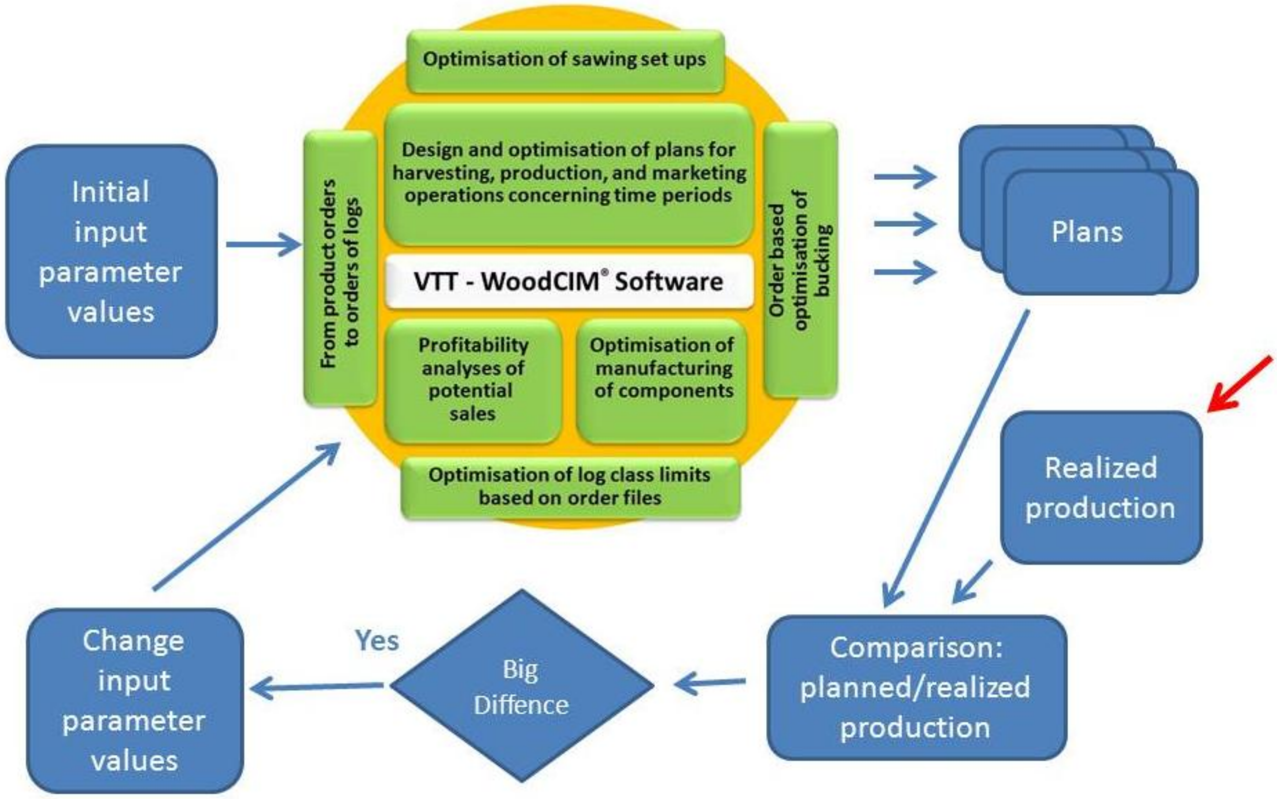


Figure 24. WoodCIM® consists of integrated software modules.

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, new parameter values are determined and implemented in the software. This is the way to improve prediction accuracy

6.1 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 25 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.

Figure 26 presents in principle the amount of information in different stages of the forest – wood chain. 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.

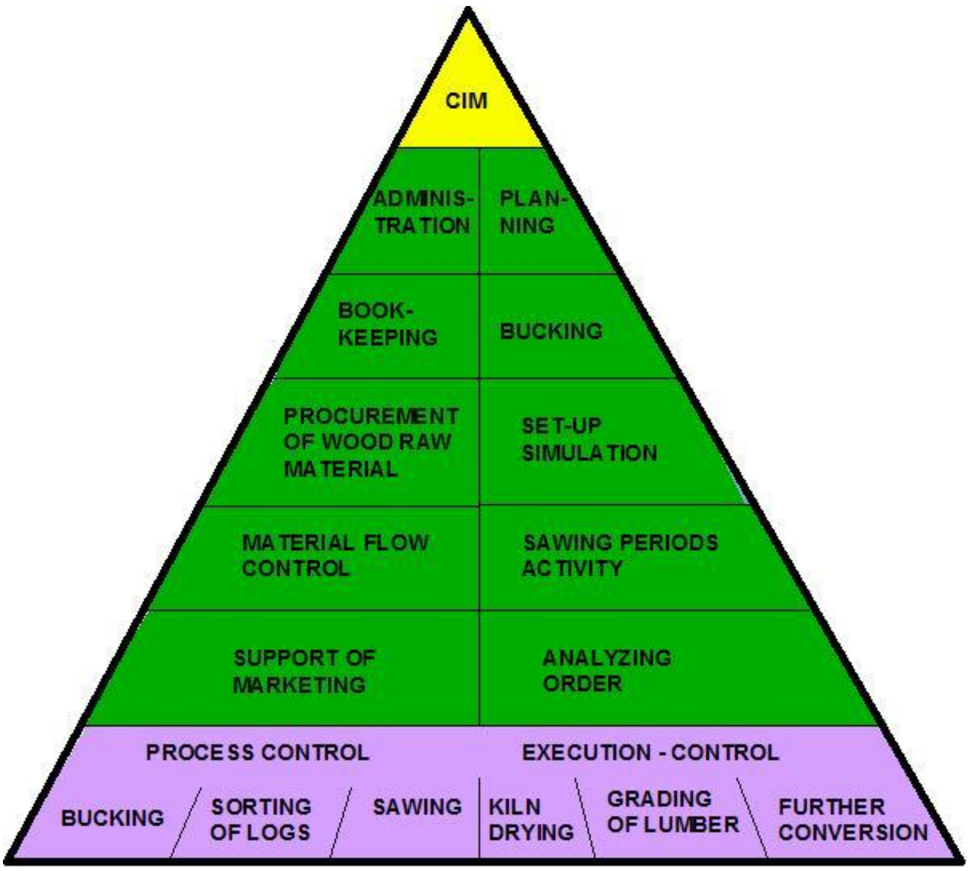


Figure 25. Information system for sawmills.

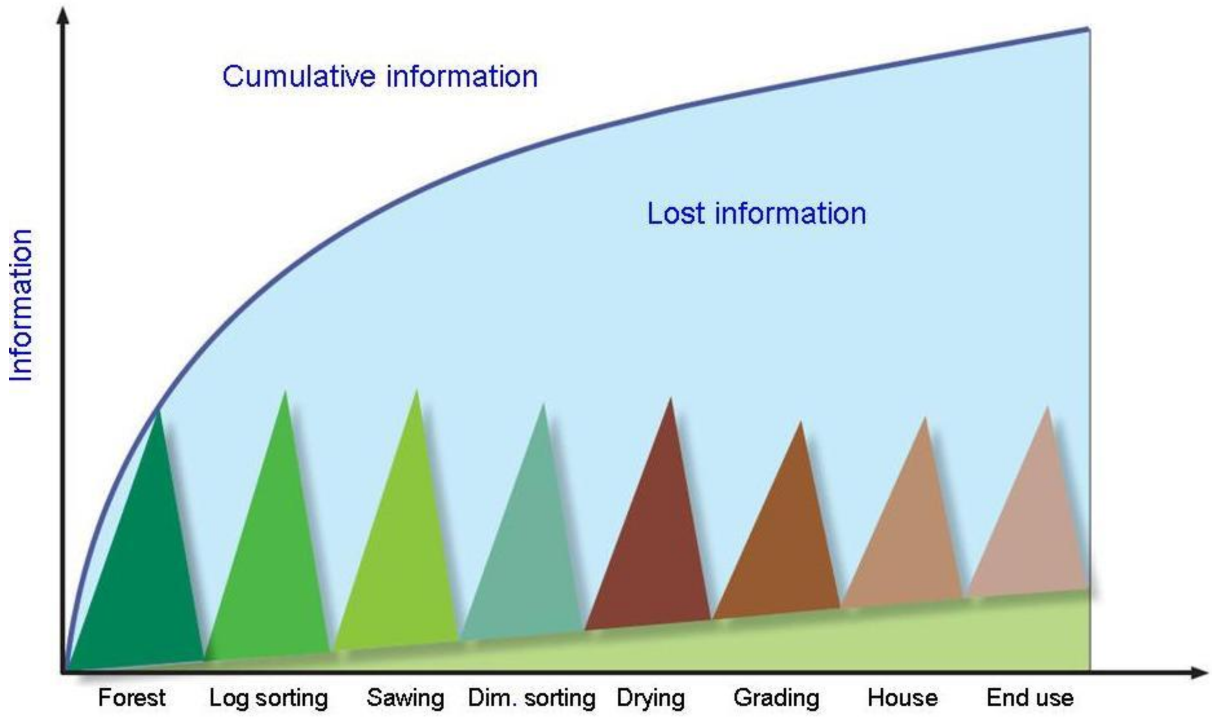


Figure 26. Recorded and lost information throughout the conversion chain.

A new system for an advanced control of forest - wood chain through marking pieces, reading the markings and data processing establishes a strong opportunity to make better business. The principal design of a Marking Reading Information processing (MRI) control system is presented in Figure 27.

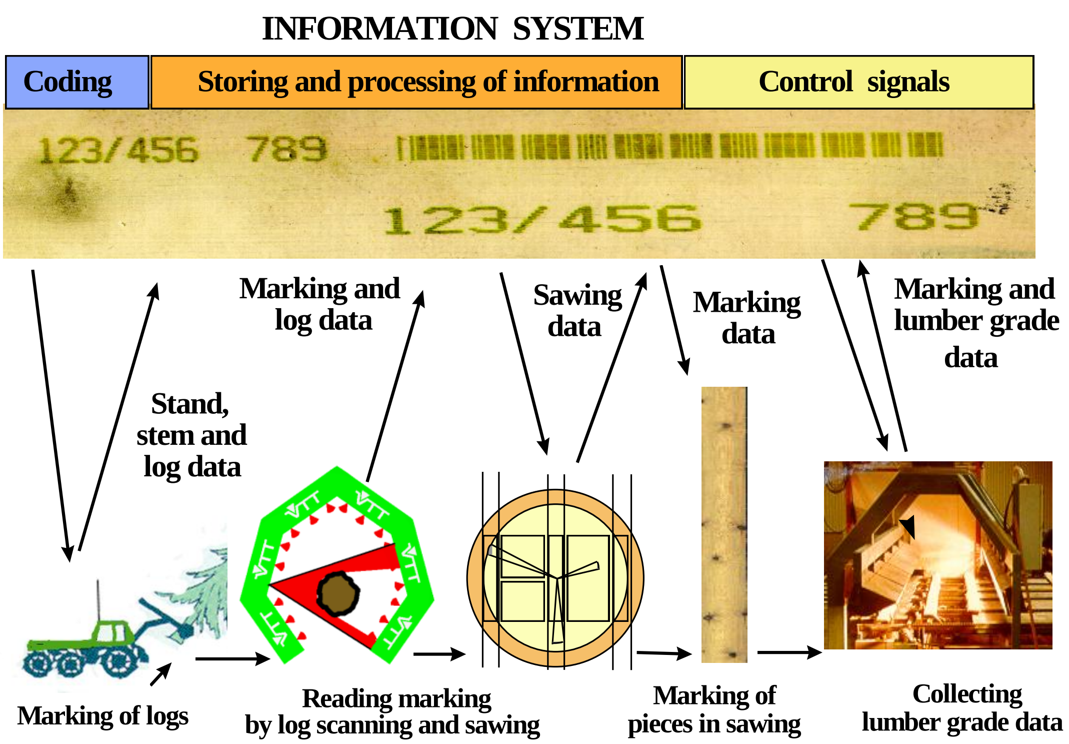


Figure 27. Marking Reading Information system.

Concepts for the industrial implementation of MRI systems have been created at VTT (Figure 27). Some concepts are based on the collective following of wood material batches producing information on how to process certain categories or classes of wood. Other concepts are more detail oriented and necessitate following of individual pieces of wood raw material, semi-finished products and final products. Economic analyses have been carried out to assess the profitability of different concepts.

Marking of pieces can be done using different techniques i.e. RF-tags (Figure 28), transponders and ink jet markings. The most potential and economical marking method for forest - wood chain at present seems to be colour marking, which can be done in the forest using traditional equipment existing on harvesters, however slightly modified. For marking boards an ink jet writer is capable to produce a high quality alphanumerical code.

Reading of the marking or the code on logs and boards can be done by a colour camera. The core of the reading system is neural network based software for decoding the code.

A MRI-control system can be applied for many different purposes, and areas of the applications include quality control, process control, planning procedures and customer service. Marking of pieces is also a way to show the origin of pieces and it can be used, for instance, to ensure that the material originates from a certified source. MRI provides a new approach for the management of material and information flows from forest to the end products supporting customer oriented business and value-added production.

KILN DRYING

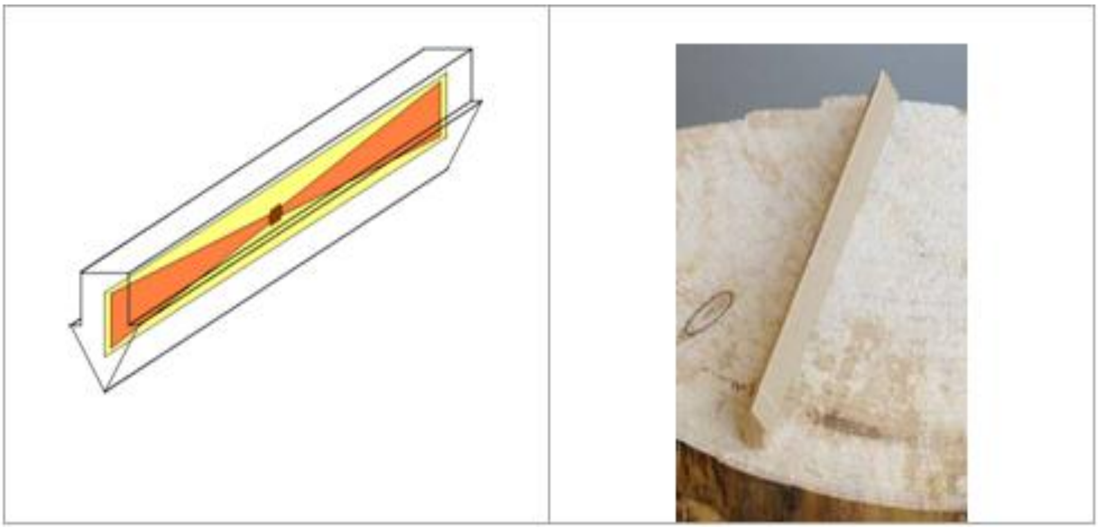


Figure 28. RFID tag for marking of logs.

Some concepts are based on the collective following of wood material batches producing information on how to process certain categories or classes of wood. Other concepts are more detail oriented and necessitate following of individual pieces of wood raw material, semi-finished products and final products

6.2 Optimisation of conversion chains

There are several essential questions to be answered affecting on the quality of the products, value yield and profitability in wood working companies. For instance,

- What is the value of a forest stand on the basis of the product specification?
- What is the optimum selection of the stands?
- What are the bucking instructions according to the actual products?
- What are the optimum log sorting procedures?
- What are the optimum grading instructions for sawn timber, flitches for manufacturing of components?
- What are the optimum sawing set-ups for the logs?
- What are the optimum wood product families – standard products or component matching the available wood raw material?
- What are the optimum further conversion business concepts – products and manufacturing processes?

Optimisation means determining the best possible solution within given constraints limiting freedom in business. In the wood products business there are always three main types of business constraints: Wood raw material, production capacities and wood products markets. For instance you cannot exceed maximum working hours in sawing line. There always have to be the criteria to be optimised – maximised or minimised. The most important criterion is annual profit. Practically this means to determine wood raw material parameters, processing values and orders in order to achieve maximum profit through the bottleneck of processing.

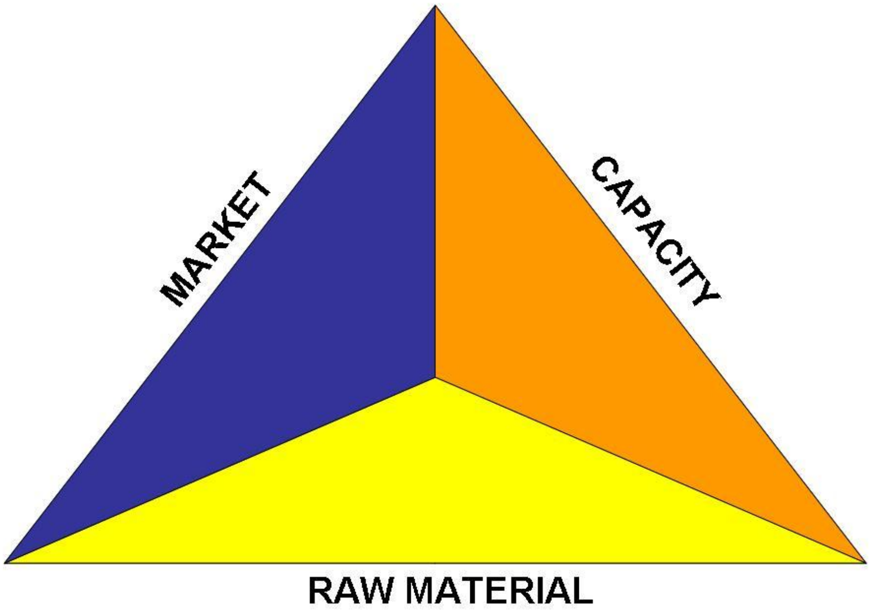


Figure 29. Constraints in saw milling concern timber markets, wood raw material and capacities.

In the optimisation there must always be the criteria to be optimised. Typically in industrial i.e. sawmilling business the criteria is profit – revenues minus costs. Thus the optimisation problem is to find out maximum profit within frames of constrains (Figure 29). Practically this means to determine wood raw material parameters, processing values and orders in order to achieve maximum profit through the bottleneck in business environment. Often the bottleneck is capacity in the processing i.e. in drying or in break down operation. Sometimes it's the availability of raw material

If we have exactly same batch of logs the conversion can result in 10 to 30 per cent more profit if the processing parameters are correct compared to uncontrolled sawing. When the sawmill switches from producing bulk sawn timber to manufacturing value added components, the difference in value yield may be even much higher. The main reason for the big gap is due to the fact that the non-homogenous wood raw material requires many processing phases that makes management and control of business difficult. This is why optimisation in timber business - wood raw material harvesting, sawn timber production and sales activities - is very important.

By using a sub optimization approach it is possible to achieve good “local” result, but from the point view of making money the solution can be very poor. In the wood conversion chain only the sales bring actual income. Raw material harvesting, transportation, processing and inventories cause costs. Profit comes from income minus costs that is a simple equation to be maximized. There are three possible ways to make a better profit

- reduce costs in conversion chain,
- increase income,
- Increase income and reduce the costs in conversion chain.

In some cases the ultimate aim is to reduce the costs. Typically this happens in wood raw material procurement. This is really sub optimizing. The fact is that the quality of logs affects directly on the quality of lumber and such also lumber prices and total income. It is almost always better to invest money for producing better log quality distribution. Increase of income can be activated by developing value added products or including service to the deliveries.

WoodCIM -- Software system for practical sawmill operation optimization

WoodCIM® is a model and software system developed by VTT Technical Research Centre of Finland. The system describes the whole conversion chain from the forest to the end products. It is comprised of the following integrated software modules:

- Simulation program for predicting the volume and value yield by sawing a log or a log class,
- Program for optimising the limits of sawlog classes,
- Sawing model based on linear programming for production planning,
- Integrated optimising model “from stump to final product”, supporting bucking decisions.

The **WoodCIM®** system can be linked to the product and material flow control system or other information systems at a sawmill, producing and transferring updated information for planning. **WoodCIM®** will in turn return information to be delivered to different phases of business operations.

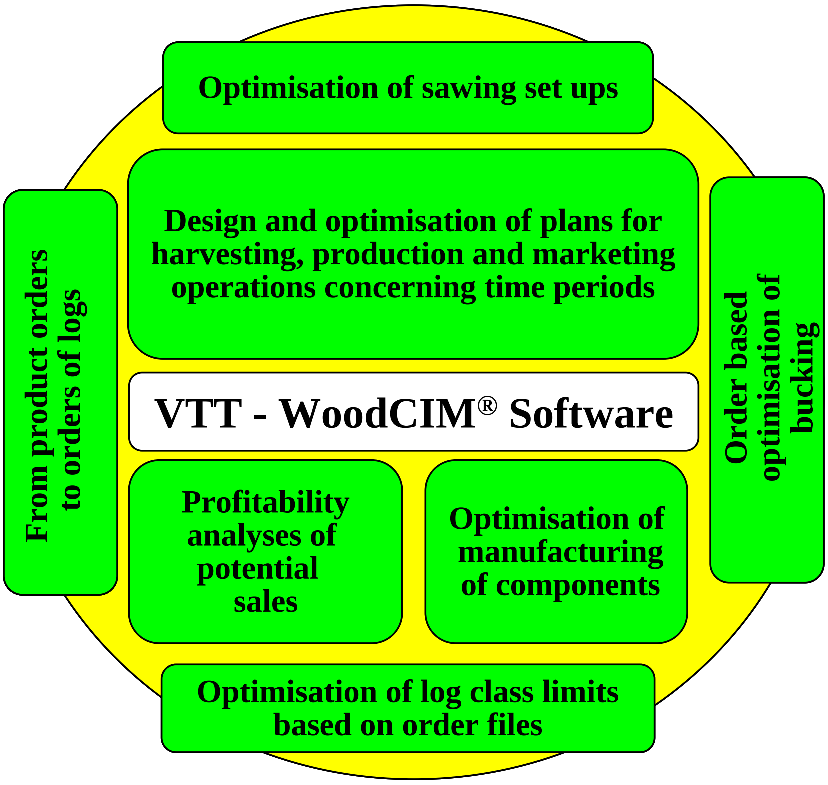


Figure 30. WoodCIM® consists of integrated software modules.

The different modules of the integrated software (Figure 30) focus on maximising profit or value yield, taking into consideration non-homogenous wood raw material, variation as well as the process and market variables. The program system operates in a PC-environment and provides by a user-friendly computer interface. The interface software contains a module for checking the correctness of input data. The software modules also allow creation of different scenarios, i.e. theoretical production lines and products, which allows studying their potential profitability.

Simulation software for predicting the volume and value yield for sawing set-ups

The simulation model mathematically “saws” the log or log class into sawn timber pieces by grades according to the end-users’ specific needs, chips and sawdust. 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.

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.

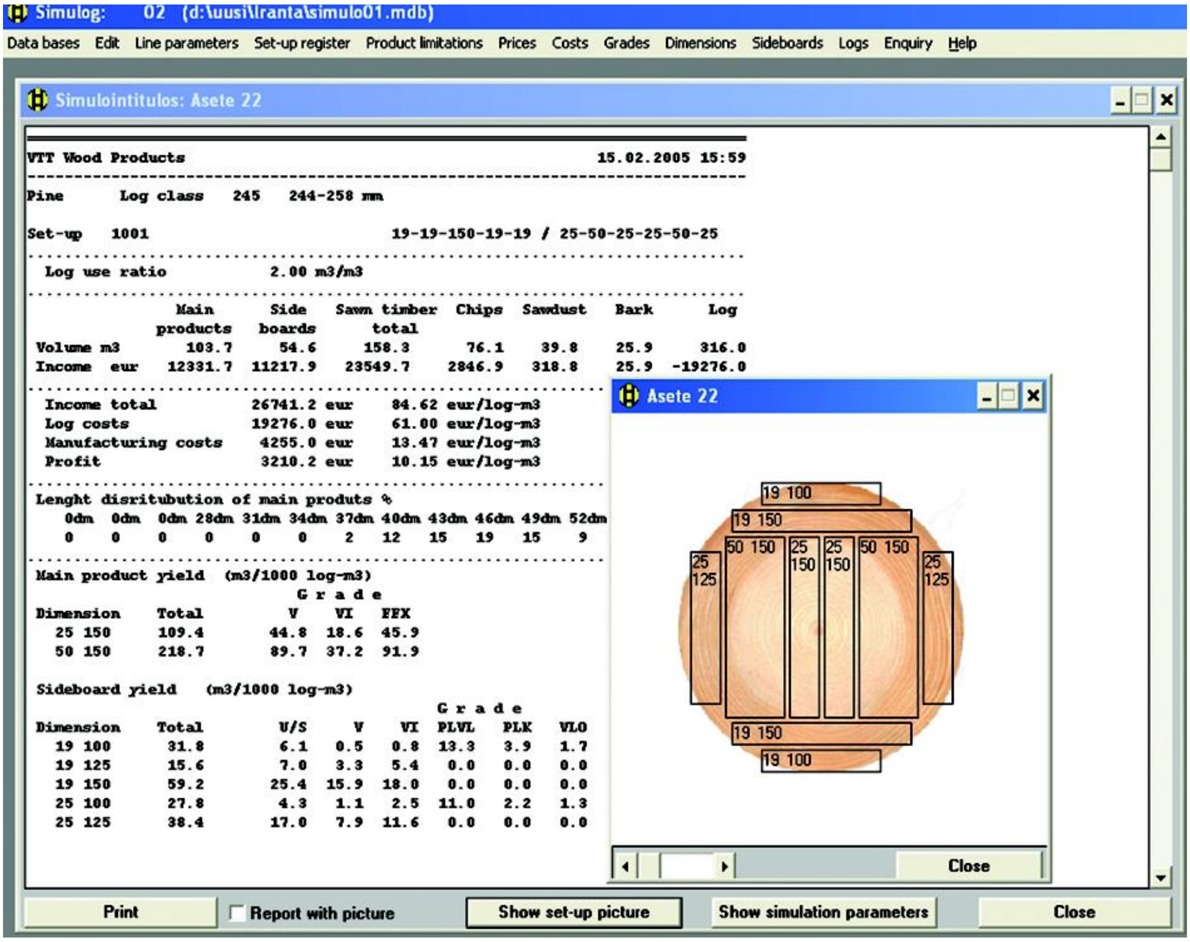


Figure 31. Examples of output data windows in the sawing simulation software.

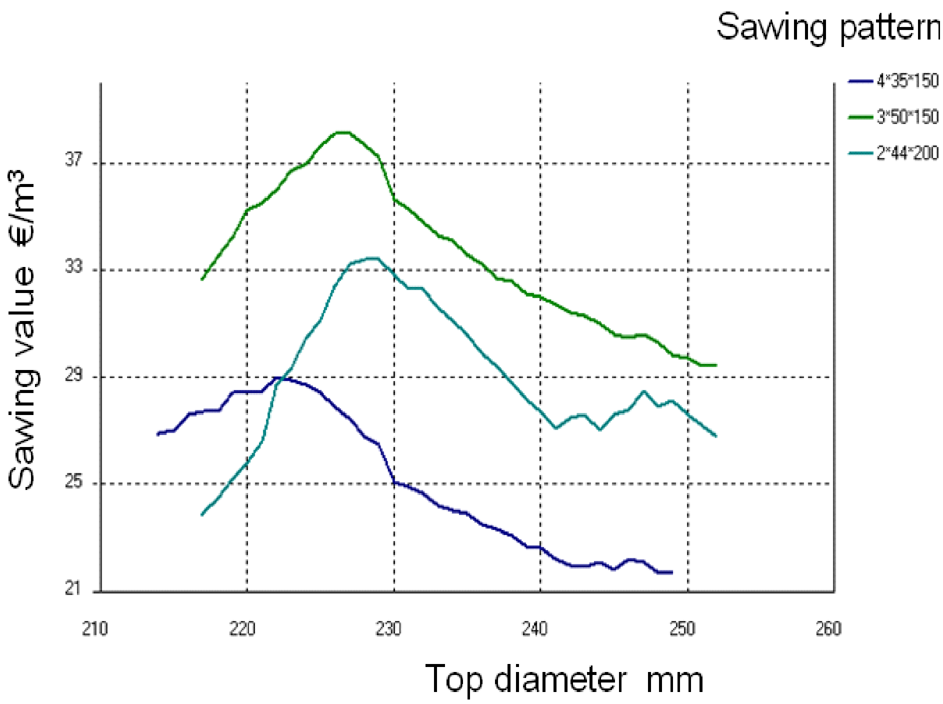


Figure 32. Simulation report: value yields of different sawing patterns / set-ups as a function of log top diameter.

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.

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 (Figure 31 and 33).

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 (Figure 33).

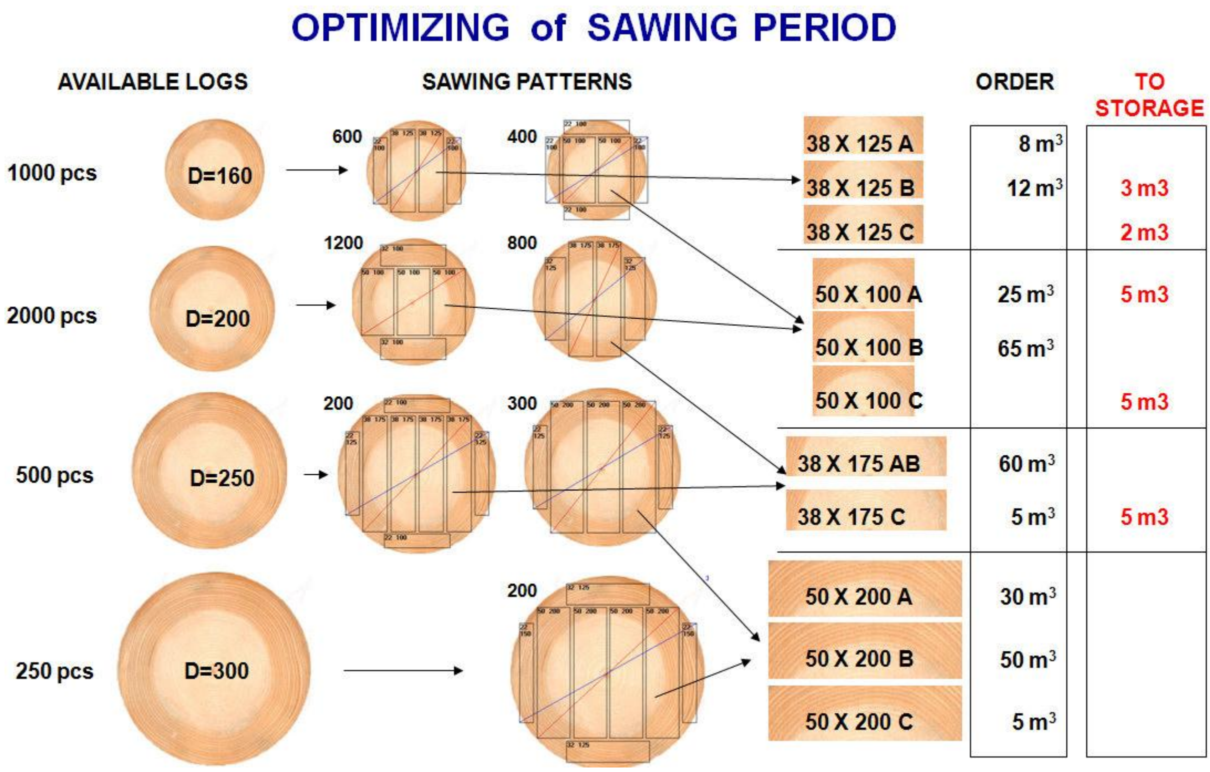


Figure 33. Objective in the optimization activities in planning periods is to combine the orders and available logs together yielding maximum value yield and profit. From the biggest log class 200 logs meet the order.

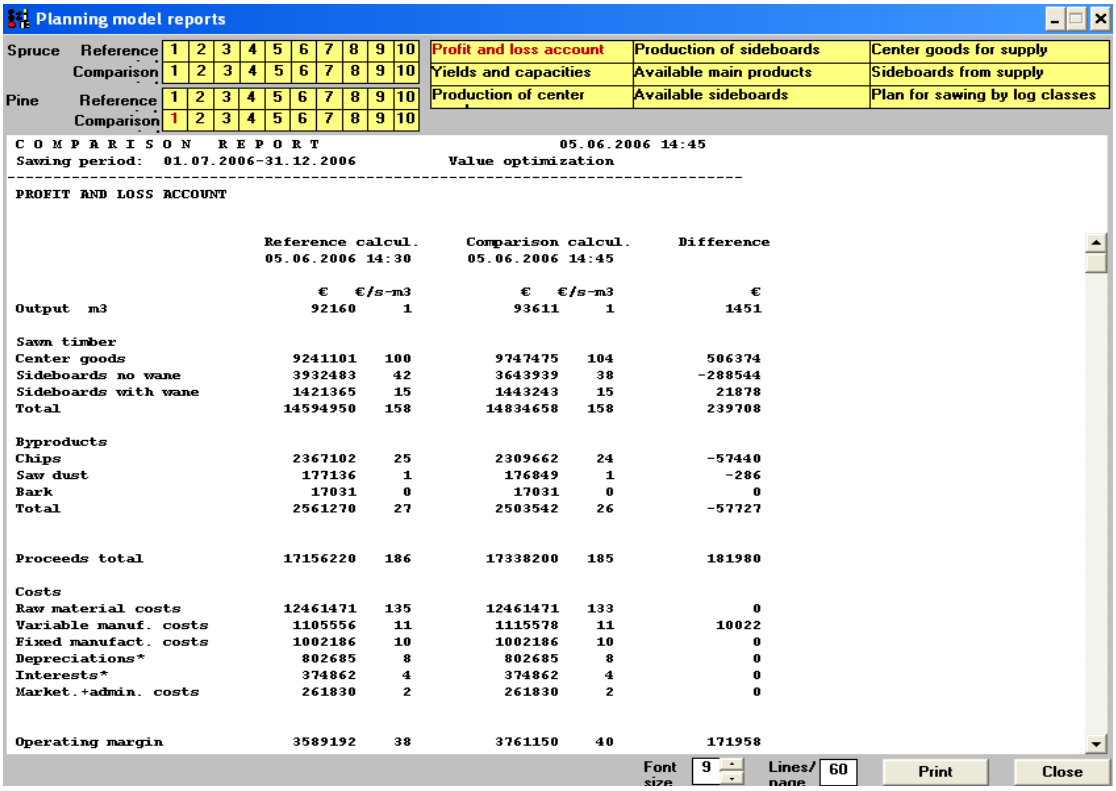


Figure 34. Main report of sawing optimising software.

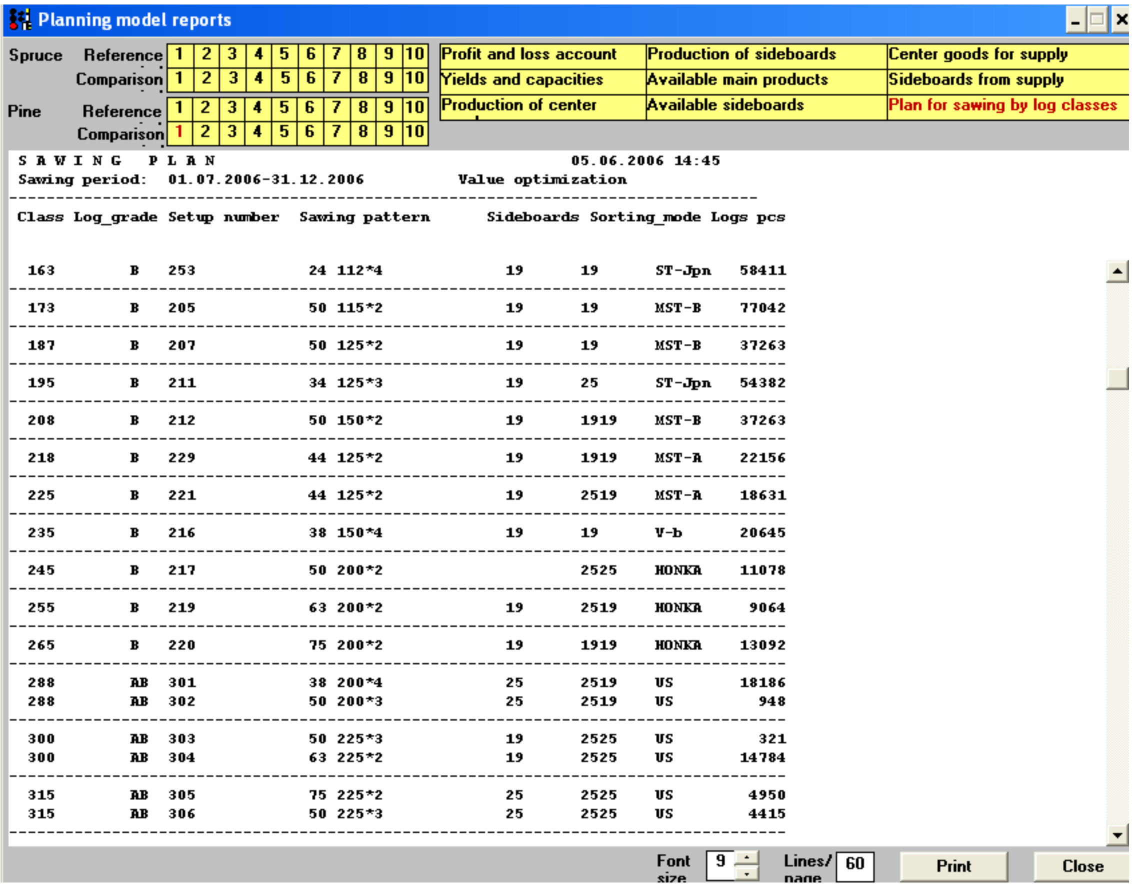


Figure 35. Production plan report. Use of sawing patterns listed by log classes.

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 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 reports of WoodCIM-program are presented in Figures 34 and 35.

Several important steps are needed prior to the implementation of **WoodCIM®** software system. The user has to define their requirements, a relevant database has to be created and the user has to learn how to interpret the results. Management's support is decisive to the successful implementation and use of advanced computer-aided planning and controlling in the sawmilling industry.

The effective use and further development of advanced planning software tools requires direct communication between the users, industrial designers and planners and the software supplier. Constructive dialogue results in ideas for adding new software features and also ways to improve industrial business. VTT's **WoodCIM®** is based on two main pillars: wood science and industrial knowledge. VTT will also in the future use all the latest research results for improving our models. Our national and international co-operation partners ensure that the latest business needs are taking into account in the development of **WoodCIM®.**

The WoodCIM® system can be used **by different sized sawmills with various business dimensions.** Some of the world's biggest sawmills, in addition to very small companies servicing local needs, have implemented the software. The different modules can be tailored to match the individual needs of the customers, which are identified during the business analysis by the implementation process. It is also very important to take into account specific market conditions. Some WoodCIM® modules are also prepared to simulate and predict value yield in the sawing of components for the **secondary conversion industrial unities**.

The **WoodCIM®** system has been implemented by **manufacturers of sawmilling machinery** in order to support planning of new machines and production lines. Software modules can also be a part of process control system, i.e. determining the best possible blade setting for a log. **Consulting companies** can also benefit from using the software when making economical calculations for their customers. Universities, schools and training organisations are using WoodCIM® for demonstration purposes, i.e. education about factors affecting the profitability of the conversion.

6.3 Optimisation of conversion chains (InnoSIM)

With the development of industrial scanning technology and the rapidly growing computing power of modern computers (e.g. PC), more sophisticated sawing simulators based on real log shape and internal defects can be developed and used in research and even in sawing process control. The biggest advantage of such kind of simulator is that each individual log could be sawn with an optimal way for the log so that the log is fully exploited with regard to its value yield under the prevailing market condition. The InnoSIM sawing simulator, adding a new functionality of research and analysis to VTT's WoodCIM® system, is based on a real log model. InnoSIM was developed to investigate the potential of value yield improvement as logs are cut into dimension lumber or user-defined wood components. Input logs for the simulator were either built with a log reconstruction model where log external envelope, geometrical shape of log internal heartwood core and internal knots are the main features of the numerical logs. As outputs of the sawing simulation, the software presents sawing results as dimension, length, grade of dimension lumber or user defined wood components for a simulated sawing pattern under the condition of input sawing parameters.

By wood components, we mean user-defined special sawn goods usually with special dimension and shorter length as compared with dimension lumber, but with strictly quality specifications concerning knots, wane and other quality properties like grain angle, resin pockets, checks, pith and annual ring width etc. The quality requirements can be specific for each face and each edge of a component. Wood components are normally produced for making furniture, joinery parts or finger-jointed wood products.

Traditionally dimension lumber products have well defined dimension series and widely accepted grading rules, mostly on a national basis like DIN 4074 in Germany for visual strength grading or geographically accepted like in the Nordic countries, e.g. the Nordic Timber Grading Rules. Comparatively EN 1611-1 grading rules, which is a European standard for sawn timber -- appearance grading for softwoods, can also be used for dimension lumber grading for Scots pine and spruce. Dimension lumbers can also be alternatively graded according to the Nordic visual strength grading rules for timber (INSTA 142). Hardwoods are graded to different national standards as softwoods, and according to different national grading rules as well.

Heartwood content based classification rules, which are defined according to customers' requirements, are used to evaluate heartwood content class of lumbers. In InnoSIM sawing simulator, Heartwood lumber classification is done by checking "heartwood wanes" of both faces and the edge with more "heartwood wane".

Therefore the following data are needed for defining lumber and side products i.e. chips and sawdust:

- Lumber grading rules with respect of knots and allowed wane rates for each grade and lumber dimension;
- Components grading rules including limitations on knots and wanes etc.
- Heartwood content classification rules and prices for each class;
- Components, lumber and side products prices.

Sawing process related input data for the model include following information:

- Sawing pattern data (i.e. blade settings for different log diameter classes)
- Sawing process parameters such as saw kerf, data of green lumber sizes for given nominal sizes.
- Other production system parameters specific to some sawmills.

Among the significant sawlog quality features, knots, in most cases, are the major concern in determining lumber quality grade. Numerous researches have been carried out to identify defects such as internal knots with modern scanning and measurement technologies (Oja et al. 2003, Thawornwong et al. 2003, Rinnhofer et al. 2003, Bhandarkar et al. 2002, Baumgartner et al. 2010). In recent years, attention has been paid to the impact of heartwood content on quality and performance of sawn products (StoraEnso 2003, Sehlstedt-Persson 2002, Venäläinen 2002, Pinto et al. 2005). It is understood that pine heartwood is more durable than sapwood for a number of reasons. The good natural durability of pine heartwood, although an old fact, has now obtained great interests from wood industrial sector as well. Stora Enso, a Finnish forest giant, has developed a new product called WoodHeart® by fully exploiting heartwood core part of sawlogs (StoraEnso 2003). In order to find out full value of sawing a log into end products, apparently in addition to internal knots and log geometrical shape, heartwood core has to be also included in a real log model.

Another development trend in sawmilling business is an increasing volume of value-added production, which includes a number of product options, such as strength-graded dimension lumber and wood components for joinery and furniture industries. Accordingly for assessing the economical results of production of such value-added products, there arose a need for simulating sawing logs into the value-added products. InnoSIM, a sawing simulator, was developed at VTT, Technical Research Centre of Finland, to meet these needs.

InnoSIM was developed as a tool for research and analysis of wood conversion chain. The software simulates the conversion process of stems and logs for achieving better economic output. InnoSIM simulates operations of the entire sawing process chain from tree stem bucking to final end products lumber, wood components, chips and sawdust. Both cant sawing method and live sawing method can be simulated to break down sawlogs into sawn goods. The input stem/logs to the software are based on a log model which includes wood quality characteristics essential to product quality, such as knots, heartwood, and external shape etc. The output products are modelled for both standard dimension lumber and wood components defined by customers' specific need. Therefore InnoSIM simulator imitates real life breakdown of logs into sawn products. The software can visually present the input sawlogs, sawing process, and output products.

6.4 Raw material characterisation

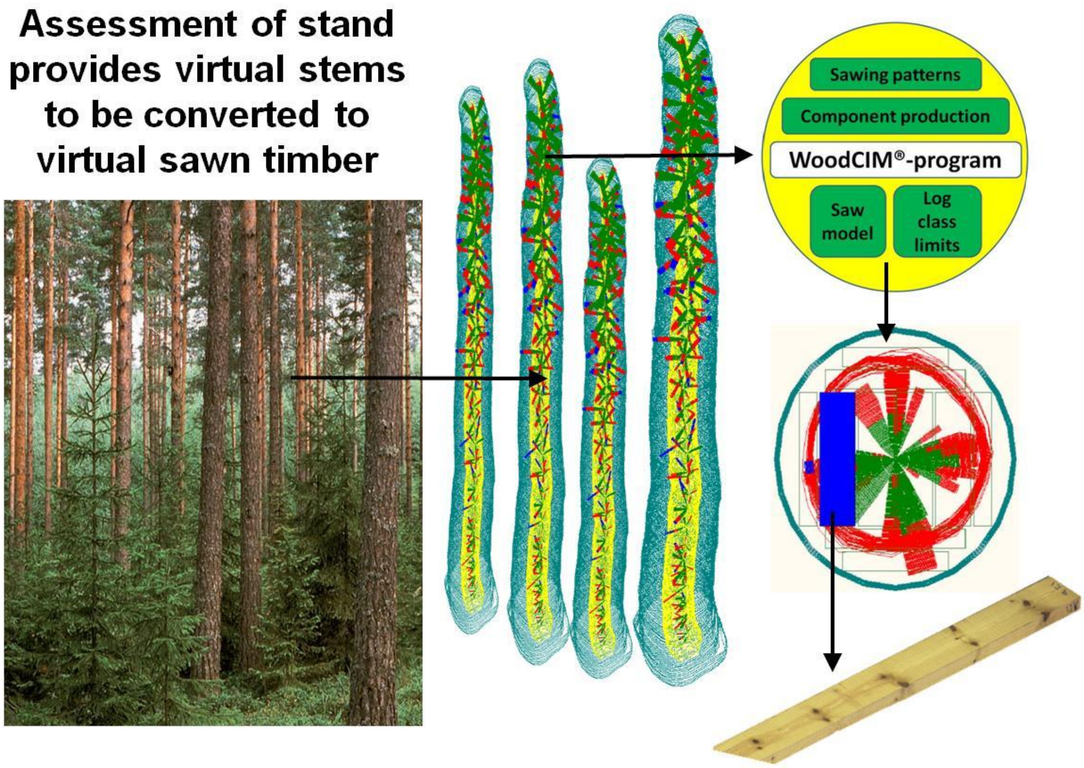


Figure 36. The assessment of a stand can be done by using virtual stem approach.

Input stems/sawlogs for the sawing simulator are based on a stem/sawlog model defined with an external envelope, an internal knots structure, and a heartwood core envelope, which are shown in Figure 36 and in Figure 37. The sawlogs can be reconstructed with either the so called flitch method, or the automatic method using scanning and measurement data of sawlogs. However, no matter which of the two log reconstruction methods is used, the reconstructed 3D logs have to comply with the defined log data model which is described in detail below.

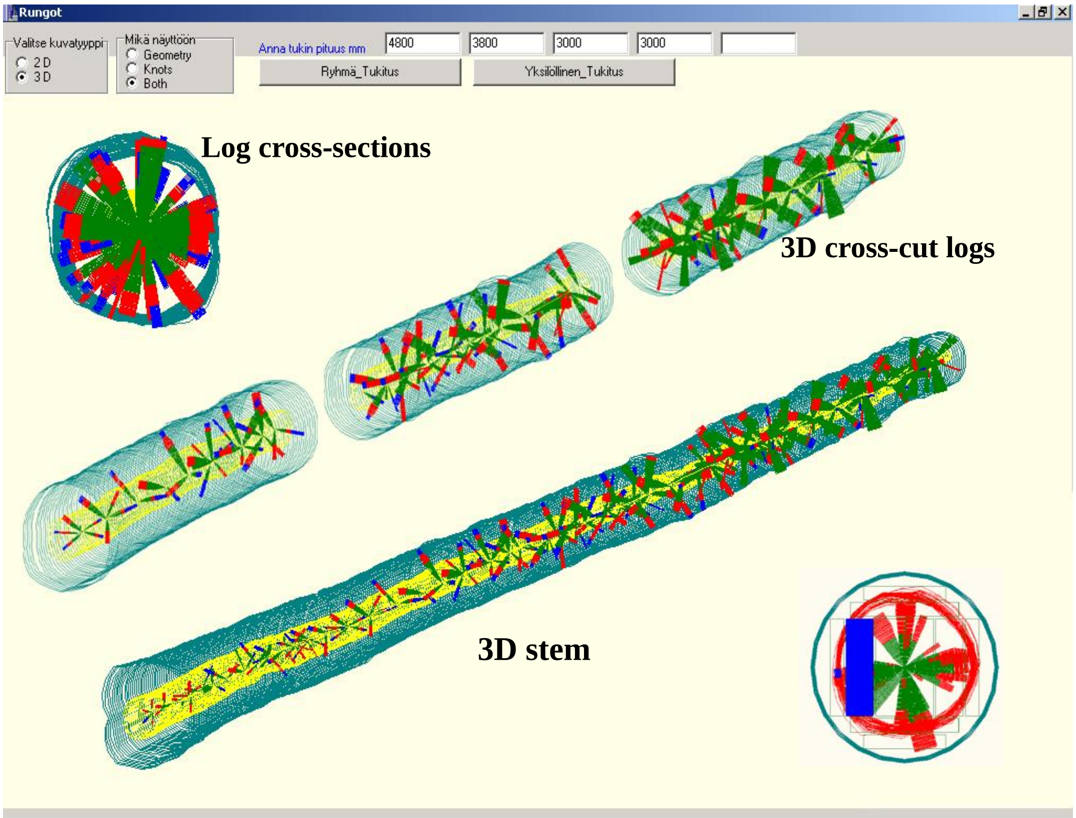


Figure 37. External and heartwood core envelopes, and internal knots of constructed logs and a stem.

Geometry of a reconstructed log is represented with a series of cross-section in the model and the cross-section of each segment is described with 24 evenly dividing vectors (Figure 38). Likewise, with 24 evenly dividing vectors originating from log pith, heartwood core geometrical shape is described numerically in the log model.

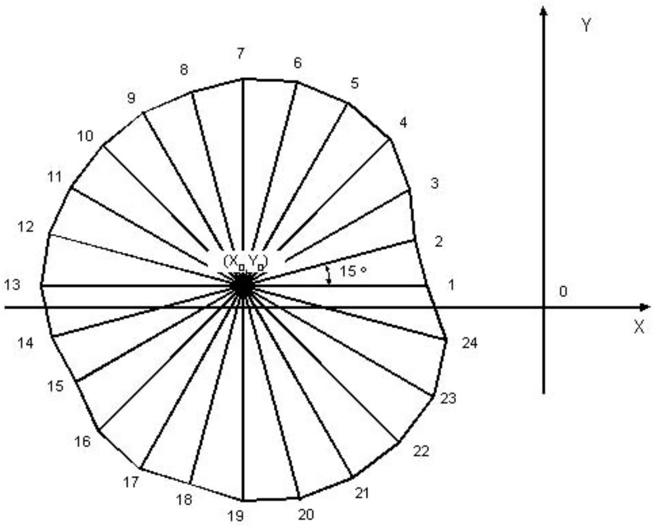


Figure 38. Cross-section description with 24 evenly dividing vectors (xo, yo) is pith point of a segment.

A knot of a log is numerically described with a group of parameters shown in Figure 39.

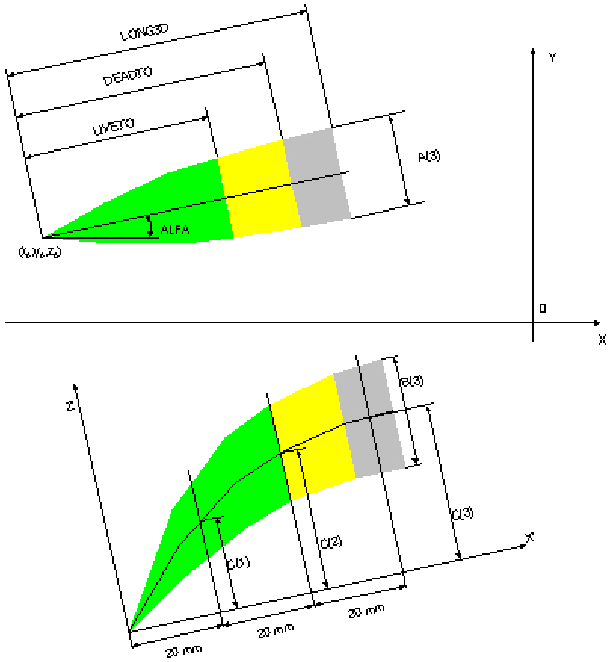


Figure 39. Single knot parameters.

Following data are needed for defining lumber and side products i.e. chips and sawdust:

- Lumber grading rules with respect of knots and allowed wane rates for each grade and lumber dimension;
- Components grading rules including limitations on knots and wanes etc.,
- Heartwood content classification rules and prices for each class;
- Prices of components, lumber and side products.

Sawmill operation analysis with InnoSIM sawing simulator

In sawing simulation studies with InnoSIM, three sources of the numerical logs/stems are available as input data for the simulator. The first one in the so-called flitch-method based log construction procedure, which was developed at VTT in the 1990's (Song 1999). More recently a new approach was developed at VTT which reconstructs logs directly with extracted information from X-ray scanning data of the logs. The third alternative is the growth model based stem generating method which can easily generate large samples of virtual stems and logs under a number of growth scenarios (Mäkelä and Mäkinen 2003). Selection of a suitable source of logs/stems is dependent on the nature and purpose of a simulation research.

A number of case studies have been carried out for sawmilling operation analysis with InnoSIM sawing simulator at VTT. Simulation researches, just like experimental researches, need good research design and sound methodology selection. Clear research objectives should be set first of all, and an appropriate research methodology must be selected to ensure achieving of the research objectives. Quality of input data is crucial for achieving reliable research results, as simulation results can never be more reliable than the input data.

6.5 How to implement WoodCIM® ?

Several important steps are needed prior to the implementation of **WoodCIM®** software system. The user has to define their requirements, a relevant database has to be created and the user has to learn how to interpret the results. Management's support is decisive to the successful implementation and use of advanced computer-aided planning and controlling in the sawmilling industry.

The effective use and further development of advanced planning software tools requires direct communication between the users, industrial designers and planners and the software supplier. Constructive dialogue results in ideas for adding new software features and also ways to improve industrial business. VTT's **WoodCIM®** is based on two main pillars: wood science and industrial knowledge. We will also in the future use all the latest research results for improving our models. Our national and international co-operation partners ensure that the latest business needs are taking into account in the development of **WoodCIM®.**

6.6 Who are the users of WoodCIM® ?

The WoodCIM® system can be used **by different sized sawmills with various business dimensions.** Some of the world's biggest sawmills, in addition to very small companies servicing local needs, have implemented the software. The different modules can be tailored to match the individual needs of the customers, which are identified during the business analysis by the implementation process. It is also very important to take into account specific market conditions. Some WoodCIM® modules are also prepared to simulate and predict value yield in the sawing of components for the **secondary conversion industrial unities**.

The **WoodCIM®** system has been implemented by **manufacturers of sawmilling machinery** in order to support planning of new machines and production lines. Software modules can also be a part of process control system, i.e. determining the best possible blade setting for a log. **Consulting companies** can also benefit from using the software when making economical calculations for their customers. Universities, schools and training organisations are using WoodCIM® for demonstration purposes, i.e. education about factors affecting the profitability of the conversion.

7. Scanning of wood and product properties – scanning and measuring technologies

Future grading will be based more and more on customer specific requirements and hence also specific grading procedures will be needed. It is almost impossible for a human grader to adopt and change continuously new grading rules, which makes the customer specific visual grading particularly difficult. In order to avoid economic losses in standard grading and in order to support grading according to the individual needs of customers, we need machine vision based grading.

In the grading supported by machine vision physical measurements are carried out concerning the surface properties or the internal characteristics of the wood material. Black and white, colour or IR cameras are used in the measurements. The data is computerized into a map of defects, which in turn is input information for the software to determine the quality of the piece. X-ray scanning provides information for the internal characteristics of logs or sawn timber pieces.

Log scanner systems for measuring shape and internal properties of logs can be used in the following processes:

- Log sorting station - optimisation of borders of log classes based on order files.
- Bucking and cross cutting terminal - optimisation of cross-cutting of stems and sorting of logs.
- Just before sawing - optimisation of log rotation angle and sawing set up for individual logs.

The purpose of X-ray inspection system is to detect properties of round wood. The analysing software should be tailored to meet application requirements. Typical functions can include measurement of dimensions/volume, moisture content, volume of knots, rot and other defects and heartwood/sapwood ratio. In the future it's possible to get a full description of wood properties i.e. individual annual ring structure and density profile.

Scanning of internal properties of stems and logs for characterisation wood raw material and for optimisation of sawing operations.

X-ray scanning is a powerful tool for detecting internal differences of solid bodies. X-ray imaging is used to identify the internal density changes inside stems and logs such as knots and defects. The system consists of X-ray sources (from one up to four). The voltage (energy kV) and the current (intensity mA) of the X-ray tube can be regulated to optimise the measurement for different objects. The optimisation is based on conveyor speed, timber thickness and moisture content. The log is moved by a conveyor system which can also rotate the log to any desired angle. Essential parts of the system are the detector and a controlling/data logging computer. The measurement data are logged by a computer which convert into greyscale and saves it for later processing and analysing e.g. to reconstruct a 3D tomography image of a measurement log or to be used as 2D images. For radiation safety, the X-ray inspection system is encapsulated in a large metal cabinet with lead lining inside (Figure 40).

The purpose of X-ray inspection system is to show the accurate position of internal wood properties and defects, knots and heartwood / sapwood areas in logs. It can also detect defects, which are not visible on any surfaces of wood. X-ray system can be used at inspecting boards, planks and logs depending on the configuration of the system. The analysis software is tailored to meet application requirements. Typical functions can include measuring of dimensions/volume, moisture content, detection of knots, rot and other defects and heartwood/sapwood ratio. Big variations in moisture content and density profiles may difficult the detection accuracy and has to be taken account for when suitable X-ray systems is to be chosen. It is not necessary easy to detect the border between living and dead parts of the knots. This needs also to be taken account when designing optimization software which uses the inside log information.

Scanners can be implemented at log sorting station, cross cutting terminals for stems and also just before sawing machines.

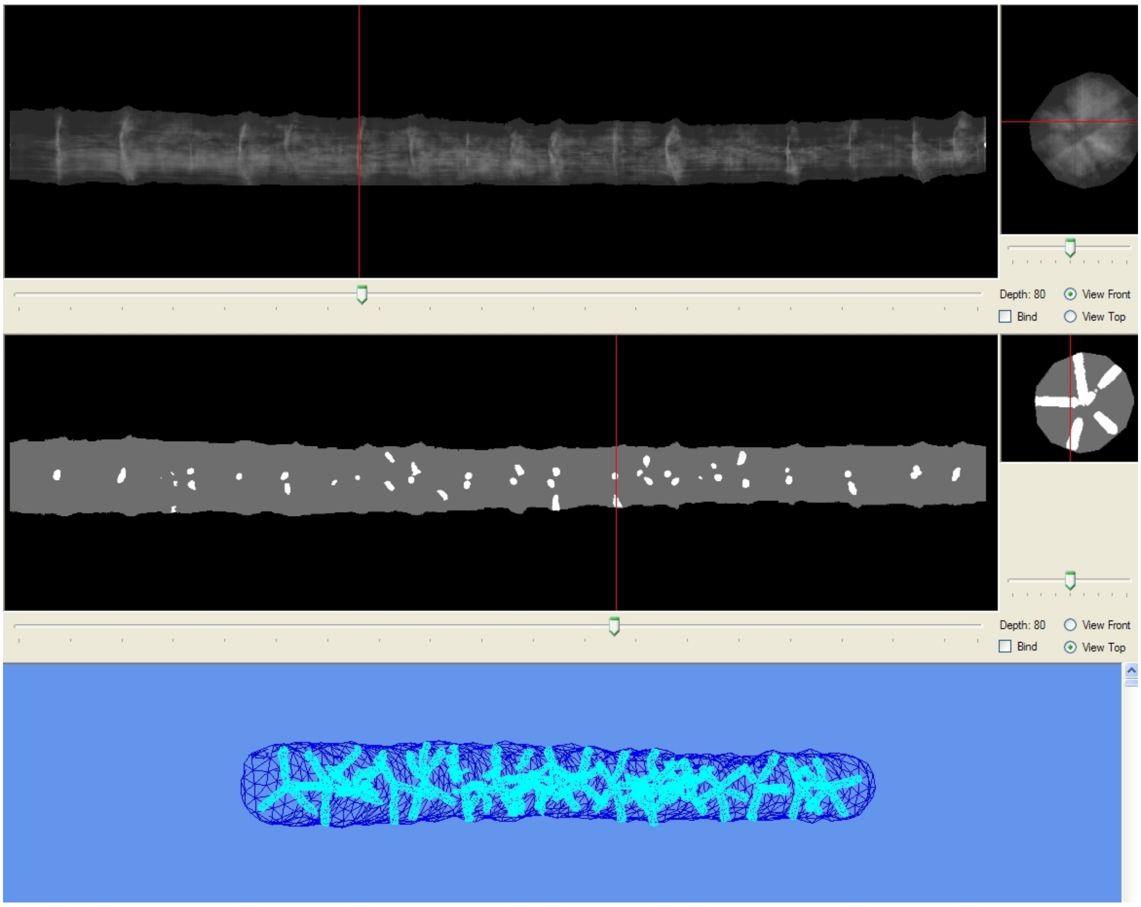


Figure 40. Special reconstruction software of X-ray data showing the X-ray images, a binary image (knot/clear wood) and 3D-mesh image with knots and surface modelled.

Present situation. Only geometrical properties of stems and logs are measured providing data like top and large end diameters, length, taper, shape of the log. In some cases logs are graded visually into quality classes.

Information about internal quality aspects is not available

New technology implementation. Precise characterisation of logs and stems can be made by scanners based i.e. x-ray technology combined with true shape data through laser applications. Depending on the system configuration, scanners provide in different detail level information about knottiness, individual knots, density, annual ring orientation, moisture content etc. Scanners provide data for planning systems and process control for sawing optimisation.

Measuring systems for characterisation and grading of sawn timber as well as supporting secondary conversion

Multisensor scanning systems are provided with several sensors like RGB-camera, IR-camera, microwave detector, ultrasound detector, x-ray camera etc. in order to detect all wood properties of interest (Figure 41). Data fusion – combining information from different sensors together ensures high resolution detection and identification result. System configuration is depending on the type of wood raw material and products and the size of the mill.

Figure 41. VTT's multisensor scanning is a powerful tool generating data of wood properties.

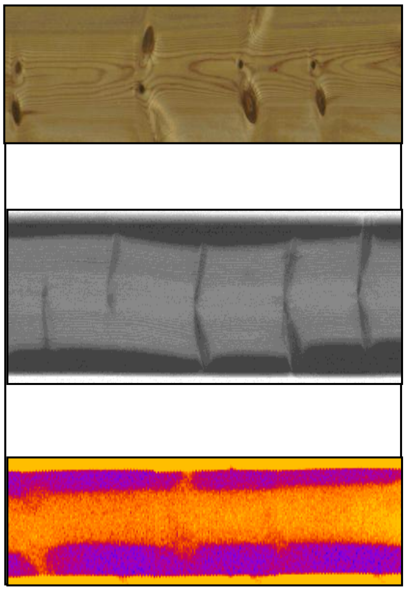


Figure 42. RGB, X-ray and IR picture of a board.

Sensors always produce images from the objects like a piece of wood. Figure 42 presents the situation where the same board has been measured with a colour camera (RGB), a infrared camera (IR) and x-ray. We can see that there are big differences between images. Knots can be detected using RGB or x-ray systems. Knots are invisible with IR sensors. However IR detection is capable to give information about moisture content. These few examples inform that different wood properties can be detected with different sensors. Multisensor approach where information from different sensors can be integrated provides possibility to confirm signals and increase detection accuracy.

Sensor signals are processed with algorithms providing information about type, size and positioning of individual defects (Figure 43) and finally map of all defects of scanned sawn timber piece. The map of defects is the input data for grading software calculating the quality of timber piece.

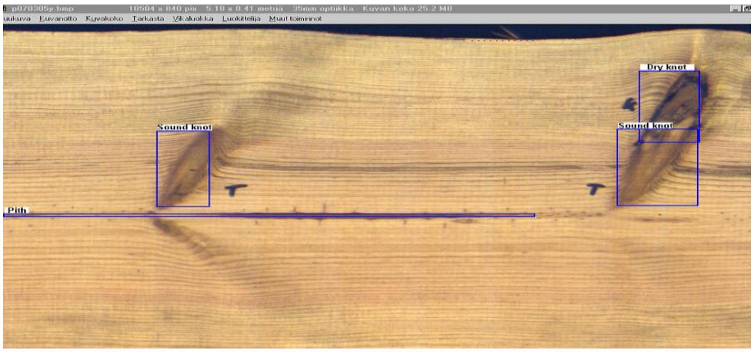


Figure 43. Image analyses provides 2D or 3D map of wood properties for grading and optimisation of secondary conversion options.

Present situation

Grading of sawn timber and components provides timber pieces in quality classes - classification. Grading is visually made by human graders especially at small mills. Grading errors cause big economic losses. It’s difficult to learn human graders to adapt new grading rules fast. Bigger sawmills are using automated grading mainly for replacing human grading. Colour and B/W cameras are used. Limited parameters are measured. Current systems are not supporting further conversion and upgrading sawn timber into components.

New technology

Scanner based grading provides precise map of wood properties on four faces of entire piece. Grading can be based on precisely defined customer’s specifications. However conventional grading can be realised with high accuracy. Map of wood defects provides possibility to convert original sawn timber piece efficiency into smaller components in secondary conversion phase. Information produced by the scanners can be stored into companies’ database and used in management of business processes and process control systems. Special low costs systems for SME’s will be developed.

8. Business concepts based on networking

In many industrial areas business is increasingly based on networking. This means active cooperation between actors within network. This approach offers good opportunity to concentrate on narrower business sectors which means effective use of human recourses. It is also possible to save investment costs because of simpler manufacturing processes. It’s very important in the business networks to share the incomes correctly. This means very clear and transparent rules.

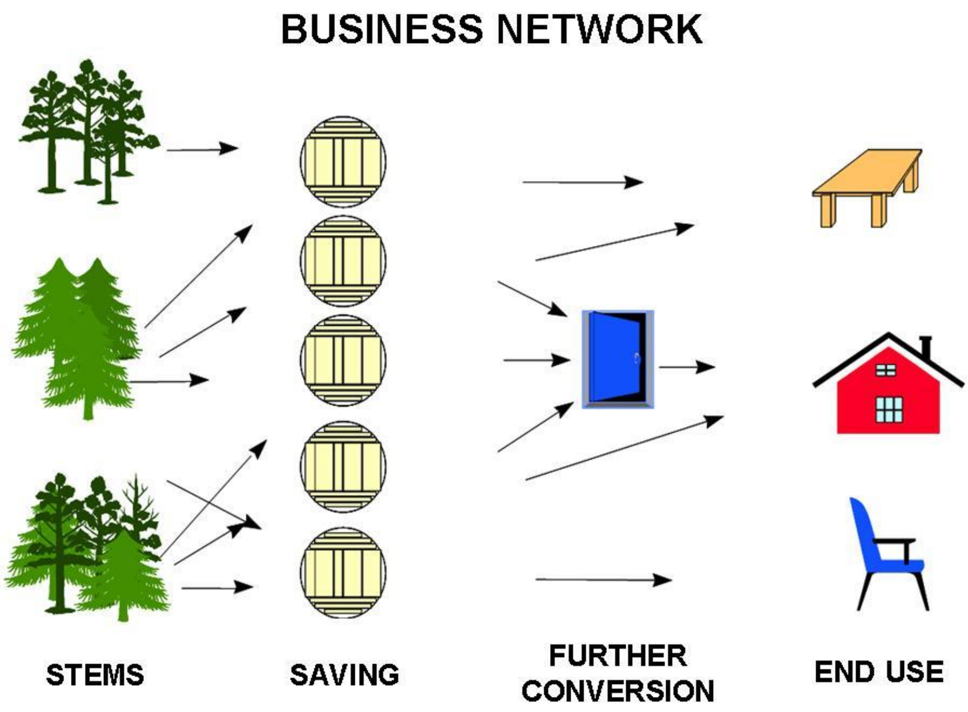


Figure 44. Business concept where wood raw material, logs are channelled to five sawmills delivering a part of sawn timber output to commonly owned further conversion mill manufacturing e.g. components to renovation purposes. A part of sawn timber and component products are sold to own customers and rest to the network's customers.

Figure 44 presents an example of business concept based on networking in which wood raw material in the form of stems or part of stems are transported to cross cutting terminal where the geometrical and quality features like knots are scanned precisely. Internal stem characterisation can be done through x-ray scanning. Data processing provides mathematical description of stems which is used in the optimisation of cross cutting based on order file. The logs are marked individually and transported to sawmill specialised in the sawing of certain type of logs. In the entrance of sawing process the log mark is read. Based on this identification optimum sawing set ups, blade settings are searched from the ICT system managing information flows for entire network. After realisation of sawing operations sawn timber and component pieces will be steered to further conversion processes and further to end use.

Business based on networking is not common so far, however it offers very big potential to improve conversion chains in different European countries resulting better customer service and economy.

Service concepts for sawmill industry

One corner stone for wood products industry future is the change of attitude towards service element. Still now most wood product enterprises do not think that service is a part of their operations, far from being essential. Partly this is due to old-fashion sales channels, where in most cases importers and wholesales companies still have a very important role and their interest is to keep suppliers and end-users away from each other. This has hindered the development towards incorporating product and service together, which in many other industries is very essential. This challenge needs very open and comprehensive information flow and exchange between the producer and the end-user. Today the novel means for communication and the free-trade zones have already opened the possibility.

One hindrance is the small size of most producers combined with the need of secure flow of products and services for the end-user. This again can be handled for example by arranging several operators who are partnering in different methods to ensure the product flow and service for the next level operator in the wood products value-chain.

There are also today very fine examples of for instance window manufacturers who are producing the windows and taking care of logistics and finally assembling themselves or arranging with networked partner the windows into the building, thus having the full chain and responsibility in their hands. In the case of renovation projects this model will include even the measuring of “old” windows and also taking care of dismantling them and the recycling of old products as much as feasible, or at least take proper care of the waste. In this case also due to unusual size windows and possibly the size of window frames, accurate and specially cut raw-materials can be provided from sawmill, which has the open and direct communication with the window manufacturer.

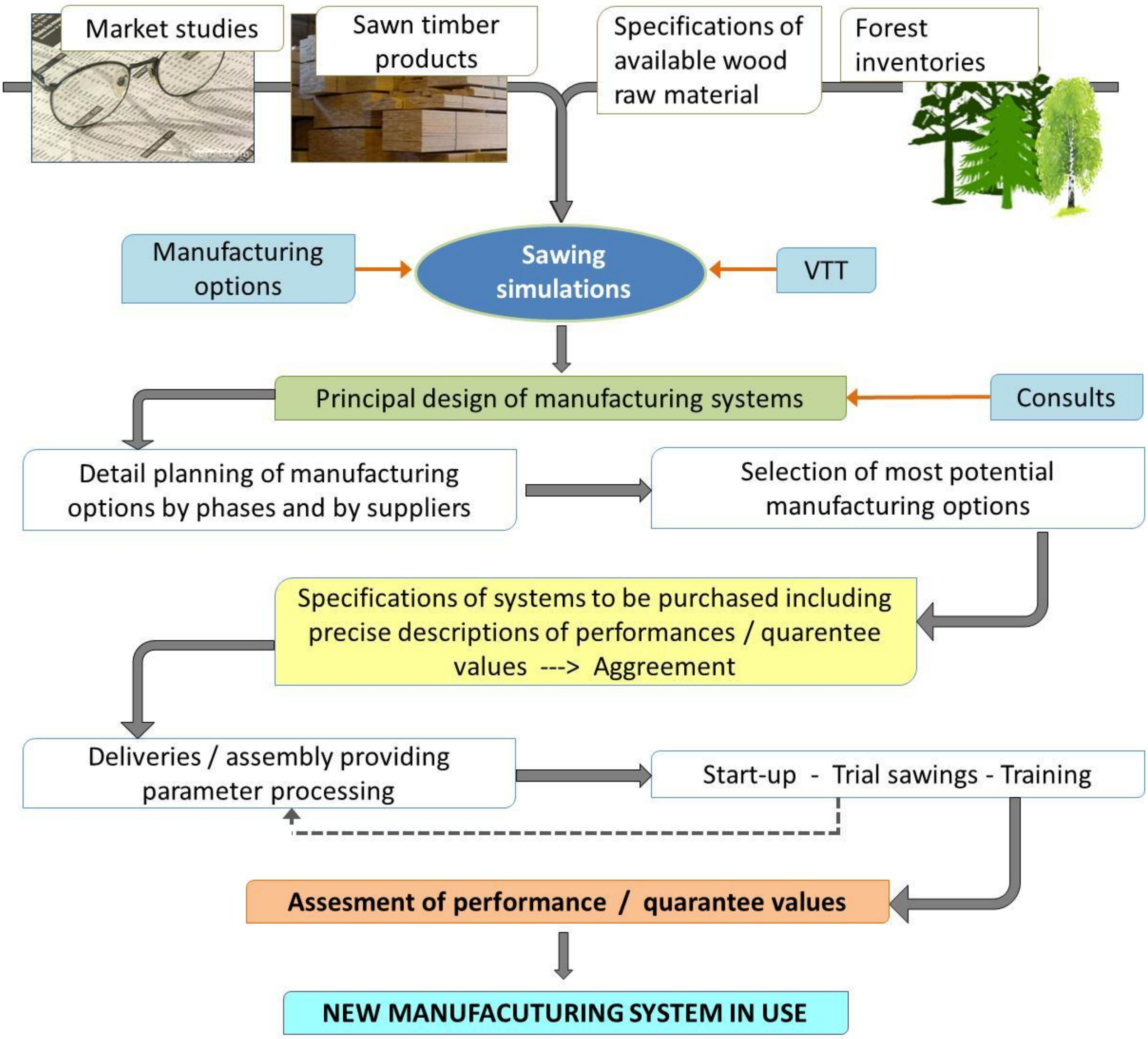


Figure 45. Phases for implementation of flexible production and manufacturing systems.

Future sawmill business concepts and manufacturing systems are flexible and strongly supported by advanced information systems. Implementation of such systems includes many phases and has to be planned carefully. Principal implementation concept is presented in

Figure 45. First phase is always sawn timber market studies which means tracing potential market sectors and future trends in the markets. It is important to define concrete demand profiles, quantities of sawn timber dimensions by qualities including price estimations providing fundamental data for sawing simulations. On the other hand knowledge about available wood raw materials, quantities, stem profile distributions, and quality features of stems has to be clarified based i.e. forest inventories.

Sawing simulation software and models developed by research institutions i.e. VTT offer tools to convert wood raw materials to final products utilising potential manufacturing systems which has to be designed. In the designing process number of parameter values has to be determined. The work can be executed with the aid of production system suppliers or/and research institutions. Simulation runs result information about value and volume yields, revenue, sawn timber distributions by dimensions and qualities, distributions of component type of products, production capacities by departments, bottle necks in the manufacturing systems etc. The most relevant manufacturing concepts shall be selected for further development.

Based on information thorough simulations, design business concept and manufacturing system can be started. Consulting companies and machine and system suppliers can execute or support this work by providing knowledge and information about processing parameter values and costs of equipment. The outcome of this phase of implementation is the selection of most potential manufacturing options. This means fixing target parameter values for production.

Next phase provides description of requirements for individual processing phases including performance targets and guarantee values and procedures how to evaluate weather values are fulfilled or not. Next step is to ask offers from potential and reliable machine and system suppliers. Offers include detail description of technical specification, prices, delivery times etc. Internal company evaluation leads to select supplier or suppliers. Finally purchase agreement will be signed. Agreement must be very clearly written, because the byer has to understand what the seller is selling and vice versa.

By the implementation of new ICT systems it’s very important that the users are right from the beginning strongly involved in the designing work. Because the really know how the new system has to work and support the users work.

Realisation of manufacturing processes includes typically assembly of machines, information systems and integration of technologies and ICT systems. Processing parameter values are defined in co-operation between machine manufacturers, ICT suppliers and the sawmill staff followed by start-up and trial sawing operations. Important part of the realisation phase is training of sawmills staff for effective use of new production systems. It is also important to deal information during the whole implementation process. This is especially important by implementation new ICT systems.

The final stage of this long procedure is the assessment of performance against guarantee values is carried out. If the values are not fulfilled, the supplier has to execute improvements in order to reach the target values. If the system cannot be reached, the price has to be reduced.

Key issues on the implementation of flexible and future manufacturing systems in the sawmilling industry

1. Future sawmill business will be more processing information than wood raw material. Relevant data has to be collected, converted into information and knowledge and final-

ly stored into data based and used planning operations, business control and process control.

2. Processes has to be provided by smart machines, advanced machines and systems
3. Self-learning machines. Self-adjusting machines.
4. Flexible machines for adaptation of different wood species, different wood qualities, different type of products, standard sawn timber, value added products, different product mix sawn at the same time.
5. There has to be god capacity balance between different phases of manufacturing chain and departments. Incompatibly between different departments affects economic losses.
6. Automated monitoring of the performance of individual machines. Direct links to machine and system suppliers
7. Information systems covering entire conversion and supply chains
8. Advanced sawing simulators for determination of sawing set ups
9. Advanced models for optimisation of business outcome taking into account of available wood raw materials, orders or potential orders and production capacities.
10. Skilled and motivated staff and people are keys for success. Advanced machines and systems needs educated and trained users and operators.
11. Positive working environment for people.
12. Business support from service providers.
13. Continuous monitoring of future trends and customer satisfaction.
14. Timing of investments should be carefully defined.
15. Design of new sawing lines and machines through simulations in order to estimate in advanced: profitability, manufacturing costs, production performance, volume and value yields, flexibility,
16. Designing, planning and implementation of manufacturing systems have always to be started through market studies and products specifications. Products should be in the first hand value added components with specific dimensions and quality requirements. Standard bulk products may be also a part of products mix especially if the quality of wood raw material is low.
17. Manufacturing has to support sustainable development taking into account economic, environmental and societal aspects.
18. Technologies to prof the origin of wood species.
19. Business in networks has to be considered carefully. Potential domestic and foreign partners

References

Baumgartner, R., Brüchert, F. & Sauter, U.H. 2010. Knots in CT scans of Scots pine logs. Conference Proceedings Final Conference of COST Action E53 “The Future of Quality Control for Wood & Wood Products”, 4–7th May 2010, Edinburgh. http://www.coste53.net/index.php?Cost_E53:E53_documents – link Cost E53 conference – all presentations: 45.pdf [Accessed 9.2.2011]

Broma, N.O. 2000. Division of Wood Technology, Luleå University of Technology, Skellefteå, Sweden.

Broman, N.O. 2001. Aesthetic properties in knotty wood surfaces and their connection with people's preferences. Journal of Wood Science, 47(3), pp.192–198. doi:10.1007/BF01171221.

Brännström, M. 2009. Integrated strength grading. Doctoral thesis. Division of Wood Technology, Luleå University of Technology, Skellefteå, Sweden:

Edlund, J. 2004. Methods for Automatic Grading of Saw Logs. Doctoral thesis. Department of Forest products and Markets. Swedish University of Agricultural Sciences, Uppsala, Sweden.

Heinemann, U., Nyrud, A. & Kliger, R. 2010. Quality control of wood products in the European timber industry - results from a survey of practices in companies and of consumer expectations. Report COST. Oslo, Norway. ISSN 03333-2020. Available at: http://www.ctib-tchn.be/main_tchn/files_pdf/Quality_Control_Cost_E53_2010.PDF [Accessed 20 April 2011].

Lundahl, C., 2009. Total Quality Management in Sawmills. Doctoral thesis. Division of Wood Technology, Luleå University of Technology, Skellefteå, Sweden.

Mäkelä, A. & Usenius, A. 2000. Impact of thinning strategy on the yield and quality distribution of Scots pine stems – projections on the PipeQual growth model and the WoodCim conversion system. In: Proceedings of Cost Action E10 "Wood Properties for Industrial Use": Third Workshop on "Measuring of wood properties, grades and qualities in the conversion chains" and "Global wood chain optimisation". Espoo, Finland, 19.–21.6.2000. Pp. 29–47.

Mäkelä, A., Mäkinen, H. & Usenius, A. 2003. Prediction of 3D stem structure from simple sample tree measurements. In: Proceedings of 4th workshop in "Connection between Silviculture and wood quality through modelling approaches and simulation softwares". Harrison, British Columbia, USA. September 8–15, 2003.

Pastila S., Mäkelä A., Usenius A. & Valsta L. 2004. Information, economic return and wood quality in Scots pine management. In: Proceedings of Conference: The Forestry Woodchain -conference "Quantifying and forecasting quality from forest to end product", Heriot-Watt University, Edinburgh, 28–30 September 2004. Pp. 130.

Optimization of the Manufacturing of Heartwood Components. 2005. ScanTech Conference, Las Vegas, USA.

Pinto, I., Usenius, A., Song, T.C. & Pereira, H. 2005. Sawing simulation of maritime pine (Pinus pinaster Ait.) stems for production of heartwood-containing components. Forest products journal, 55(4),pp. 88–96.

Pinto, I. 2004. Raw material characteristics of maritime pine (Pinus pinaster Ait.) and their influence on simulated sawing yield. Doctoral thesis. Helsinki University of Technology, Espoo, Finland.

Saukkonen, E., Temmes, J. & Usenius, A., Wahlström B. 1983. Method for control of piece flow in difficult production circumstances, FINNISH patent.

Song, T., Pinto, I., & Usenius, A. 2005. Sawing Simulation of pine heartwood products as a new WoodCIM® feature. In: Nepveu, G. (Ed.). Proceedings of IUFRO WP S5.01-04 Fifth Workshop 'Connection between forest resources and wood quality: Modelling approaches and simulation software'. Waiheke Island Resort, Auckland, November 20–26, 2005, New Zealand.

Song, T. & Usenius A. 2007. INNOSIM – a simulation model of wood conversion chain. COST E 44 Conference proceedings on Modelling the Wood Chain Forestry – Wood Industry – Wood Products Markets. September 17–19, 2007, Helsinki, Finland. Pp. 95–108

Usenius, A. & Niittylä K., 2002. Uusia mahdollisuuksia sahaustoiminnan ohjaukseen kappaleiden merkinnän avulla. (New possibilities for controlling activities in sawmilling business through marking of pieces). Puumies, 2002, No 9. [In Finnish].

Usenius, A. 2007. Flexible and Adaptive Production Systems for Manufacturing of Wooden Components. *In* Proceedings of 18th International Wood Machining Seminar. May 7–9, 2007 – Vancouver, Canada. Pp. 187–196.

Usenius, A. 2007. Adaptive and flexible production systems for woodworking industry. In Proceedings of IUFRO All Division 5 Conference, Oct 29–Nov 2, 2007 – Taipei Taiwan.

Usenius, A. 2003. Optimization of Sawing Operation Based on Internal Characterization of the LogsScanTech 2003. In: Proceedings of the 10th international conference on scanning technology and process optimization for the wood industry. Seattle, Washington, USA. Nov. 3–4, 2003. Wood Machining Institute.

Usenius A. & Heikkilä A. 2007. WoodCIM® – model system for optimization activities throughout supply chain. COST E 44 Conference proceedings on Modelling the Wood Chain Forestry – Wood Industry – Wood Products Markets. September 17–19, 2007, Helsinki, Finland. Pp. 173–183.

Usenius, A., Heikkilä, A., Song, T., Fröblom, J. & Usenius, T. 2010. Joustavat ja itseoppivat tuotantojärjestelmät sahateollisuudessa. VTT Research Notes 2544. Espoo, Finland. ISSN 1455-0865. Available at: http://www.vtt.fi/inf/pdf/tiedotteet/2010/T2544.pdf [Accessed 20 April 2011].

Usenius, A. & Song, T. 2005. Optimal Model system for optimal allocation of wood raw material throughout conversion chains. In: Nepveu, G. (Ed.). Proceedings of IUFRO WP S5.01-04 Fifth Workshop 'Connection between forest resources and wood quality: Modelling approaches and simulation software'. Waiheke Island Resort, Auckland, November 20–26, 2005, New Zealand.

Usenius, A., Song, T. & Heikkilä, A., 2007 Optimization of activities throughout the wood supply chain. Proceedings International Scientific Conference on Hardwood Processing. September 24–26, 2007 Quebec City, Canada. Pp. 199–205.

Wooden Components. 2007. In: Proceedings of 18th International Wood Machining Seminar. May 7–9, 2007 – Vancouver, Canada. Pp. 187–196.